

**SECTION 23 0700
DUCTWORK INSULATION**

PART 1 - GENERAL

1.01 RELATED SECTIONS

- A. Section 20 1000 - General Mechanical Provisions
- B. Section 20 2000 - Mechanical Operation and Maintenance Manuals

1.02 QUALITY ASSURANCE

- A. Products shall have flame spread and smoke developed ratings based on test procedures in accordance with NFPA-255 and UL-723. Ratings shall be indicated on the product or on the shipping cartons.
- B. Unless otherwise specified herein, products shall have flame spread ratings not to exceed 25 and smoke developed ratings not to exceed 50.
- C. Products shall comply with the requirements of Oregon Revised Statute (ORS) 453.005 (7) (e), effective January 1, 2011. The referenced statute limits the use of three types of brominated fire retardant chemicals, which are defined as hazardous substances.

1.03 SHOP DRAWINGS, PRODUCT DATA, OPERATION & MAINTENANCE DATA

- A. Submittals required for the products listed in the Product Table, in accordance with Section 20 1000. Operation & Maintenance Information required as indicated in the Product Table in accordance with Section 20 2000.
- B. Operation & Maintenance Information requirements indicated by number designation as follows. Refer to Section 20 2000 for a description of each type of information.
 - 1. Shop Drawings (submittal data)
 - 2. Product Data (submittal data), including documentation of ORS 453.005 (7) (e) compliance.
 - 3. Manufacturer's Operation Manuals
 - 4. Manufacturer's Service and Lubrication Requirements
 - 5. Service Contracts and Field Start-up Reports
 - 6. Cleaning, Certification, and Test Reports
 - 7. System Information
 - 8. Warranties

PRODUCT TABLE	Operation & Maintenance Information							
	1	2	3	4	5	6	7	8
Duct Insulation		X				X		
Accessories		X						

PART 2 - PRODUCTS

2.01 DUCT INSULATION

- A. Fiberglass Duct Wrap:
 - 1. Type: Flexible wrap with factory applied vapor barrier facing.
 - 2. R-Values (hr.ft2.deg F/Btu) with "Installed" / "Out-Of-Package" rating based on material thickness compressed to a maximum of 25%:
 - a. One and one half inch thickness: R-value = 4.2 / 5.2 minimum
 - b. Two inch thickness: R-value = 5.6 / 6.9 minimum
 - c. Three inch thickness: R-Value = 8.3 / 10.3 minimum
 - 3. Thermal Conductivity("k"): 0.29 at 75 degrees F mean temperature labeled thickness.
 - 4. Facing: Laminated aluminum foil, glass scrim, and kraft paper vapor barrier; with 2 inch sealing flap.

5. Facing Permeability: Not to exceed 0.04 perms.
 6. Manufacturer and Model: Johns Manville, Certain Teed, Knauf, Owens Corning, or approved. Similar to Johns Manville Microlite XG Type 75.
- B. Fiberglass Duct Liner:
1. Type: Flexible fiberglass liner in roll form with black mat coating exposed to airstream.
 2. Noise Reduction Coefficient: Not less than 0.7, in accordance with ASTM C-423-81a.
 3. R-Values (hr.ft².deg F/Btu) rating based on material thickness at 75 degrees F mean temperature:
 - a. One inch thickness: R-value = 4.2 minimum
 - b. One and one half inch thickness: R-value = 6.3 minimum
 - c. Two inch thickness: R-value = 8.0 minimum
 4. Thermal Conductivity("k"): 0.24 at 75 degrees F mean temperature for 1" thickness.
 5. Maximum Service Velocity: Not less than 4,000 feet per minute.
 6. Manufacturer: CertainTeed, Knauf, Owens Corning, Johns Manville, or approved. Equivalent to Johns Manville Linacoustic RC.

2.02 ACCESSORIES

- A. Mastic, Coatings, Tapes, and Adhesives: Comply with manufacturer's installation instructions for each type of insulation.
- B. Weld Pins:
1. Type: Retainer disk attached to pin, for resistance welding to duct surface after liner is in place.
 2. Retainer Disk: Not less than 0.75 square inches.
 3. Pin: 0.1 inch shorter than liner thickness. Pins shall not protrude into airstream.
 4. Manufacturer: Similar to Duro-Dyne "CP Series Clip-Pins."
- C. Stick Pins:
1. Type: Perforated base with protruding pin, for gluing to duct surface prior to application of liner.
 2. Pin: 0.25 inches longer than liner thickness.
 3. Self-locking Washer: Attaches to pin after application of liner.
 4. Manufacturer: Similar to Gemco series PH.

PART 3 - EXECUTION

3.01 GENERAL

- A. Prior to installation of insulation, verify that:
1. Ductwork has been tested and approved.
 2. Duct seams have been sealed.
 3. Duct surfaces are clean and dry.
- B. Do not insulate the following:
1. Duct access doors. Tape insulation to duct around duct access door
- C. Install products in accordance with manufacturer's recommendations.
- D. Install products in accordance with MICA (Midwest Insulation Contractors Association) - National Commercial & Industrial Insulation Standards.

3.02 FIBERGLASS DUCT WRAP WITH VAPOR BARRIER

- A. Fully wrap duct, with facing to the outside.
- B. Overlap vapor barrier facing 2 inches minimum at seams and joints.
- C. Seal all seams, joints, and penetrations with foil-faced pressure sensitive tape of same material as insulation facing, to provide a continuous vapor barrier.
- D. On ducts 24 inches or more in width, secure insulation on underside of ducts with stick pins 18 inches maximum on center, 6 inches minimum from edges of duct. Cut pins off flush with washer and seal with vapor barrier tape.

3.03 DUCT LINER

- A. Apply 90 percent coverage of approved adhesive to inside of duct per NAIMA and SMACNA guidelines.
- B. Cover interior of duct with liner, with mat coating of liner toward the airstream.
- C. Seams and joints shall be neatly butted, with edges coated with adhesive.
- D. Coat leading edges with adhesive or provide liner with factory-applied edge coating. For duct velocities above 2000 fpm, provide metal nosing around leading edges.
- E. Install weld pins, spaced according to liner manufacturer's instructions, not greater than 18 inches on center or greater than 3 inches from any edge.
- F. Weld pins shall be resistance welded to duct with a machine similar to Duro-Dyne "Pinspotter."

3.04 APPLICATION TO DUCT SYSTEMS

- A. Definitions:
 - 1. Duct Liner: Ducts and plenums shown on drawings to be provided with duct liner. External duct wrap is not required when liner is used unless specifically shown or specified.
 - 2. Conditioned space: An area or room within a building heated and cooled to normal comfort level or with a fixed opening directly into an adjacent conditioned space.
- B. Ducts Located Outside Building Insulation Envelope:
 - 1. Applications:
 - a. Supply and return ducts or plenums exposed to outdoor temperatures
 - 2. Fiberglass Duct Liner :
 - a. Supply and Return Ducts or Plenums:
 - 1) R-Value: R-8 minimum
 - 2) Insulation Thickness: 2 inches
- C. Ducts or Plenums Located Inside Building Insulation Envelope:
 - 1. Applications:
 - a. Supply ducts or plenums in "indirectly conditioned" ceiling space i.e. separated from the conditioned space by a ceiling with conditioned space on floor above
 - b. Return ducts or plenums shown with duct liner on the drawings used for acoustic attenuation
 - 2. Fiberglass Duct Wrap:
 - a. Supply Air Ducts or Plenums:
 - 1) R-Value: R-5 minimum (Installed)
 - 2) Insulation Thickness: 2 inches
 - 3. Fiberglass Duct Liner (where indicated on Drawings):
 - a. Supply Ducts or Plenums:
 - 1) R-Value: R-5 minimum
 - 2) Insulation Thickness: 1-1/2 inches
 - b. Return Ducts or Plenums:
 - 1) R-Value: R-4.2 minimum
 - 2) Insulation Thickness: 1 inch

END OF SECTION

**SECTION 23 0900
CONTROLS**

PART 1 - GENERAL

1.01 RELATED SECTIONS

- A. Section 20 1000 - General Mechanical Provisions
- B. Section 20 2000 - Mechanical Operation and Maintenance Manuals
- C. Section 20 6000 - Mechanical Identification
- D. Section 20 9100 - Testing, Adjusting, and Balancing
- E. Section 23 1000 – Controls Sequence of Operations
- F. Section 23 3600 - Air Terminal Units
- G. Section 23 7410 - Packaged Air Conditioning Units
- H. Section 23 7420 - Packaged Heat Pumps

1.02 WORK INCLUDED

- A. Building Automation System (BAS) Contractor shall provide and install: A fully integrated Building System (BAS), incorporating direct digital control (DDC) for energy management, equipment monitoring and control, and subsystems with open communications capabilities as herein specified.
- B. Provide engineering, installation, calibration, software, software programming, and checkout for complete and fully operational BAS. The following shall be included:
 - 1. Workstation operator interface terminal (desktop computer workstation) Coordinate with the Owner's Representative for exact location.
 - 2. Prepare individual hardware layouts, interconnection drawings, and software configuration from project design data.
 - 3. Implement the detailed design for analog and binary objects, system databases, graphic displays, logs, and management reports based on control descriptions, logic drawings, configuration data, and bid documents.
 - 4. Design, provide, and install equipment cabinets, panels, data communication network cables needed, and associated hardware.
 - 5. Electronic controls for items indicated on Drawings and described hereinafter including sensors, switches, relays, transformers, thermostats, temperature sensors, control panels and central processing hardware and software.
 - 6. Graphics programming for systems and functions indicated and required.
 - 7. Install interconnecting cables between supplied cabinets, application controllers, and input/output devices.
 - 8. Provision and installation of interconnecting cables between operator's terminals and peripheral devices (such as printers, etc.) supplied under this section.
 - 9. Provide complete manufacturer's specifications for items that are supplied. Include vendor name of every item supplied.
 - 10. Provide supervisory specialists and technicians at the job site to assist in each phase of system installation, startup, and commissioning.
 - 11. A comprehensive operator and technician training program as described herein.
 - 12. As-built documentation, operator's terminal software, diagrams, and other associated project operational documentation (such as technical manuals) on approved media, the sum total of which accurately represents the final system.
 - 13. New sensors, dampers, valves, and install only new electronic actuators. No used components shall be used as any part or piece of installed system.
 - 14. Adjustment and validation of control system. System testing. System demonstration to Mechanical Engineer and Owner's Representative.

15. No gateways shall be used for communication to controllers installed under this section. Gateways may be used for communication to existing systems or to systems installed under other sections.

1.03 WORK BY OTHERS:

- A. Installation of wells, valves, taps, dampers, flow switches, flow stations, etc. furnished by BAS manufacturer.
- B. Provided under Division 26:
 1. Wiring of power feeds to disconnects where starters or VFD's are furnished as an integral part of equipment.
 2. Wiring between disconnects and starters to electrical motors and variable speed drives where starters or drives are not an integral part of equipment.

1.04 SYSTEM DESCRIPTION

- A. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. BACnet protocol shall be ANSI/ASHRAE Standard 135-2004 or higher. This system will control mechanical equipment, including unitary equipment such as VAV terminal units, heat pumps, fan coils, AC units, etc. and air handlers, boilers, chillers, and any other listed equipment using native BACnet compliant components. Non BACnet compliant or proprietary equipment or systems (including gateways) shall not be acceptable and are specifically prohibited.
- B. The control system shall consist of a high-speed, peer-to-peer network of DDC controllers and a web-based operator interface. Depict each mechanical system and building floor plan by a point-and-click graphic. A web server with a network interface card shall gather data from this system and generate web pages accessible through a conventional web browser on each PC connected to the network. Operators shall be able to perform all normal operator functions through the web browser interface.
- C. The system shall directly control HVAC equipment as specified in Section 23 1000 – Controls Sequence of Operations. Furnish energy conservation features such as optimal start and stop, night setback, request-based logic, and demand level adjustment of setpoints as specified in the sequence.
- D. Building controllers shall include complete energy management software, including scheduling building control strategies with optimum start and logging routines. Energy management software and firmware shall be resident in field hardware and shall not be dependent on the operator's terminal. Operator's terminal software is to be used for access to field-based energy management functions only. Provide zone-by-zone direct digital logic control of space temperature, scheduling, runtime accumulation, equipment alarm reporting, and override timers for after-hours usage.
- E. Schedules, I/O points, setpoints, trends, and alarms specified in Section 23 1000 – "Controls Sequence of Operations" shall be BACnet objects.
- F. Application specific controllers for each equipment type (VAV Terminal Unit, Heat Pump (HP), Air Conditioning Unit (ACU), Unit Ventilator (UV), etc.) air handler, central plant equipment, and any other piece of controlled equipment shall be fully programmable. Application specific controllers shall be mounted near the controlled equipment.

1.05 APPROVED CONTROL SYSTEMS AND VENDORS

- A. Direct Digital Control system components and shall be as manufactured, designed, and installed by:
 1. Alerton, installed by Environmental Control Corporation.
 2. Automated Logic installed by Clima-Tech.
 3. Tracer Summit, installed by Trane.
 4. System and vendor, as approved.

- B. The above list is alphabetical and does not indicate preference. Inclusion on this list does not guarantee acceptance of products or installation. Control systems shall comply with the terms of this specification.
 - 1. The Contractor shall use only operator workstation software, controller software, custom application programming language, and controllers from the corresponding manufacturer and product line unless Owner approves use of multiple manufacturers.
 - 2. Other products specified herein (such as sensors, valves, dampers, and actuators) need not be manufactured by the above manufacturers.

1.06 QUALITY ASSURANCE

- A. The BAS system shall be designed and installed, commissioned and serviced by manufacturer factory trained personnel employed manufacturer or manufacturer representative. Manufacturer shall have an in-place support facility within 2 hours response time of the site with technical staff, spare parts inventory and necessary test and diagnostic equipment. Distributors or licensed installing contractors are not acceptable.
- B. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the specification requirements.
- C. BAS peer-to-peer network controllers, central system controllers and local user displays shall be UL Listed under Standard UL 916, category PAZX.
- D. Electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference and be so labeled.

1.07 REFERENCE STANDARDS

- A. The latest edition of the following standards and codes in effect and amended as of supplier's proposal date, and any applicable subsections thereof, shall govern design and selection of equipment and material supplied:
 - 1. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
 - 2. ANSI/ASHRAE Standard 135-2004, BACnet.
 - 3. International Building Code (IBC), 2009, including local amendments.
 - 4. UL 916 Underwriters Laboratories Standard for Energy Management Equipment. Canada and the US.
 - 5. National Electrical Code (NEC).
 - 6. FCC Part 15, Subpart J, Class A
 - 7. EMC Directive 89/336/EEC (European CE Mark)
 - 8. UL-864 UUKL listing for Smoke Controls for any equipment used in smoke control sequences
- B. City, county, state, and federal regulations and codes in effect as of contract date.
- C. Except as otherwise indicated the system supplier shall secure and pay for permits, inspections, and certifications required for his work and arrange for necessary approvals by the governing authorities.

1.08 SHOP DRAWINGS, PRODUCT DATA, OPERATION & MAINTENANCE DATA

- A. Submittals required for the products listed in the Product Table, in accordance with Section 20 1000. Operation & Maintenance Information required as indicated in the Product Table in accordance with Section 20 2000.
- B. Drawings:
 - 1. The system supplier shall submit engineered drawings, control sequence, and bill of materials for approval, as indicated in Product Table included herein.
 - 2. Drawings shall be submitted in the following standard sizes: 8.5"x11" and 11" x 17".
 - 3. Drawings shall be made available on DVD or CD-ROM.
- C. Operation & Maintenance Information requirements indicated by number designation as follows. Refer to Section 20 2000 for a description of each type of information.
 - 1. Shop Drawings (submittal data)

2. Product Data (submittal data)
3. Manufacturer's Operation Manuals
4. Manufacturer's Service and Lubrication Requirements
5. Service Contracts and Field Start-up Reports
6. Cleaning, Certification, and Test Reports
7. System Information
8. Warranties

PRODUCT TABLE	Operation & Maintenance Information							
	1	2	3	4	5	6	7	8
Index sheet, listing contents in alphabetical order							X	
Valve schedules		X	X					
Damper schedules		X	X					
Equipment data cut sheets for equipment to be furnished as part of this project		X	X	X				
Point List	X							
System Schematics, including: Sequence of operations, point names and addresses, Wiring diagrams, Panel layouts, and System riser diagrams	X						X	
Logic flow diagrams for digital control sequences	X							
Acceptance test procedure list					X		X	
Manufacturer's equipment parts list of functional components of system, and data sheets for equipment furnished.							X	
AutoCAD disk and hard copy of system schematics, including wiring diagrams.							X	
Description of sequence of operations							X	
Auto-CAD compatible as-installed drawings.							X	
As-installed logic flow diagrams for digital control sequences.							X	
As-installed interconnection wiring diagrams							X	
Operator's Manual							X	
Trunk cable schematic showing remote electronic panel locations, and trunk data.							X	
List of connected data points, including panels to which they are connected and input device (detector, thermostat, etc.)							X	
Software programming literature.							X	
Conduit routing diagrams							X	

1.09 TRAINING

- A. Contractor shall provide training in operation, maintenance, and programming of DDC system for Owner Designated Personnel. Training shall be presented by factory trained instructor, provided through installing control system manufacturer, to give full instruction to designated personnel in operation of system installed. Instructors shall be thoroughly familiar with subject matter they are to teach. Training shall conform to, and include, the following:
 1. Provide 8 hours of training for Owner's designated operating personnel.
 2. Students shall be provided with binder containing product and system specific training modules for system installed. Minimum of one copy per student plus one extra copy.

3. Training shall be held during normal working hours of 8:00 am to 4:30 PM weekdays, on dates and times as selected by Owner.
 4. Explanation of drawings, operations and maintenance manuals.
 5. Walk-through of job to locate control components.
 6. Operator workstation and peripherals.
 7. DDC controller and ASC operation/function.
 8. Operator control functions including graphic generation and field panel programming.
 9. Operation of portable operator's terminal.
 10. Explanation of adjustment, calibration and replacement procedures.
- B. Since Owner may require personnel to have more comprehensive understanding of hardware and software, additional training must be available from the Contractor. If such training is required by Owner, it will be contracted at a later date.
 - C. Provide application engineer to instruct owner in operation of systems and equipment.
 - D. Provide system operator's training to include (but not limited to) such items as the following: modification of data displays, alarm and status descriptors, requesting data, execution of commands and request of logs.

1.10 WARRANTY

- A. Warranty shall cover costs for parts, labor, associated travel, and expenses for a period of one year from completion of system acceptance.
- B. Hardware and software personnel supporting this warranty agreement shall provide on-site or off-site service in a timely manner after failure notification to the vendor. The maximum acceptable response time to provide this service at the site shall be 24 hours Monday through Friday, 48 hours on Saturday and Sunday.
- C. This warranty shall apply equally to both hardware and software.
- D. Warrant labor and materials for specified control system free from defects for a period of 12 months after final acceptance. Failures on control systems that include all computer equipment, transmission equipment and all sensors and control devices during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
- E. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
- F. Provide updates to operator workstation software, project-specific software, graphic software, database software, and firmware that resolve Contractor identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with the above-mentioned items. Do not install updates or upgrades without Owner's authorization.

PART 2 - PRODUCTS

2.01 GENERAL

- A. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved in writing by Owner. Spare parts shall be available for at least five years after completion of this contract.

2.02 NETWORKING COMMUNICATIONS

- 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 135-2004, BACnet.
- B. Install new wiring and network devices as required to provide a complete and workable control network.

- C. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.
- D. 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, and control algorithms 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 control strategies specified in Section 23 1000. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.
- E. Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated controller via the internetwork. System shall automatically adjust for daylight saving and standard time.
- F. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.
- G. System shall support Web services data exchange with any other system that complies with XML (extensible markup language) and SOAP (simple object access protocol) standards specified by the Web Services Interoperability Organization (WS-I) Basic Profile 1.0 or higher. Web services support shall as a minimum be provided at the workstation or web server level and shall enable data to be read from or written to the system.
 - 1. System shall support Web services read data requests by retrieving requested trend data or point values (I/O hardware points, analog value software points, or binary value software points) from any system controller or from the trend history database.
 - 2. System shall support Web services write data request to each analog and binary object that can be edited through the system operator interface by downloading a numeric value to the specified object.
 - 3. For read or write requests, the system shall require user name and password authentication and shall support SSL (Secure Socket Layer) or equivalent data encryption.
 - 4. System shall support discovery through a Web services connection or shall provide a tool available through the Operator Interface that will reveal the path/identifier needed to allow a third party Web services device to read data from or write data to any object in the system which supports this service.

2.03 OPERATOR'S INTERFACE

- A. General structure of workstation interaction shall be a standard client/server relationship. Server shall be used to archive data and store system database. Clients shall access server for archived data. Each client shall include flexibility to access graphics from server or local drive. Server shall support a minimum of 50 clients simultaneously.
- B. Operators workstation or web server shall reside on high-speed network with building controllers. Each standard browser connected to server shall be able to access all system information.
- C. Communication. Web server or workstation and controllers shall communicate using BACnet protocol. Web server or workstation and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ANSI/ASHRAE 135-2004, BACnet Annex J.
- D. Provide operator's workstation/web server at location shown on Drawings.
- E. Workstation/web server hardware:
 - 1. Type: desktop computer.

2. Computer: Equipment shall consist of color monitor, personal computer with minimum 3 GB DDR2 SDRAM, 500 GB Serial ATA hard drive and controller, 16X DVD +/- RW Drive, front access USB ports, Ethernet 10/100 integrated port, optical mouse and 101-key enhanced keyboard. Personal computer shall be an IBM Compatible PC, and shall include a minimum 2.8 GHz Pentium dual-core processor with Intel Integrated Graphics Media Accelerator X3100 with a DVI video input, with operating system as recommended by controls system manufacturer.
 3. Monitor: The display provided for system operation shall be an LCD monitor with a diagonal screen measurement of no less than 19 inches and a minimum display resolution of no less than 1280 x 1024 pixels with a maximum response time of 5ms, and a DVI video output.
- F. BACnet Conformance:
1. Operator's workstation shall as a minimum support Point-to-Point (PTP) and Ethernet BACnet LAN types. It shall communicate directly via these BACnet LANs as a native BACnet device. Operator's terminal shall comply with the requirements of a BACnet conformance class 3 device and support BACnet services necessary to provide the following BACnet functional groups:
 - a. Clock Functional Group
 - b. Event Response Functional Group
 - c. Time Master Functional Group
 - d. Device Communications
 2. Refer to section 22.2, BACnet Functional Groups, in the BACnet standard for a complete list of the services that must be directly supported to provide each of the functional groups listed above. Proprietary services, if used in the system, shall be thoroughly documented and provided as part of the submittal data. Necessary tools shall be supplied for working with proprietary information.
 3. Standard BACnet object types accessed by the workstation shall include as a minimum: Analog Value, Analog Input, Analog Output, Binary Value, Binary Input, Binary Output, Calendar, Device, Event Enrollment, File, Notification Class, Program and Schedule object types. Proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. Necessary tools shall be supplied for working with proprietary information.
 4. The Operator Workstation shall comply with Annex J of the BACnet specification for IP connections. This device shall use Ethernet to connect to the IP internetwork, while using the same Ethernet LAN for non-IP communications to other BACnet devices on the LAN. Must support interoperability on wide area networks (WANs) and campus area networks (CANs). Workstation shall support Foreign Device Registration to allow temporary workstation connection to IP network.
- G. Displays:
1. Operator's workstation shall display data associated with project as called out on drawings and/or object type list supplied. Graphic files shall be created using digital, full color photographs of system installation, AutoCAD or Visio drawing files of field installation drawings and wiring diagrams from as-built drawings. Operator's workstation shall display data using three-dimensional graphic representations of mechanical equipment. System shall be capable of displaying graphic file, text, and dynamic object data together on each display and shall include animation. Information shall be labeled with descriptors and shall be shown with the appropriate engineering units. Information on any display shall be dynamically updated without any action by the user. Workstation shall allow user to change field-resident EMCS functions associated with the project, such as setpoints, weekly schedules, exception schedules, etc. from any screen no matter if that screen shows text or a complete graphic display. This shall be done without any reference to object addresses or other numeric/mnemonic indications.
 2. Displays and programming shall be generated and customized by the local EMCS supplier and installer. Systems requiring or using factory development of graphics or programming of DDC logic are specifically prohibited.

3. Binary objects shall be displayed as ACTIVE/INACTIVE/NULL or with customized text. Text shall be justified left, right or center as selected by the user. Also, allow binary objects to be displayed as individual change-of-state graphic objects on the display screen such that they overlay the system graphic. Each binary object displayed in this manner shall be assigned up to three graphic files for display when the point is ON, OFF or in alarm. For binary outputs, toggle the object's commanded status when the graphic item is selected with the system mouse. Similarly, allow the workstation operator to toggle the binary object's status by selecting with the mouse a graphic of a switch or light, for example, which then displays a different graphic (such as an "ON" switch or lighted lamp). Additionally, allow binary objects to be displayed as an animated graphic. Animated graphic objects shall be displayed as a sequence of multiple graphics to simulate motion. For example: when a pump is in the OFF condition, display a stationary graphic of the pump. When the operator selects the pump graphic with the mouse, the represented object's status is toggled and the graphic of the pump's impeller rotates in a time-based animation. The operator shall be able to click on an animated graphical object or switch it from the OFF position to ON, or ON to OFF. Allow operator to change graphic file assignment and also create new and original graphics online. System shall be supplied with a library of standard graphics, which may be used unaltered or modified by the operator. Systems that do not allow customization or creation of new graphic objects by the operator (or with third-party software) shall not be allowed.
 4. Analog objects shall be displayed with operator modifiable units. Analog input objects may also be displayed as individual graphic items on the display screen as an overlay to the system graphic. Each analog input object may be assigned a minimum of five graphic files, each with high/low limits for automatic selection and display of these graphics. As an example, a graphic representation of a thermometer would rise and fall in response to either the room temperature or its deviation from the controlling setpoint. Analog output objects, when selected with the mouse, shall be displayed as a prompted dialog (text only) box. Selection for display type shall be individual for each object. Analog object values may be changed by selecting either the "increase" or "decrease" arrow in the analog object spinner box without using the keypad. Pressing the button on the right side of the analog object spinner box allows direct entry of an analog value and accesses various menus where the analog value may be used, such as trendlogs.
 5. Analog objects may also be assigned to an area of a system graphic, where the color of the defined area changes based on the analog object's value. For example, an area of a floor-plan graphic served by a single control zone would change color with respect to the temperature of the zone or its deviation from setpoint. Editing and area assignment shall be created or modified online using simple icon tools.
 6. A customized menu label (push-button) shall be used for display selection. Menu items on a display shall allow penetration to lower level displays or additional menus. Dynamic point information and menu label push buttons may be mixed on the same display to allow sub-displays to exist for each item. Each display may be protected from viewing unless operator has appropriate security level. A security level may be assigned to each display and system object. The menu label shall not appear on the graphic if the operator does not have the appropriate security level.
 7. A mouse shall be used to move the pointer arrow to the desired item for selection of new display or to allow the operator to make changes to object data.
- H. Password Protection:
1. Provide security system that prevents unauthorized use unless operator is logged on. Access shall be limited to operator's assigned functions when user is logged on. This includes displays as outlined above.
 2. Each operator's terminal shall provide security for 200 users minimum. Each user shall have an individual User ID, User Name and Password. Entries are alphanumeric characters only and are case sensitive (except for User ID). User ID shall be 0–8 characters, User Name shall be 0–29 characters, and Password shall be 4–8 characters long. Each system user shall be allowed individual assignment of only those control functions and menu items to which that user requires access. All passwords, user names,

and access assignments shall be adjustable online at the operator's terminal. Each user shall also have a set security level, which defines access to displays and individual objects the user may control. System shall include 10 separate and distinct security levels for assignment to users.

3. System shall include an Auto Logout Feature that shall automatically logout user when there has been no keyboard or mouse activity for a set period of time. Time period shall be adjustable by system administrator. Auto Logout may be enabled and disabled by system administrator. Operator terminal shall display message on screen that user is logged out after Auto Logout occurs.
- I. Operator Activity Log:
1. Operator Activity Log shall be included with system that tracks operator changes and activities. System shall track what is changed in the system, who performed this change, date and time of system activity and value of the change before and after operator activity. Operator shall be able to display activity, sort the changes by user and also by operation.
 2. Log shall be gathered and archived to hard drive on operator workstation as needed. Operator shall be able to export data for display and sorting in a spreadsheet.
 3. Any displayed data, that is changeable by the operator, may be selected using the right mouse button and the operator activity log shall then be selectable on the screen. Selection of the operator activity log using this method shall show operator changes of just that displayed data.
- J. Scheduling:
1. Operator's workstation shall show information in easy-to-read daily format including calendar of this month and next. Schedules shall show actual ON/OFF times for day based on scheduling priority. Priority for scheduling shall be events, holidays and daily with events being the highest.
 2. Holiday and special event schedules shall display data in calendar format. Operator shall be able to schedule holidays and special events directly from these calendars.
 3. Operator shall be able to change information for a given weekly or exception schedule if logged on with the appropriate security access.
 4. System shall include a Schedule Wizard for set up of schedules. Wizard shall walk user through steps necessary for schedule generation. Wizard shall have its own pull-down selection for startup or may be started by right clicking on value displayed on graphic and then selecting Schedule.
 5. Scheduling shall include optimum start based on outside air temperature, current heating/cooling setpoints, indoor temperature and history of previous starts. Each and every individual zone shall have optimum start time independently calculated based on parameters listed. User shall input schedules to set time that occupied setpoint is to be attained. Optimum start feature shall calculate the startup time needed to match zone temperature to setpoint. User shall be able to set a limit for the maximum startup time allowed.
- K. Alarm Indication and Handling:
1. Operator's workstation shall provide audible, visual, and printed means of alarm indication. The alarm dialog box shall always become the top dialog box regardless of the application(s), currently running. Printout of alarms shall be sent to the assigned terminal and port.
 2. System shall provide log of alarm messages. Alarm log shall be archived to the hard disk of the system operator's terminal. Each entry shall include a description of the event-initiating object generating the alarm. Description shall be an alarm message of at least 256 characters in length. Entry shall include time and date of alarm occurrence, time and date of object state return to normal, time and date of alarm acknowledgment and identification of operator acknowledging alarm .
 3. Alarm messages shall be in user-definable text (English or other specified language) and shall be entered either at the operator's terminal or via remote communication.
 4. Alarms shall be configured to either annunciate at selected workstations, print, page, or email in any combination.

5. System shall include an Alarm Wizard for set up of alarms. Wizard shall walk user through steps necessary for alarm generation. Wizard shall have its own pull-down selection for startup or may be started by right clicking on value displayed on graphic and then selecting alarm setup.
- L. Trendlog Information:
1. System server shall periodically gather historically recorded data stored in the building controllers and archive the information Archived files shall be appended with new sample data, allowing samples to be accumulated. Systems that write over archived data shall not be allowed, unless limited file size is specified. Samples may be viewed at the operator's workstation. Operator shall be able to scroll through trended data. Trendlog information shall be displayed in standard engineering units.
 2. Software shall be included that is capable of graphing the trend logged object data. Software shall be capable of creating two-axis (x, y) graphs that display up to ten object types at the same time in different colors. Graphs shall show object values relative to time.
 3. Operator shall be able to change trend log setup information. This includes the information to be logged as well as the interval at which it is to be logged. Input, output, and value object types in the system may be logged. Operations shall be password protected. Setup and viewing may be accessed directly from graphics on which object is displayed.
 4. System shall include a trend Wizard for setup of logs. Wizard shall walk user through necessary steps. Wizard shall have its own pull-down selection for startup, or may be started by right clicking on value displayed on graphic, and then selecting Trendlogs from the displayed menu.
- M. Configuration/Setup:
1. Provide means for operator to display and change system configuration. This shall include, but not be limited to, system time, day of the week, date of daylight savings set forward/set back, printer termination, port addresses, modem port and speed, etc. Items shall be modified using understandable terminology with simple mouse/cursor key movements.
- N. Field Engineering Tools
1. Operator's workstation software shall include field-engineering tools for programming controllers supplied. Controllers shall be programmed using graphical tools that allow the user to connect function blocks on screen that provide sequencing of control logic. Function blocks shall be represented by graphical displays that are easily identified and distinct from other types of blocks. Graphical programming that uses simple rectangles and squares is not acceptable.
 2. User shall be able to pick graphical function block from menu and place on screen. Provide zoom in and zoom out capabilities. Function blocks shall be downloaded to controller without any reentry of data.
 3. Programming tools shall include a real time operation mode. Function blocks shall display real time data and be animated to show status of data inputs and outputs when in real time operation. Animation shall show change of status on logic devices and countdown of timer devices in graphical format.
 4. Field engineering tools shall also include a database manager of applications that include logic files for controllers and associated graphics. Operator shall be able to select unit type, input/output configuration and other items that define unit to be controlled. Supply minimum of 250 applications as part of workstation software.
 5. Field engineering tool shall include Device Manager for automatic detection of devices connected anywhere on the system network by scanning of the entire network. This function shall display device instance, network identification, model number and description of connected devices. It shall record and display software file loaded into each controller. A copy of each file shall be stored on the computer's hard drive. If needed, this file shall be downloaded to the appropriate controller by selection using the mouse.
 6. System shall include backup/restore function that will back up entire system to selected medium and then restore system from that media.
- O. Software:

1. At the conclusion of project, contractor shall leave with owner CD ROM(s) or DVD(s) that include the complete software operation system and project graphics, setpoints, system parameters, etc. This backup shall allow the owner to completely restore the system in the case of a computer malfunction.

2.04 BUILDING CONTROLLER

A. General Requirements:

1. Building Controller shall be of modular construction such that various modules may be selected to fit the specific requirements of a given project. Modules shall consist of a power supply module, a BACnet Ethernet-MS/TP module, a BACnet MS/TP only module as a minimum. Ethernet communications and controllers including central plant controllers, advanced application specific controllers and unitary controllers supplied by BMS manufacturer shall utilize the BACnet protocol standard.
2. Modules shall be selected to fit the particular project application. Up to 7 modules shall be powered by a single power supply module. Modules shall be panel mounted on DIN rail for ease of addition and shall be interconnected via simple plug in cable. A module in the middle shall be replaceable without removing any other modules.
3. Modules shall be capable of providing global control strategies for the system based on information from any objects in the system regardless if the object is directly monitored by the building controller module or by another controller. The software program implementing these strategies shall be completely flexible and user definable. Software tools necessary for programming shall be provided as part of project software. Any systems utilizing factory pre-programmed global strategies that cannot be modified by field personnel on-site, via a wide area network or downloaded via remote communications are not acceptable. Changing global strategies via firmware changes is also unacceptable.
4. Programming shall be object-oriented using control function blocks, supporting DDC functions, 1000 Analog Values and 1000 Binary Values. Flowcharts shall be generated and automatically downloaded to controller. Programming tool shall be supplied and be resident on workstation. The same tool shall be used for controllers.
5. Provide means to graphically view inputs and outputs to each program block in real-time as program is executing. This function may be performed via the operator's workstation or field computer.
6. Controller shall have a memory needed to ensure high performance and data reliability. Battery shall provide power for orderly shutdown of controller and storage of data in nonvolatile flash memory. Battery backup shall maintain real-time clock functions for a minimum of 20 days.
7. Global control algorithms and automated control functions shall execute via 32-bit processor.
8. Schedules:
 - a. Each building controller module shall support a minimum of 80 BACnet Schedule Objects and 80 BACnet Calendar Objects.
 - b. Building controller modules shall provide normal 7 day scheduling, holiday scheduling and event scheduling.
9. Logging Capabilities:
 - a. Each building controller shall log as minimum 320 values. Any object in the system (real or calculated) may be logged. Sample time interval shall be adjustable at the operator's workstation.
 - b. Logs may be viewed both on-site and off-site via WAN or remote communication.
 - c. Building controller shall periodically upload trended data to networked operator's workstation for long term archiving if desired.
 - d. Archived data stored in database format shall be available for use in third-party spreadsheet or database programs.
10. Alarm Generation:
 - a. Alarms may be generated within the system for any object change of value or state either real or calculated. This includes things such as analog object value changes, binary object state changes, and various controller communication failures.

- b. Each alarm may be dialed out as noted elsewhere.
 - c. Alarm log shall be provided for alarm viewing. Log may be viewed on-site at the operator's terminal or off-site via remote communications.
 - d. Controller must be able to handle up to 320 alarm setups stored as BACnet event enrollment objects – system destination and actions individually configurable.
11. Standard BACnet object types supported shall include as a minimum: Analog Value, Binary Value, Calendar, Device, File, Group, Notification Class, Program and Schedule object types. Proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. Necessary tools shall be supplied for working with proprietary information.
 12. The Building Controller shall comply with Annex J of the BACnet specification for IP connections. This device shall use Ethernet to connect to the IP internetwork, while using the same Ethernet LAN for non-IP communications to other BACnet devices on the LAN. Must support interoperability on wide area networks (WANs) and campus area networks (CANs) and function as a BACnet Broadcast Management Device (BBMD).
 13. Refer to section 22.2, BACnet Functional Groups, and Annex L in the BACnet standard for a complete list of the services that must be directly supported to provide each of the functional groups listed above. Proprietary services, if used in the system, shall be thoroughly documented and provided as part of the submittal data. Necessary tools shall be supplied for working with proprietary information.
 - a. BACnet Conformance: Device shall communicate directly via these BACnet LANs as a native BACnet device and shall support simultaneous routing functions between supported LAN types. Global controller shall be BTL Certified BACnet B-BC profile. Including BACnet services necessary to provide the following BACnet functional groups:
 - 1) Clock Functional Group
 - 2) Files Functional Group
 - 3) Reinitialize Functional Group
 - 4) Device Communications Functional Group
 - 5) Event Initiation Functional Group
- B. Ethernet – MS/TP Module:
1. Ethernet – MS/TP Module shall support every function as listed under paragraph A, General Requirements, of this section and the following.
 2. Communication with operator workstation and application specific controllers shall be via BACnet. Building controller Ethernet – MS/TP module shall incorporate as a minimum, the functions of a 2-way BACnet router. Controller shall route BACnet messages between the high-speed LAN (Ethernet 10/100MHz) and master slave token passing (MS/TP) LAN. Ethernet – MS/TP module shall also route messages from other Building Controller modules onto the BACnet Ethernet network.
 - a. MS/TP LAN must be software configurable from 9.6 to 76.8Kbps.
 - b. The RJ-45 Ethernet connection must accept either 10Base-T or 100Base-TX BACnet over twisted pair cable (UTP).
 - c. Ethernet – MS/TP module shall as a minimum support MS/TP and Ethernet BACnet LAN types.
- C. MS/TP Module:
1. MS/TP Module shall support every function as listed under paragraph A, General Requirements, of this section and the following.
 2. Building Controller MS/TP module communications shall be via BACnet master slave token passing (MS/TP) LAN to advanced application and application specific controllers. MS/TP module shall also route messages to Ethernet-MS/TP module for communication over WAN.
 - a. MS/TP LAN must be software configurable from 9.6 to 76.8Kbps
 - b. Configuration shall be via RS-232 connection.
 - c. MS/TP module shall as a minimum support MS/TP BACnet LAN type.
- D. Power Supply Module:

1. Power supply module shall power up to 7 Building Controller Modules. Input for power shall accept between 17 and 30 VAC, 47 to 65 Hz.
2. Power supply module shall include rechargeable battery for orderly shutdown of controller modules including storage of data in flash memory and for continuous operation of real time clocks for minimum of 20 days.

2.05 EXPANDABLE CENTRAL PLANT APPLICATION CONTROLLERS

A. General:

1. Expandable application controller shall be capable of providing control strategies for the system based on information from any or connected inputs. The program that implements these strategies shall be completely flexible and user definable. Any systems utilizing factory pre-programmed global strategies that cannot be modified by field personnel on-site via simple download are not acceptable. Changing global strategies via firmware changes is also unacceptable. Program execution of controller shall be a minimum of once per second.
2. Programming shall be object-oriented using control program blocks. Controller shall support a minimum of 500 Analog Values and 500 Binary Values. Each and every analog and binary value shall support standard BACnet priority arrays. Programming tool shall be provided with system and shall be the same tool that is used to program the Building Controller. Flowcharts shall be generated and automatically downloaded to controller. No re-entry of database information shall be necessary.
3. Provide means to graphically view inputs and outputs to each program block in real-time as program is executing. This function may be performed via the operator's terminal or field computer.
4. Controller shall have adequate data storage to ensure high performance and data reliability. Battery shall retain static RAM memory and real-time clock functions for a minimum of 1.5 years (cumulative). Battery shall be a field-replaceable (non-rechargeable) lithium type. Unused battery life shall be 10 years.
5. The onboard, battery-backed real time clock must support schedule operations and trend logs.
6. Global control algorithms and automated control functions should execute via 32-bit processor.
7. Controller shall include both on-board 10BASE-T/100BASE-TX Ethernet BACnet communications over twisted pair cable (UTP) and shall include BACnet IP communication. In addition, controller shall include BACnet PTP connection port.
8. The base unit of the controller shall host up to 8 expansion modules with various I/O combinations. These inputs and outputs shall include universal 12-bit inputs, binary triac outputs, and 8-bit switch selectable analog outputs (0-10V or 0-20 mA). Inputs shall support 3K and 10K thermistors, 0-5VDC, 0-10VDC, 4-20mA, dry contacts and pulse inputs directly.
9. Outputs must have onboard Hand-Off-Auto switches and a status indicator light. HOA switch position shall be monitored. Each analog output shall include a potentiometer for manually adjusting the output when the HOA switch is in the Hand position.
10. The position of each and every HOA switch shall be available system wide as a BACnet object. Expandable Central Plant Controller shall provide up to 176 discreet inputs/outputs per base unit.

B. BACnet Conformance:

1. Central Plant/AHU Controller shall as a minimum support Point-to-Point (PTP), MS/TP and Ethernet BACnet LAN types. It shall communicate directly via these BACnet LANs as a native BACnet device and shall support simultaneous routing functions between supported LAN types. Building controller shall be BTL Certified BACnet B-AAC profile. Including BACnet services necessary to provide the following BACnet functional groups support BACnet services necessary to provide the following BACnet functional groups:
 - a. Clock Functional Group
 - b. Files Functional Group
 - c. Reinitialize Functional Group

- d. Device Communications Functional Group
 - e. Event Initiation Functional Group
 - 2. Refer to section 22.2, BACnet Functional Groups, and Annex L in the BACnet standard for a complete list of the services that must be directly supported to provide each of the functional groups listed above. Necessary tools shall be supplied for working with proprietary information.
 - 3. Standard BACnet object types supported shall include as a minimum: Analog Input, Binary Input, Analog Output, Binary Output, Analog Value, Binary Value, Device, File, Group, Event Enrollment, Notification Class, Program and Schedule object types. Necessary tools shall be supplied for working with proprietary information.
 - 4. The Controller shall comply with Annex J of the BACnet specification for IP connections. This device shall use Ethernet to connect to the IP internetwork, while using the same Ethernet LAN for non-IP communications to other BACnet devices on the LAN. Must support interoperability on wide area networks (WANs) and campus area networks (CANs) and function as a BACnet Broadcast Management Device (BBMD).
- C. Schedules:
- 1. Each Central Plant/AHU controller shall support a minimum of 50 BACnet Schedule Objects.
- D. Logging Capabilities:
- 1. Each controller shall support a minimum of 200 trend logs. Any object in the system (real or calculated) may be logged. Sample time interval shall be adjustable at the operator's workstation.
 - 2. Controller shall periodically upload trended data to system server for long term archiving if desired.
 - 3. Archived data stored in database format shall be available for use in third-party spreadsheet or database programs.
- E. Alarm Generation:
- 1. Alarms may be generated within the system for any object change of value or state either real or calculated. This includes things such as analog object value changes, binary object state changes, and various controller communication failures.
 - 2. Alarm log shall be provided for alarm viewing. Log may be viewed on-site at the operator's terminal or off-site via remote communications.
 - 3. Controller must be able to handle up to 200 alarm setups stored as BACnet event enrollment objects – system destination and actions individually configurable.

2.06 CENTRAL PLANT AND AIR HANDLER APPLICATION CONTROLLERS

- A. Provide one or more native BACnet application controllers for each air handler and provide native BACnet application controllers as needed for central plant control that adequately cover objects listed in object list. Controllers shall interface to building controller via MS/TP LAN using BACnet protocol. No gateways shall be used. Controllers shall include input, output and self-contained logic program as needed for complete control of units. Controllers shall be fully programmable using graphical programming blocks. Programming tool shall be resident on operator workstation and be the same tool as used for the building controller. No auxiliary or non-BACnet controllers shall be used.
- B. BACnet Conformance
- 1. Application controllers shall as a minimum support MS/TP BACnet LAN types. They shall communicate directly via this BACnet LAN at 9.6, 19.2, 38.4 and 76.8 Kbps, as native BACnet devices. Application controllers shall be BTL Certified BACnet B-ASC profile. Including BACnet services necessary to provide the following BACnet functional groups and support BACnet services necessary to provide the following BACnet functional groups:
 - a. Files Functional Group
 - b. Reinitialize Functional Group
 - c. Device Communications Functional Group
 - 2. Refer to section 22.2, BACnet Functional Groups, and Annex L in the BACnet standard, for a complete list of the services that must be directly supported to provide each of the

functional groups listed above. Proprietary services, if used in the system, shall be thoroughly documented and provided as part of the submittal data. Necessary tools shall be supplied for working with proprietary information.

3. Standard BACnet object types supported shall include as a minimum—Analog Input, Analog Output, Analog Value, Binary Input, Binary Output, Binary Value, Device, File, and Program object types. Proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. Necessary tools shall be supplied for working with proprietary information.
- C. Application controllers shall include universal inputs with 10-bit resolution that accept 3K and 10K thermistors, 0–10VDC, 0–5 VDC, 4–20 mA and dry contact signals. Any input on a controller may be either analog or digital with a minimum of 3 inputs that accept pulses. Controller shall also include support and modifiable programming for interface to intelligent room sensor with digital display. Controller shall include binary and analog outputs on board. Analog outputs shall be switch selectable as either 0–10VDC or 0–20mA. Software shall include scaling features for analog outputs. Application controller shall include 24VDC voltage supply for use as power supply to external sensors.
- D. Program sequences shall be stored on board application controller in EEPROM or flash memory. No batteries shall be needed to retain logic program. Program sequences shall be executed by controller 10 times per second and capable of multiple PID loops for control of multiple devices. Calculations shall be completed using floating-point math and system shall support display of information in floating-point nomenclature at operator's terminal. Programming of application controller shall be completely modifiable in the field over installed BACnet LANs or remotely via modem interface. Operator shall program logic sequences by graphically moving function blocks on screen and tying blocks together on screen. Application controller shall be programmed using programming tools as described in operator's terminal section.

2.07 APPLICATION SPECIFIC CONTROLLERS, VAV TERMINAL UNITS (SINGLE DUCT)

- A. Provide one native BACnet ASC for each VAV terminal unit that adequately covers objects listed in object list for unit. Controllers shall interface to building controller via MS/TP LAN using BACnet protocol. No gateways shall be used. Controllers shall include on board CFM flow sensor, inputs, outputs and programmable, self-contained logic program as needed for control of units.
- B. BACnet Conformance:
 1. ASCs shall as a minimum support MS/TP BACnet LAN types. They shall communicate directly via this BACnet LAN at 9.6, 19.2, 38.4 and 76.8 Kbps, as a native BACnet device. Application controllers shall be BTL Certified BACnet B-ASC profile. Including BACnet services necessary to provide the following BACnet functional groups and support BACnet services necessary to provide the following BACnet functional groups:
 - a. Files Functional Group
 - b. Reinitialize Functional Group
 - c. Device Communications Functional Group
 2. Refer to section 22.2, BACnet Functional Groups, and Annex L in the BACnet standard, for a complete list of the services that must be directly supported to provide each of the functional groups listed above. Proprietary services, if used in the system, shall be thoroughly documented and provided as part of the submittal data. Necessary tools shall be supplied for working with proprietary information.
 3. Standard BACnet object types supported shall include as a minimum—Analog Input, Analog Output, Analog Value, Binary Input, Binary Output, Binary Value, Device, File and Program Object Types. Proprietary object types, if used in the system, shall be thoroughly documented and provided as part of the submittal data. Necessary tools shall be supplied for working with proprietary information.
- C. ASCs shall include universal inputs with 10-bit resolution that can accept 3K and 10K thermistors, 0–5 VDC, and dry contact signals. Inputs on controller may be either analog or digital. Controller shall also include support and modifiable programming for interface to

intelligent room sensor with digital display. Controller shall also include binary outputs on board. For applications using variable speed parallel fans, provide a single analog output selectable for 0-10 V or 0-20 mA control signals. ASC shall include microprocessor driven flow sensor for use in pressure independent control logic. Terminal units shall be controlled using pressure independent control algorithms and flow readings shall be in CFM.

- D. Program sequences shall be stored on board application controller in EEPROM or flash memory. No batteries shall be needed to retain logic program. Program sequences shall be executed by controller 10 times per second and shall be capable of multiple PID loops for control of multiple devices. Programming of application controller shall be completely modifiable in the field over installed BACnet LANs or remotely via modem interface. Operator shall program logic sequences by graphically moving function blocks on screen and tying blocks together on screen. ASC shall be programmed using the same programming tool as Building Controller and as described in operator workstation section. Programming tools shall be provided as part of system.
- E. On board flow sensor shall be microprocessor driven and precalibrated at the factory. Precalibration shall be at 16 flow points as a minimum. Factory calibration data shall be stored in EEPROM or flash memory. Calibration data shall be field adjustable to compensate for variations in VAV terminal unit type and installation. Calibration parameters shall be adjustable through intelligent room sensor. Operator workstation, portable computers and special hand-held field tools shall not be needed for field calibration.
- F. Provide duct temperature sensor at discharge of each VAV terminal unit that is connected to controller for reporting back to operator workstation.

2.08 PRIMARY CONTROL DEVICES

- A. General:
 - 1. Major components shall conform to following requirements. Provide additional components as required for complete system.

2.09 CONTROL DAMPERS AND ACTUATORS

- A. General:
- B. Damper Actuators:
 - 1. Damper operators shall be electronic type and shall be fully proportioning unless otherwise specified. Damper operators shall have metal bodies. Operators shall have ample power to overcome friction of damper linkage and air pressure acting on damper blades plus 50% safety factor. Damper operator mounting arrangement shall be outside airstream wherever possible. Operators shall have external adjustable stops to limit stroke. Operator linkage arrangement shall be such as to permit normally open or normally closed positions of damper as indicated.
 - 2. Outside air, return air, relief air, and exhaust air damper actuators shall be mechanical spring return. Capacitors or other non-mechanical forms of fail-safe are not acceptable. The actuator mounting arrangement and spring return feature shall permit normally open or normally closed positions of the damper as required.
 - 3. Damper operators on modulating dampers that are to be sequenced with other control devices shall, where required to meet sequencing needs, have pilot positioner of full relay type with interconnecting linkage to provide mechanical feedback so as to accurately position and control damper.
 - 4. One electronic actuator shall be direct shaft mounted per damper section. No connecting rods or jackshafts shall be needed. Small outside air and return air economizer dampers may be mechanically linked together if one actuator has sufficient torque to drive both and damper drive shafts are both horizontal installed.
 - 5. Multi-section dampers with electric actuators shall be arranged so that each damper section operates individually. One electronic actuator shall be direct shaft mounted per damper section. (See below execution section for more installation details.)

6. Electric damper actuators (including VAV box actuators) shall be direct shaft mounted and use a V-bolt and toothed V-clamp causing a cold weld effect for positive gripping. Single bolt or setscrew type fasteners are not acceptable.
7. Air handler damper actuators shall utilize analog control (2-10vdc, 4-20ma), floating control is not acceptable.
8. VAV terminal unit damper actuation shall be floating type or analog (2-10vdc, 4-20ma).
9. Normal (fail) Position:
 - a. Outside Air: Normally closed, spring return.
 - b. Return Air: Normally open, spring return.
 - c. Relief Air: Normally closed, spring return.
 - d. Exhaust Air: Normally closed, spring return.

2.10 SENSORS

- A. Room Temperature Sensors (standard):
 1. DDC room sensor.
 2. 10k Ohm thermister.
 3. Range 40 to 90 deg F with +/- 0.5 degrees F at factory calibrated point of 70 deg F.
 4. Override button for initiation of occupied mode during unoccupied hours.
 5. Set point adjustment: The high accuracy set point adjustment incorporates dual temperature scale indication and an access door that covers the setpoint adjustment switch.
 6. Built-in port allows connection of portable operators terminal to query and modify operating parameters on room level sensor.
 7. Cover color: White.
 8. Model: JCI, Alerton, Siemens, Automated Logic, or approved. Similar to Siemens Series 1000 room sensor.
- B. Temperature sensors:
 1. Duct temperature sensors shall be rigid or averaging as required by sequence of operations. Averaging sensors shall have sufficient length to span duct diagonally.
 2. Water temperature sensor shall be liquid immersion type, stainless steel thermister, with resistance varying proportionally to temperature. Temperature range shall be suitable for application.
- C. Outside Air Temperature Sensor:
 1. Platinum RTD type sensor.
 2. Assembly includes platinum RTD sensing element, transmitter and mounting enclosure.
 3. Output Signal: 4-20 mA.
- D. Air Static Pressure Sensor:
 1. Duct static pressure range: -0.5" to +7.0" w.c.
 2. Accuracy: +/-0.05" w.c.
 3. Output signal: 4-20 mA.
- E. High Limit Thermostats:
 1. High limit thermostats shall be manual reset type set at 120 degrees F.
- F. Low Limit Thermostats (Freezestat):
 1. Electric low temperature detection cut-out and alarm thermostat with remote vapor filled sensing element. Thermostat shall actuate when any one foot length of the element is exposed to temperatures below thermostat setting.
 2. Element Length: 20 foot minimum.
 3. Contacts: Main and auxiliary contacts. Electrical rating as required for application.
 4. Setpoint Adjustment Range: 15 to 55 deg. F.
 5. Differential: 5 deg. F. minimum.
 6. Reset: Manual button.
- G. Current Transformers:
 1. Current transformer switches shall be furnished for status purposes in air and water applications.

2. The current transformers shall be designed to be installed or removed without dismantling the primary bus or cables. The transformer shall be of a split core design. The core and windings shall be completely encased in a UL approved thermoplastic rated 94VA. No metal parts shall be exposed other than the terminals. The current transformers shall meet the following specifications:
 - a. Accuracy: 1% at 5.0 to 25.0 VA accuracy class with U.P.F. burden.
 - b. Provide a disconnect switch for each current transformer.
- H. Air Differential Pressure Switch:
 1. Differential pressure switches shall be diaphragm type, with die-cast aluminum housing and adjustable set point. Switch rating shall be a minimum 5 amps at 120 VAC. Switches shall be SPDT and be used for fan status as specified in the point schedule. Switch pressure range shall be suited for application. (e.g. filter 0-2.0", fan status 0-5.0", etc.).

2.11 SPACE PRESSURIZATION SENSORS

- A. Indoor Space Pressure Sensor:
 1. Material: aluminum welded casing.
 2. Construction: Ceiling mounted shielded static pressure sensor with multiple sensing ports, pressure impulse suppression chamber, airflow shielding and 1/8 inch FPT takeoff fitting.
 3. Measurement: within 1% of actual pressure value while being subjected to maximum airflow of 1000 fpm from a radial source.
 4. Manufacturer: Paragon, Veris, Mamac, or approved.
- B. Outdoor Pressure Sensor (Reference):
 1. Material: heavy gauge aluminum with hard-anodized finish and 2 inch diameter FPT connection.
 2. Construction: two circular perforated parallel plates with an integral pressure sensing chamber.
 3. Measurement: within 2% of actual value when being subjected to varying wind flows with velocities up to 80 miles per hour with approach angles up to 30 degrees to the horizontal.
 4. Manufacturer: Paragon, or approved.

2.12 MISCELLANEOUS

2.13 SYSTEM DIAGNOSTIC TOOLS

- A. LCD Operator Terminal:
 1. The LCD operator terminal is a small wall- or panel-mounted operator terminal that connects directly to the BACnet LAN. The communication design and messaging structure shall comply with ANSI/ASHRAE Standard 135-2004, BACnet. Each operator terminal shall be able to display any BACnet object from anywhere in the BACnet network.
 2. Each of these operator's terminals shall have a keypad and an adjustable backlit LCD, with a simple menu structure to give occupants and technicians intuitive access to system information. It shall have a minimum 4-line by 20-character display to allow an operator to query and adjust system values.
 3. The system shall allow the connection of up to 16 LCD operator terminals to each Building Controller. The operator shall have the ability to connect to each of these operator terminals with a laptop computer via an RS-232 cable to gain system access, troubleshooting, and display programming.
 4. Provide LCD operator terminals in the locations shown on the drawings.
- B. Field Service Tool:
 1. Field service tool shall allow technician to view and modify all setpoints and tuning parameters stored in application controller. In addition, technician shall be able to view status of all inputs and outputs on digital readout. Each piece of data shall have a data code associated with it that is customizable.
 2. Field service tool shall plug into wall sensor and provide all the functionality specified. Operator workstation shall include the capability to disable operation of the field service tool.
 3. Provide 1 Field Service Tool for this project.

- C. Network Connection Tool:
 - 1. Network connection tool shall allow technician to connect a laptop to any MS/TP network or at any MS/TP device and view and modify all information throughout the entire BACnet network. Laptop connection to tool shall be via Ethernet or PTP.
 - 2. Provide quick connect to MS/TP LAN at each controller. Tool shall be able to adjust to all MS/TP baud rates specified in the BACnet standard.
 - 3. Provide 1 Field Service Tool for this project.

PART 3 - EXECUTION

3.01 CONTROL SYSTEM INSTALLATION (GENERAL)

- A. Installation shall be by Control System Manufacturer, or as Authorized by Section 1.05A. Installation by Wholesalers, Franchised Dealers, or any firm whose principal business is not that of manufacturing and installing automatic temperature control systems shall not be acceptable.
- B. Install products in accordance with manufacturer's instructions.
- C. Provide miscellaneous devices, hardware, software, interconnections installation and programming required to ensure a complete operating system in accordance with the sequences of operation and point schedules.
- D. Contractor shall collaborate with Owner directly to determine Owner's preference for naming conventions, etc. before entering data in system.
- E. Prepare and start logic control system under provisions of this section.
- F. Provide Owner's Representative with spare parts list. Identify equipment critical to maintaining the integrity of the operating system.

3.02 EXAMINATION:

- A. The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to the architect/engineer for resolution before rough-in work is started.
- B. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started.
- C. Prior to starting work, carefully inspect installed work of other trades and verify that such work is complete to the point where work of this Section may properly commence.
- D. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate—or if any discrepancies occur between the plans and the contractor's work and the plans and the work of others—the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor's work with the work of others.
- E. Do not begin work until unsatisfactory conditions are resolved.

3.03 ELECTRICAL AND WIRING

- A. Provide wiring as required by functions as specified and as recommended by equipment manufacturers, to serve specified control functions. Provide shielded low capacitance wire for communications trunks.
- B. Wiring shall be installed neatly and professionally, in accordance with Specification Division 26 and national, state and local electrical codes.
- C. Control wiring shall not be installed in power circuit raceways. Magnetic starters and disconnect switches shall not be used as junction boxes. Provide auxiliary junction boxes as required. Coordinate location and arrangement of control equipment with the owner's representative prior to rough-in.
- D. Provide auxiliary pilot duty relays on motor starters as required for control function:
 - 1. Provide required interposing relays for motor starters and contactors.

2. Motor starters, pilot power transformers, and enclosures provided under Division 26. Coordinate 120 VAC or 24 VAC requirements with Division 26.
- E. NEC Class 1 (line voltage) wiring shall be UL Listed in approved conduit according to NEC and Division 26 requirements.
- F. Low-voltage wiring shall meet NEC Class 2 requirements. (Low-voltage power circuits shall be sub fused when required to meet Class 2 current limit.)
- G. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in conduit may be used provided that cables are UL Listed for the intended application. For example, cables used in ceiling plenums shall be UL Listed specifically for that purpose.
- H. Provide power for control components from nearest electrical control panel or as indicated on the electrical drawings—coordinate with electrical contractor.
- I. Control wiring in the mechanical, electrical, telephone and boiler rooms to be installed in raceways. Other wiring to be installed neatly and inconspicuously per local code requirements. If local code allows, control wiring above accessible ceiling spaces may be run with plenum rated cable (without conduit).
- J. Wiring in mechanical, electrical, or service rooms—or where subject to mechanical damage—shall be installed in conduit.

3.04 IDENTIFICATION

- A. Provide nameplates for switches, starters, and control devices in accordance with Section 20 6000.
- B. Nameplate wording shall be consistent with device names used on shop drawings and in Contract Documents.
- C. Point name and address shall be indicated at each end of control wire connections to DDC equipment.
- D. Identifiers shall match record documents.

3.05 PROTECTION

- A. The contractor shall protect work and material from damage by its employees and/or subcontractors and shall be liable for damage thus caused.
- B. The contractor shall be responsible for its work and equipment until finally inspected, tested, and accepted.

3.06 COORDINATION

- A. Site
 1. The project coordination between trades is the responsibility of the prime contractor who is the one tier higher contractual partner such as mechanical contractor, general contractor, construction manager, owner or owner's representative as applicable.
 2. The controls contractor shall follow prime contractor's job schedule and coordinate project related activities through the prime contractor except otherwise agreed or in minor job site issues. Reasonable judgment shall be applied.
 3. Where the work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment.
 4. If the contractor deviates from the job schedule and installs work without coordinating with other trades, so as to cause interference with work of other trades, the contractor shall make the necessary changes to correct the condition without extra charge.
 5. Coordinate and schedule work with other work in the same area, or with work that is dependent upon other work, to facilitate mutual progress.
- B. Test and Balance
 1. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.

2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.
 3. In addition, the contractor shall provide a qualified technician for duration of 8 hours to assist in the test and balance process.
 4. The tools used during the test and balance process shall be returned at the completion of the testing and balancing.
- C. Life Safety
1. Duct smoke detectors required for air handler shutdown are supplied under Division 26. The contractor shall interlock smoke detectors to air handlers for shutdown as described in Section 23 1000 Controls Sequence of Operation.
- D. Coordination with controls specified in other sections or divisions.
1. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:
 - a. All communication media and equipment shall be provided as specified in Part 2, "Communication" of this specification.
 - b. Each supplier of controls product is responsible for the configuration, programming, startup, and testing of that product to meet the sequences of operation described in this section.
 - c. The Contractor shall coordinate and resolve any incompatibility issues that arise between the control products provided under this section and those provided under other sections or divisions of this specification.
 - d. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.
 - e. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

3.07 GENERAL WORKMANSHIP

- A. Install equipment, piping, and wiring/raceway parallel to building lines (i.e., horizontal, vertical, and parallel to walls) wherever possible.
- B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.
- C. Install all equipment in readily accessible locations as defined by Chapter 1, Article 100, Part A of the National Electrical Code (NEC).
- D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.
- E. All equipment, installation, and wiring shall comply with acceptable industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

3.08 EXISTING EQUIPMENT

- A. Unless otherwise directed, the contractor is not responsible for the repairs or replacement of existing energy equipment and systems, valves, dampers, or actuators. Should the contractor find existing equipment that requires maintenance, the engineer is to be notified immediately.

3.09 LOCATION AND INSTALLATION OF SENSORS AND COMPONENTS

- A. General:
 1. Install sensors in accordance with the manufacturer's recommendations.
 2. Mount sensors rigidly and adequately for the environment within which the sensor operates.
 3. Room temperature sensors shall be installed on concealed junction boxes properly supported by the wall framing.
 - a. Mount space temperature sensors 48 inches above finished floor or adjacent to room light switch/sensor, where shown on Drawings.

4. All wires attached to sensors shall be air sealed in their raceways or in the wall to stop air transmitted from other areas affecting sensor readings.
 5. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type.
 6. Instruments, switches, transmitters, etc., shall be suitably wired and mounted to protect them from vibration, moisture and high or low temperatures.
 - a. Provide stainless steel or brass thermowells suitable for respective application and for installation under other sections—sized to suit pipe diameter without restricting flow.
 7. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across the full face of the coil.
 8. All pipe-mounted temperature sensors shall be installed in wells. Install all liquid temperature sensors with heat-conducting fluid in thermal wells.
 9. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location.
 10. Locate and install components for easy accessibility; in general, mount 48 inches above floor with minimum 3'-0" clear access space in front of units. Obtain approval on locations from owner's representative prior to installation. This includes, but is not limited to space temperature sensors, carbon dioxide sensors, etc.
- B. Room Sensors:
1. Mounting Height: Four feet above finish floor for wall mounted devices, where shown on Drawings.
- C. Temperature Limit Switches
1. A temperature limit switch (Low Temperature Detector) shall be provided to sense the temperature.
 2. A sufficient number of temperature limit switches shall be installed to provide complete coverage of the duct section.
 3. Manual reset limit switches shall be installed in approved, accessible locations where they can be reset easily.
 4. The temperature limit switch sensing element shall be installed in a serpentine pattern and in accordance with the manufacturer's installation instructions.
 5. Each bend shall be supported with a capillary clip. Provide 1 ft of sensing element for each 1 ft² of coil area.
 6. Install limit switch wiring such that temperature limits are in effect with unit running in hand and automatic modes.
- D. Averaging Temperature Sensing Elements
1. Sensing elements shall be installed in a serpentine pattern.
 2. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.
- E. Air Differential Pressure Switches:
1. Install limit switch wiring such that pressure limits are in effect with unit running in hand and automatic modes.
- F. Differential air static pressure.
1. Supply Duct Static Pressure: Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the high-pressure tap tubing of the corresponding building static pressure sensor (if applicable) or to the location of the duct high-pressure tap and leave open to the plenum.
 2. Return Duct Static Pressure: Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor.
 3. Building Static Pressure: Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.
 4. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.

5. All pressure transducers, other than those controlling VAV boxes, shall be located in field device panels, not on the equipment monitored or on ductwork.
6. Mount transducers in a location accessible for service without use of ladders or special equipment.

3.10 ACTUATORS

- A. Mount and link control damper actuators according to manufacturer's instructions.
 1. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, and then tighten the linkage.
 2. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
 3. Provide all mounting hardware and linkages for actuator installation.
 4. Dampers: Actuators shall be direct-mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5° available for tightening the damper seals. Actuators shall be mounted following manufacturer's recommendations.
 5. Valves: Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

3.11 DDC OBJECT TYPE SUMMARY

- A. Provide database generation.
- B. Displays:
 1. System displays shall show analog and binary object types within the system. They shall be logically laid out for easy use by the owner. Provide outside air temperature indication on system displays associated with economizer cycles.
 2. Provide software HOAs for major pieces of equipment such as fans, pumps, valves, and dampers.
- C. Run Time Totalization:
 1. At a minimum, run time totalization shall be incorporated for each monitored supply fan, return fan, exhaust fan, hot water and chilled water pumps. Warning limits for each point shall be entered for alarm and or maintenance purposes.
- D. Trendlog:
 1. Binary and analog object types (including zones) shall have the capability to be automatically trended.
- E. Alarm:
 1. Analog inputs (High/Low Limits) and selected binary input alarm points shall be prioritized and routed (locally or remotely) with alarm message per owner's requirements.
- F. Database Save:
 1. Provide back-up database for stand-alone application controllers on disk.

3.12 START-UP AND COMMISSIONING

- A. Start-up and commission systems. Allow sufficient time for start-up and commissioning prior to placing control systems in permanent operation.
- B. System Start -up: When installation of system is complete, calibrate equipment and verify transmission media operation before system is placed on-line. Testing, calibrating, adjusting and final field tests shall be completed by system installer. Verify that systems are operable from local controls in specified failure mode upon panel failure or loss of power. Upon completion of calibration, Contractor shall startup system, perform necessary testing and run diagnostic tests to ensure proper operation. Contractor shall be responsible for generating software and entering database information necessary to perform sequence of control and specified software routines.

- C. Verify that each control panel has been installed according to plans, specifications and approved shop drawings. Calibrate, test, and have signed off each control sensor and device.
- D. Each BMS program shall be put on line and commissioned. The contractor shall, confirm each programmed sequence of operation and compare the results in writing. In addition, each control loop shall be tested to verify proper response and stable control, within specified accuracy. Any discrepancies between the specification and the actual performance will be immediately rectified and re-tested. System program test results shall be recorded on data sheets and submitted to Engineer.
- E. Modifications: Provide any recommendation for system modification in writing to Owner's Representative. Do not make any system modification, including operating parameters and control settings, without prior approval from Owner's Representative.
- F. After final adjustments and testing, provide trend logs of control points of each system over a 24 hour period to demonstrate operation of control system. Trend logs of systems to be run simultaneously for maximum number of trendable points possible with each controller, to show interaction of various systems.
- G. After final acceptance, allow 12 hours of technician's time to monitor, trend and adjust control system during warranty period to fine tune programmed items and ensure system is operating properly. Time normally required to address warranty issues is excluded. Submit trend logs of controlled equipment, as requested by Engineer periodically, to verify control system performance.

END OF SECTION

SECTION 23 1000
CONTROLS SEQUENCE OF OPERATIONS

PART 1 - GENERAL

1.01 GENERAL

- A. Provide a complete and operational temperature control and building automation system based on the following points and sequence of operation. The system shall be complete as to sequences and standard control practices. The determined point list is the minimum amount of points that are to be provided. If additional points are required to meet the sequence of operation, they shall be provided.
- B. Point Definitions and Abbreviations:
 - 1. The following points as defined for each piece of equipment are designated as follows:
 - a. Binary Input (BI) - Defined as any two-state input to controller, such as an alarm, status, etc.
 - b. Binary Output (BO) - Defined as any two-state output from controller, such as start/stop, enable/disable, etc.
 - c. Analog Input (AI) - Defined as any variable input to controller, such as temperature, pressure, position, etc.
 - d. Analog Output (AO) - Defined as any electrical variable output. 0–20mA, 4–20mA and 0–10VDC are the only acceptable analog outputs. The driver for analog outputs must come from both hardware and software resident in the controllers. Transducers will not be acceptable under any circumstance.
 - e. Floating Point Control Output (FO): Use of floating point control will utilize two (2) BO outputs or single AO where indicated.
- C. Control setpoints noted herein are estimated setpoints for initial start-up. During testing and monitoring, Control Contractor shall be responsible for setpoint adjustment to obtain optimum system performance. Record final settings in Operation and Maintenance Manual.
- D. System setpoints (i.e., temperatures, static pressure, operating times, alarm percentage tolerance, Lead-lag times, etc.) shall be adjustable.
 - 1. Whenever a setpoint is referred to as adjustable in these standards, the setpoint is to be easily and directly adjustable at the operator's terminal, and will not to require any code modification. This may require assigning virtual points to adjustable setpoints. Frequently adjusted points, including space temperature setpoints, shall be adjustable from the graphics screen (e.g., floor plan screen).
- E. Equipment shut-down to safeties shall automatically restart when conditions return to within normal operating limits.
- F. Reset loop parameters and setpoints to initial values at the beginning of each operating mode, and after restart due to power failure.
- G. Equipment with VFD's and bypass starters: Safety interlocks and limit controls shall remain in effect during by-pass mode.

PART 2 - PRODUCTS

2.01 NOT USED

PART 3 - EXECUTION

3.01 PACKAGED AIR CONDITIONING SYSTEM (RTU-1)

- A. RTU-1 is a packaged single zone, variable volume air handler with electric cooling. Return fan modulation shall track supply fan modulation. System components shall modulate in response to BAS in accordance with these listed operational requirements and set points, subject to safeties. BAS shall control supply and return fans, occupancy mode, discharge temperature setpoints, and outside air damper minimum position. Packaged unit controller shall control unit economizer, cooling, and heating operations in response to BAS temperature command.

1. RTU Automatic Dampers: RTU outside/return air and relief dampers operated by packaged unit controller.
2. Warm-up:
 - a. One-half hour before scheduled start of occupied period start RTU.
 - b. Unit shall operate with outside air and relief dampers closed, as commanded by packaged unit controller.
 - c. If the occupied period begins before setpoint is reached, system shall switch over to occupied mode operation with packaged unit controller resetting operation accordingly.
 - d. BAS shall monitor warm-up mode operation and self-adjust the pre-occupied operational period required using optimal start algorithms.
3. Night Flush:
 - a. Enable after 12:00 am, if building schedule will have occupied period the same day.
 - b. During unoccupied schedule, if space temperatures, exceeds 78 deg F, and outside air temperature is below 65 deg F, mode until occupied space heating setpoint is obtained.
 - c. If occupied period begins before occupied space heating setpoint F is reached, system shall switch to occupied mode operation.
4. Occupied Hour Operation:
 - a. Zone temperature setpoints maintained by packaged rooftop unit controller to maintain following setpoints:
 - 1) Heating setpoint = 70 deg F.
 - 2) Cooling setpoint = 75 deg F.
5. Unoccupied Operation:
 - a. System shall operate in response to the night setback program to maintain minimum and maximum space temperatures as follows:
 - 1) Heating setpoint = 55 deg F (on at 55 deg F, off at 60 deg F).
 - 2) Cooling setpoint = 85 deg F (on at 85 deg F, off at 80 deg F).
6. Cooling:
 - a. Packaged unit controller shall operate economizer, and stage mechanical cooling to maintain discharge air temperature as determined by BAS. Unit controller shall also provide control over integrated economizer function with outside air free cooling and compressor operation.
 - b. When the space temperature exceeds the cooling (economizer) setpoint for a minimum of 5 minutes, the space setpoint increases to the cooling (mechanical) setpoint.
 - c. BAS shall control supply fan speed between minimum and maximum (100%). speeds through reset of duct static pressure setpoint to satisfy space cooling demand and maintain airflow circulation through space. Minimum fan speed is initially 40% (adjustable) when operating in economizer cooling, and 80% (adjustable) when unit DX cooling is operating.
 - d. Supply air temperature reset:
 - 1) Enabled when supply fan speed is 80% or greater.
 - 2) BAS resets the discharge air cooling setpoint between 55 deg F and 65 deg F (adjustable) to satisfy space cooling demand. Temperature reset accomplished slowly in increments of 1 deg F every 5 minutes until the upper or lower limit is reached.
7. Fire Protection:
 - a. Duct-mounted smoke detector signal to stop system through starter circuit, and shut down interlocked equipment to meet NFPA 90A and IMC 606.
 - b. Smoke detector and relay and 120 volt circuit to relay, provided by Division 26.
8. Input/Output Point Monitoring Summary:
 - a. As a minimum, the following points and features shall be monitored and alarmed, through the packaged unit controller as available. Control Contractor shall add additional points necessary to accomplish the sequence of operation and interface with other control equipment.

- b. Inputs:
 - 1) Supply fan run status (BI)
 - 2) Return fan run status (BI)
 - 3) Outside air temperature (AI)
 - 4) Return air temperature. (AI)
 - 5) Supply air temperature (AI)
 - 6) Space Temperature (AI)
 - 7) Occupancy status (AI)
 - 8) Duct static pressure (AI)
 - 9) Supply fan speed feedback (AI)
 - 10) Return fan speed feedback (AI)
 - c. Outputs:
 - 1) ACU on/off (BO)
 - 2) Outside air minimum position (AO)
 - 3) Duct Static pressure setpoint (AO)
 - d. General Alarms (any unscheduled fan shutdown):
 - 1) Air handling unit control panel communication failure.
 - 2) Supply fan failure (annunciated)
 - 3) Return fan failure (annunciated)
 - 4) Smoke detector shutdown (annunciated)
 - 5) Supply air low temperature limit.
 - 6) Zone temperature high / low limit.
 - (a) Alarm at excess of 5% above or below setpoint.
 - 7) Refrigeration high/low pressure alarm.
- B. Terminal Units, TU-1 through TU-8:
- 1. Control damper and coil control valve at coil shall modulate in response to Space Sensor for that zone, in accordance with heating, cooling, and deadband temperature setpoints.
 - 2. Provide sensor downstream of each terminal unit to monitor supply air temperature.
 - 3. Optimal Start/Warm-up:
 - a. Primary Airflow Settings:
 - 1) Maximum = Scheduled Primary CFM (adjustable)
 - b. Primary Damper Operation:
 - 1) Modulate damper to maintain maximum primary airflow setpoint when zone temperature is below occupied heating setpoint.
 - 2) Modulate damper to minimum primary flow when zone temperature reaches or rises above the occupied heating setpoint.
 - c. Heating Coil Valve Position: Modulating.
 - 4. Night Flush/Pre-cooling:
 - a. Primary Airflow Settings:
 - 1) Maximum = Scheduled Primary CFM (adjustable)
 - b. Primary Damper Operation: Modulate damper to maintain maximum primary airflow setpoint when zone temperature is above occupied heating setpoint. Close damper (to zero flow) when zone temperature reaches or drops below the occupied heating setpoint.
 - c. Heating Coil Valve Position: Closed.
 - 5. Occupied Operation:
 - a. Zone temperature setpoints maintained by modulating terminal unit air valves and electric heating coil, in conjunction with modulating components at central unit to maintain setpoints listed for specific system.
 - b. Heating setpoint = 70 deg F.
 - c. Cooling setpoint = 75 deg F.
 - d. Damper Position:

- 1) Cooling: Damper modulates to meet cooling requirement.
 - 2) Dead-band region: Damper at minimum setpoint.
 - 3) Heating: Damper to modulate to minimum setpoint before opening heating coil valve.
 - e. Electric Heat:
 - 1) Cooling: Electric heat is off.
 - 2) Dead-band region: Electric heat is off.
 - 3) Heating: Electric heat is energized to meet heating requirement.
 6. Unoccupied Modes:
 - a. Terminal units will signal the AHU unit to operate on call for heating or cooling supply air.
 - b. Unoccupied Low Limit Mode:
 - 1) Heating setpoint = 60 deg F. Call for heat initiates at 5 deg F below unoccupied setpoint. System shall remain ON until space temperature reaches unoccupied setpoint.
 - c. Unoccupied High Limit Mode:
 - 1) Cooling setpoint = 80 deg F. Call for cooling initiates at 5 deg F above unoccupied setpoint. System shall remain ON until space temperature is reaches unoccupied setpoint.
 - d. Unoccupied hour override switch:
 - 1) Applies during scheduled building unoccupied periods.
 - 2) When activated by space occupant, the switch shall temporarily activate the affected terminal unit and AHU to occupied operational mode.
 - 3) After expiration of preset time, system shall return to unoccupied mode.
 - 4) Time duration for change over to occupied mode shall be adjustable from 1/2 to 3 hours. Initially set for 1 hour.
 7. Input/Output Point Monitoring Summary:
 - a. As a minimum, the following points and features are to be monitored and alarmed. Control Contractor shall provide additional points necessary to accomplish sequence of operation and interface with other control equipment.
 - b. Inputs:
 - 1) Terminal unit supply air temperature (AI)
 - 2) Terminal unit air flow, cfm (AI)
 - 3) Space Temperatures (AI) (each zone)
 - c. Outputs:
 - 1) Heating Coil (AO) (each zone)
 - 2) Terminal unit damper position (AO) (each zone)
 - d. General Alarms:
 - 1) Zone temperature high/low limit
 - a) Alarm at excess of 3% above or below setpoint
- C. Exhaust Fan EF-1:
1. Relays or starters provided under Division 26.
 2. Exhaust fan(s) operation interlocked with RTU-1 to operate when this system is operating.
 3. Operation of the exhaust fan shall be monitored with a current transformer switch.
 4. Input/Output Point Monitoring Summary:
 - a. As a minimum, the following points and features are to be monitored and alarmed. Control Contractor shall provide additional points necessary to accomplish sequence of operation and interface with other control equipment.
 - b. Inputs:
 - 1) Fan run status (BI)
 - c. Outputs:
 - 1) Fan start/stop (BO)
 - d. General Alarms:

- 1) Fan run failure (annunciated)

3.02 ROOFTOP PACKAGED HEAT PUMP SYSTEM (RTU-2)

- A. RTU-2 is constant volume with occupied/unoccupied period operation. System components shall modulate in response to BAS in accordance with these listed operational requirements and set points, subject to safeties.
- B. Operation of system fan shall be monitored with current transformer switch.
 1. Automatic Dampers:
 - a. Dedicated actuators shall operate outside, return and relief air dampers in accordance with system operating status and supply and return air temperatures.
 - b. Outside Air Dampers, Automatic Return, and Relief:
 - 1) Outside Air Damper:
 - a) Modulating damper controlled in response to space thermostats, time of day, minimum outside air and free cooling (economizer). Economizer cycle shall be utilized when outside air temperature is at or below return air temperature.
 - b) Minimum position setting shall provide volume of outside air scheduled on drawings when AHU is operating.
 - c) Closed when system is not operating.
 - 2) Return air damper:
 - a) Modulating.
 - 3) Relief damper:
 - a) Modulating.
 - b) Damper operates shall track inverse operation of return damper, off common signal. Relief damper full open when return air damper is fully closed.
 - c) Closed when HP is not operating.
 2. Occupied Hour Operation:
 - a. Zone temperature setpoints maintained by modulating outside air and return dampers, in conjunction with heat pump operation for heating and cooling modes to maintain following setpoints:
 - 1) Heating setpoint = 70 deg F.
 - 2) Cooling setpoint = 75 deg F.
 3. Night Setback/Unoccupied Operation:
 - a. System shall operate in response to the night setback program to maintain minimum and maximum space temperatures as follows:
 - b. Heating setpoint = 60 deg F (on at 55 deg F, off at 60 deg F).
 - c. Cooling setpoint = 80 deg F (on at 85 deg F, off at 80 deg F).
 - C. Fire Protection:
 1. Duct-mounted smoke detector signal to stop system through starter circuit, and shut down interlocked equipment to meet NFPA 90A and IMC 606.
 2. Smoke detector and relay and 120 volt circuit to relay, provided by Division 26.
 - D. Heating Mode:
 1. Heat pump system shall initiate heating as per BAS subject to internal safeties and controls.
 2. Electric heating coils operate as modulated using internal SCR control to control supply air temperature per BAS, defrost mode, and safeties.
 3. Electric Heating mode off during cooling mode except during defrost mode.
 - E. Warm Up Mode:
 1. One-half hour before scheduled start of occupied period start HP unit.
 2. Outside air and relief dampers remain closed.
 3. If the occupied period begins before setpoint is reached, system shall switch over to occupied mode operation with dampers resetting accordingly.
 4. BAS shall monitor warm-up mode operation and self-adjust the pre-occupied operational period required.

- F. Cooling Mode:
1. Modulate outside air and return dampers to utilize economizer and DX cooling to maintain space temperature setpoint.
- G. Input/Output Point Monitoring Summary:
- a. As a minimum, the following points and features shall be monitored and alarmed. Control Contractor shall add additional points necessary to accomplish the sequence of operation and interface with other control equipment.
 - b. Inputs:
 - 1) Supply fan run status (BI)
 - 2) Outside air temperature (AI)
 - 3) Mixed air temperature (AI)
 - 4) Supply air temperature (AI)
 - 5) Space Temperature (AI)
 - c. Outputs:
 - 1) Outside air damper (AO)
 - 2) Return air damper (AO)
 - 3) Relief air damper (AO)
 - 4) Electric heat (AO)
 - 5) Supply fan (BO)
 - 6) DX operation (BO) (steps as required)
 - d. General Alarms (any unscheduled fan shutdown):
 - 1) Air handling unit control panel communication failure.
 - 2) Mixed air high/low temperature.
 - 3) Supply fan failure (annunciated)
 - 4) Freeze shutdown (annunciated)
 - 5) Supply air low temperature limit.
 - 6) Zone temperature high / low limit.
 - (a) Alarm at excess of 5% above or below setpoint.

END OF SECTION

**SECTION 23 3100
DUCTWORK**

PART 1 - GENERAL

1.01 RELATED SECTIONS

- A. Section 20 1000 - General Mechanical Provisions
- B. Section 20 2000 - Mechanical Operation and Maintenance Manuals
- C. Section 23 0700 - Ductwork Insulation
- D. Section 23 3300 - Ductwork Accessories

1.02 SHOP DRAWINGS, PRODUCT DATA, OPERATION & MAINTENANCE DATA

- A. Submittals required for the products listed in the Product Table, in accordance with Section 20 1000. Operation & Maintenance Information required as indicated in the Product Table in accordance with Section 20 2000.
- B. Operation & Maintenance Information requirements indicated by number designation as follows. Refer to Section 20 2000 for a description of each type of information.
 - 1. Shop Drawings (submittal data)
 - 2. Product Data (submittal data)
 - 3. Manufacturer's Operation Manuals
 - 4. Manufacturer's Service and Lubrication Requirements
 - 5. Service Contracts and Field Start-up Reports
 - 6. Cleaning, Certification, and Test Reports
 - 7. System Information
 - 8. Warranties

PRODUCT TABLE	Operation & Maintenance Information							
	1	2	3	4	5	6	7	8
Round and Oval Duct, Medium Pressure and/or Exposed	X	X				X		
Flexible Duct		X						
Duct Sealants		X						

PART 2 - PRODUCTS

2.01 DUCTWORK

- A. Fabrication and Site Delivery:
 - 1. Factory / Shop sealed by blanking or capping duct ends, bagging of small fittings, surface wrapping or shrink wrapping.
- B. Rectangular Ducts:
 - 1. Material: Galvanized steel.
 - 2. Fabricate and support in accordance with:
 - a. Oregon Mechanical Specialty Code, current edition.
 - b. SMACNA HVAC Duct Construction Standards, current edition.
 - 3. Pressure Classification:
 - a. Supply Ducts: 2 inch w.g. positive static pressure, except where noted otherwise on Drawings.
 - b. Return and Exhaust Ducts: 2 inch w.g. negative static pressure, except where noted otherwise on Drawings.
 - 4. Transverse Joints: In accordance with details in SMACNA HVAC Duct Construction Standards or one of the following proprietary joint systems:
 - a. Ductmate "25" with butyl gasket tape.
 - b. Ductmate "35" with butyl gasket tape.

- c. Lockformer "TDC" with butyl gasket tape.
 - d. Ward Duct Connectors Inc. "WDCI Lite" with butyl gasket tape.
 - e. Ward Duct Connectors Inc. "WDCI Heavy" with butyl gasket tape.
 - f. Spinfinity "AccuFlange."
5. Transverse Joints, Outdoors: SMACNA "T-20" or "T-24" flanged joint or approved proprietary joint system. Outdoor joints shall have continuous cleats for complete coverage of flanges on top and sides of duct. Top cleat shall overhang corners approximately 1/4 inch.
 6. Crossbreaking or Rollbeading:
 - a. Duct panels 16 inches wide and larger shall be rollbeaded or crossbroken, regardless of whether or not duct is lined or insulated.
 - b. Rollbeads shall be 1/8 inch deep, shall be parallel to transverse joints on tops of outdoor ducts, and shall be spaced maximum 12 inches on centers.
 - c. Ducts installed outdoors shall be crossbroken on top panels, to drain water.
 7. Material Thickness:
 - a. Duct gauges shall be determined using tables in SMACNA HVAC Duct Construction Standards, based on duct size, material, pressure class, joint type, and reinforcement spacing.
 - b. "Addendums to SMACNA" and other publications by proprietary joint manufacturers shall not be used for determining material thickness.
 - c. For determining duct gauges using SMACNA tables, proprietary joint systems shall be considered equivalent to the following SMACNA rigidity classes:
 - 1) Lockformer "TDC," 24 gauge: Class "D."
 - 2) Lockformer "TDC," 22 gauge: Class "E."
 - 3) Lockformer "TDC," 20 gauge: Class "F."
 - 4) Lockformer "TDC," 18 gauge, with tie rod(s) on each side of joint: Class "K."
 - 5) Ductmate "25": Class "F."
 - 6) Ductmate "35": Class "J."
 - 7) Ward "WDCI Lite": Class "F."
 - 8) Ward "WDCI Heavy": Class "J."
 - d. Ducts with proprietary joints shall be 24 gauge minimum.
 - e. Equivalent aluminum duct gauges shall be determined in accordance with SMACNA HVAC Duct Construction Standards.
 8. Sealing Requirements: Seal transverse joints and longitudinal seams with tape-and-adhesive or liquid duct sealer, specified herein. Not required for gasketed, flanged joints.
 9. Fittings: Refer to details on Drawings.
- C. Rectangular Ducts, Medium Pressure:
1. Ducts Included:
 - a. Supply ducts from Air Handling Units to Air Terminal Units.
 2. Material: Galvanized steel.
 3. Fabricate and support in accordance with:
 - a. Oregon Mechanical Specialty Code, current edition.
 - b. SMACNA HVAC Duct Construction Standards, current edition.
 4. Pressure Classification:
 - a. Supply Ducts: 3 inch w.g. positive static pressure.
 5. Transverse Joints: In accordance with details in SMACNA HVAC Duct Construction Standards "T-25" configuration or one of the following proprietary joint systems:
 - a. Ductmate "35" with DM 440 gasket tape.
 - b. Ductmate "45" with DM 440 gasket tape.
 - c. Ward Duct Connectors Inc. "WDCI Lite" with butyl gasket tape.
 - d. Ward Duct Connectors Inc. "WDCI Heavy" with butyl gasket tape.
 - e. "Spinfinity AccuFlange."
 6. Transverse Joints, Outdoors: SMACNA "T-24" flanged joint or approved proprietary joint system. Outdoor joints shall have continuous cleats for complete coverage of flanges on top and sides of duct. Top cleat shall overhang corners approximately 1/4 inch.
 7. Crossbreaking or Rollbeading:

- a. Duct panels 16 inches wide and larger shall be rollbeaded or crossbroken, regardless of whether or not duct is lined or insulated.
- b. Rollbeads shall be 1/8 inch deep, shall be parallel to transverse joints on tops of outdoor ducts, and shall be spaced maximum 12 inches on centers.
- c. Ducts installed outdoors shall be crossbroken on top panels, to drain water.
- 8. Material Thickness:
 - a. Duct gauges shall be determined using tables in SMACNA HVAC Duct Construction Standards, based on duct size, material, pressure class, joint type, and reinforcement spacing.
 - b. "Addendums to SMACNA" and other publications by proprietary joint manufacturers shall not be used for determining material thickness.
 - c. For determining duct gauges using SMACNA tables, proprietary joint systems shall be considered equivalent to the following SMACNA rigidity classes:
 - 1) Ductmate "35": Class "J."
 - 2) Ductmate "45": Class "K."
 - 3) Ward "WDCI Heavy": Class "J."
 - d. Ducts with proprietary joints shall be 24 gauge minimum.
- 9. Sealing Requirements: Seal transverse joints and longitudinal seams with tape-and-adhesive or liquid duct sealer, specified herein. Flanged, gasketed joints that meet testing requirements need not have duct sealer applied.
- 10. Fittings: Refer to details on Drawings.
- D. Round Ducts, Indoors, Except Medium Pressure and Exposed:
 - 1. Material: Galvanized steel.
 - 2. Fabricate and support in accordance with latest editions of:
 - a. Oregon Mechanical Specialty Code
 - b. SMACNA HVAC Duct Construction Standards
 - 3. Pressure Classification:
 - a. Supply Ducts: 2 inch w.g. positive static pressure, except where noted otherwise on Drawings.
 - b. Return and Exhaust Ducts: 2 inch w.g. negative static pressure, except where noted otherwise on Drawings.
 - 4. Duct Joints:
 - a. Seams: Longitudinal or spiral, in accordance with SMACNA HVAC Duct Construction Standards. Longitudinal seams shall be spot welded. Snaplock not acceptable.
 - b. Transverse Joints, except outdoors:
 - 1) Option 1: In accordance with details in SMACNA HVAC Duct Construction Standards "T-25" configuration or one of the following proprietary joint systems:
 - a) Ductmate "35" with DM 440 gasket tape.
 - b) Ductmate "45" with DM 440 gasket tape.
 - c) Ward Duct Connectors Inc. "WDCI Lite" with butyl gasket tape.
 - d) Ward Duct Connectors Inc. "WDCI Heavy" with butyl gasket tape.
 - e) "Spinfinity AccuFlange."
 - 2) Option 2: Slip joints, crimped or expanded.
 - c. Transverse Joints, Outdoors: SMACNA "T-24" flanged joint or approved proprietary joint system. Outdoor joints shall have continuous cleats for complete coverage of flanges on top and sides of duct.
 - 5. Material Thickness: In accordance with tables in SMACNA HVAC Duct Construction Standards, based on duct diameter, duct material, pressure class, and seam type.
 - 6. Sealing Requirements: Seal transverse joints with tape-and-adhesive or liquid duct sealer, specified herein. Not required for gasketed, flanged joints.
 - 7. Fittings: Refer to details on Drawings.
- E. Round and Oval Ducts, Medium Pressure and/or Exposed:
 - 1. Ducts Included:
 - a. Ducts from Air Handling Units to Air Terminal Units.
 - b. Exposed ducts.

2. Material: Galvanized steel.
 3. Fabricate and support in accordance with latest editions of:
 - a. Oregon Mechanical Specialty Code
 - b. SMACNA HVAC Duct Construction Standards
 4. Pressure Classification: 10 inch w.g. positive static pressure, except where noted otherwise on Drawings.
 5. Duct Joints:
 - a. Seams: Spiral lockseam.
 - b. Transverse Joints, except outdoors and exposed: In accordance with details in SMACNA HVAC Duct Construction Standards "T-25" configuration or one of the following proprietary joint systems:
 - 1) Ductmate "35" with DM 440 gasket tape.
 - 2) Ductmate "45" with DM 440 gasket tape.
 - 3) Ward Duct Connectors Inc. "WDCI Lite" with butyl gasket tape.
 - 4) Ward Duct Connectors Inc. "WDCI Heavy" with butyl gasket tape.
 - 5) "Spinfinity AccuFlange."
 - c. Transverse Joints, Outdoors: SMACNA "T-24" flanged joint or approved proprietary joint system. Outdoor joints shall have continuous cleats for complete coverage of flanges on top and sides of duct. Top cleat shall overhang corners approximately 1/4 inch.
 - d. Transverse Joints, Exposed Ducts: Flanged joints, TDC, Accu-Flange, or similar.
 6. Material Thickness: In accordance with tables in SMACNA HVAC Duct Construction Standards, based on duct diameter, duct material, and pressure class.
 7. Sealing Requirements:
 - a. Medium Pressure: Seal transverse joints with tape-and-adhesive or liquid duct sealer, specified herein. Flanged, gasketed joints that meet testing requirements need not have duct sealer applied.
 - b. Exposed: Seal transverse joints with liquid duct sealer, specified herein, applied to male fittings only, so that sealer shall not be visible when joint is assembled.
 8. Duct Liner:
 - a. Where Required:
 - 1) Ducts and fittings shown on Drawings to have internal liner.
 - 2) Ducts specified to have internal lining. Refer to Section 23 0700.
 - b. Liner Type: Fiberglass duct liner, covered by a perforated sheet metal inner shell, factory installed by duct manufacturer. Inner shell shall be supported on spacers, where required by SMACNA Standards, to prevent compression of liner. Duct size indicated on Drawings is measured to inside face of inner shell.
 - c. Liner Thickness:
 - 1) Minimum 1 inch thickness on ducts installed indoors.
 - 2) Minimum 2 inch thickness on ducts installed outdoors.
 9. Fittings:
 - a. Factory-fabricated by duct manufacturer.
 - b. Elbows shall be of die-stamped, pleated, standing seam, or gored (segmented) construction. Die-stamped fittings 8" diameter and larger 22 gauge minimum. Die-stamped fittings smaller than 8" diameter 24 gauge minimum.
 - c. 90° gored elbows shall be 5 piece.
 - d. 45° gored elbows shall be 3 piece.
 - e. Joints of standing seam fittings shall be fully sealed with liquid sealant.
 - f. See details on Drawings.
 10. Manufacturer: Metco, Dee's Sheet Metal, SEMCO, Arrow, Arjae Sheet Metal, Omni Duct Systems, Rolok Products, Robert Lloyd Sheet Metal, or approved.
- F. Rectangular Ducts, Outdoors:
1. Construction: Double wall galvanized steel.
 2. Fabricate and support in accordance with latest editions of:
 - a. Oregon Mechanical Specialty Code

- b. SMACNA HVAC Duct Construction Standards
 - 3. Pressure Classification: 4 inch w.g. positive static pressure, except where noted otherwise on Drawings.
 - 4. Seam Type: Longitudinal seams pittsburg lock, transverse joints flanged.
 - 5. Construction: Factory fabricated double-wall insulated ductwork with solid sheetmetal outer pressure shell and a perforated sheetmetal inner liner with insulation sandwiched between. Inner shell shall be supported on spacers where required by SMACNA Standards to prevent compression of insulation.
 - 6. Crossbreaking or Rollbeading:
 - a. Duct panels 16 inches wide and larger shall be rollbeaded or crossbroken, regardless of whether or not duct is lined or insulated.
 - b. Rollbeads shall be 1/8 inch deep, shall be parallel to transverse joints on tops of outdoor ducts, and shall be spaced maximum 12 inches on centers.
 - c. Ducts shall be crossbroken on top panels, to drain water.
 - 7. Material Thickness: In accordance with tables in SMACNA HVAC Duct Construction Standards, based on duct diameter, duct material, and pressure class.
 - 8. Sealing Requirements: Seal transverse and longitudinal joints with shop-injected liquid duct sealer, specified herein. Not required for gasketed, flanged joints.
 - 9. Internal Insulation:
 - a. Insulation Type: 2 inch thick fiberglass, factory installed by duct manufacturer.
 - 10. Fittings:
 - a. For fabrication details refer to Details on Drawings.
 - b. Fittings to be factory-fabricated by duct manufacturer.
 - 11. Manufacturer: United McGill Corporation "Rectangular k-27," ROLOK Products, or approved.
- G. Flexible Duct:
- 1. Pressure Rating: 6 inch w.g. positive, 1/2 inch w.g. negative.
 - 2. Core: Steel or aluminum helix bonded to continuous liner.
 - 3. Insulation: Fiberglass blanket between core and outer jacket.
 - 4. Thermal Conductance: 0.24 btuh/sq ft/deg. F max.
 - 5. Vapor Barrier Outer Jacket: Seamless polymer.
 - 6. Connect and support in accordance with latest editions of:
 - a. Oregon Mechanical Specialty Code
 - b. SMACNA HVAC Duct Construction Standards
 - 7. U.L. Listing: U.L. 181 Class 1 Air Duct.
 - 8. Manufacturer:
 - a. Flexmaster Type 3
 - b. ATCO UPC #070
 - c. Thermaflex G-KM
 - d. Hart & Cooley F114
- H. Liquid Duct Sealer, Indoors:
- 1. U.L. Classification: Flame spread rating not to exceed 25; smoke developed rating not to exceed 50; when applied in a 2 inch wide strip at a thickness of 0.0032 inch.
 - 2. Application Temperature Limits: 40 to 110 deg. F.
 - 3. Manufacturer: United McGill Corp., Accumetric, Vulkem, Carlisle Hardcast, Alcoa, Design Polymeric, Miracle Adhesives, Ductmate, or approved. Similar to Accumetric Boss 350.
- I. Tape-and-Adhesive Duct Sealer, Indoors:
- 1. U.L. Classification: Flame spread rating not to exceed 25; smoke developed rating not to exceed 50; when applied in a 2 inch wide strip at a thickness of 0.0032 inch.
 - 2. Application Temperature Limits: 30 to 110 deg. F.
 - 3. Manufacturer:
 - a. Hardcast Inc. DT tape with FTA-20 adhesive
 - b. United McGill MDT6-300 tape with MTA-20 adhesive
- J. Tape-and-Adhesive Duct Sealer, Outdoors:

1. Application Temperature Limits: 30 to 110 deg. F.
2. Manufacturer:
 - a. Hardcast Inc. DT tape with RTA-50 adhesive
 - b. United McGill MDT6-300 tape with MTC-50 adhesive

PART 3 - EXECUTION

3.01 GENERAL

- A. Install products in accordance with manufacturer's recommendations.
- B. Provide duct fittings and offsets not shown on Drawings, if required for coordination with the work of other sections.
- C. Install products in accordance with Manufacturer's recommendations and standards referenced herein.
- D. Duct sizes on Drawings are net inside dimensions, measured to inside face of internal liner or internal insulation.
- E. Fabricate and install ductwork to minimize gaps. Gaps in sheetmetal shall be no larger than allowed for sealant per sealant manufacturer's installation instructions.

3.02 DUCT AND FITTING HANDLING

- A. Delivery to Site:
 1. At site, sealed ends shall be visually examined and resealed as required.
- B. Storage:
 1. Store away from high dust generating processes.
 2. Provide pallets or blocking to keep above floor.
 3. Provide temporary cover to protect stored material.
- C. Installation:
 1. Protective coverings shall be removed immediately before installation and inspected to determine if wipe down is necessary.
 2. During construction, provide temporary sealing of openings into duct systems, to prevent accumulation of dust in ducts.
 3. Open ends of completed duct and overnight work-in-progress shall be sealed.

3.03 DUCT SEALANTS

- A. Clean duct surfaces prior to applying sealant.
- B. Prior to application, verify that ducts are dry and within specified temperature limits.
- C. Inspect after first application of sealant to identify areas where shrinkage has occurred. Fill voids with a second application.

3.04 FLEXIBLE DUCT

- A. Installation to conform to SMACNA HVAC Duct Construction Standards.
- B. Maximum Length: 6 feet, unless noted otherwise on Drawings.
- C. Limitations to Use: Flexible duct shall not be substituted for round or rectangular duct indicated on Drawings. Flexible duct is acceptable only where shown on Drawings.
- D. Connections to Collars: Secure core with stainless steel or nylon drawband under the insulation. Secure vapor barrier with an additional stainless steel or nylon drawband outside of insulation.

3.05 DUCT TESTING

- A. Testing for medium pressure ducts:
 1. Ducts Included:
 - a. Ducts between Air Handling Units and Air Terminal Units.
 - b. Outdoor ducts.
 - c. Ducts with pressure class greater than 2" w.g. noted on Drawings.
 2. Test Conditions:

- a. Test pressure: 5 inches w.g.
 - b. Allowable leakage: 1% of total duct branch airflow.
3. Test Apparatus:
- a. Blower: Capable of supplying 200% of allowable duct branch leakage rate at specified test pressure. Equipped with volume control device (inlet damper, bypass damper, or variable speed controller).
 - b. Flow Meter: Accurate within 7.5% at the indicated flow rate and test pressure. Certified calibration by independent testing agency or provide certificate signifying manufacture in conformance with ASME Requirements for Fluid Meters. Provide legible certified flow meter calibration curve and formula, cross-referenced to flow meter model/serial number, type, and size.
 - c. Pressure Differential Sensing Instruments:
 - 1) Differential below 0.5" w.g.: Readable to 0.05" scale divisions.
 - 2) Differential above 0.5" w.g.: Readable to 0.10" scale divisions.
4. Test Procedure:
- a. Test apparatus and calibration data to be approved by Engineer prior to testing.
 - b. Test after duct joints have been sealed and before ducts are concealed by ceilings and walls.
 - c. Test in accordance with SMACNA HVAC Air Duct Leakage Test Manual.
 - d. If leakage rate is exceeded in initial test, reseal ductwork and repeat test procedure until requirements are met.
 - e. Final test to be witnessed by Engineer. Notify Engineer two days in advance of final test.

END OF SECTION

**SECTION 23 3300
DUCTWORK ACCESSORIES**

PART 1 - GENERAL

1.01 RELATED SECTIONS

- A. Section 20 1000 - General Mechanical Provisions
- B. Section 20 2000 - Mechanical Operation and Maintenance Manuals
- C. Section 23 3100 - Ductwork

1.02 SHOP DRAWINGS, PRODUCT DATA, OPERATION & MAINTENANCE DATA

- A. Submittals required for the products listed in the Product Table, in accordance with Section 20 1000. Operation & Maintenance Information required as indicated in the Product Table in accordance with Section 20 2000.
- B. Operation & Maintenance Information requirements indicated by number designation as follows. Refer to Section 20 2000 for a description of each type of information.
 - 1. Shop Drawings (submittal data)
 - 2. Product Data (submittal data), including documentation of ORS 453.005 (7) (e) compliance.
 - 3. Manufacturer's Operation Manuals
 - 4. Manufacturer's Service and Lubrication Requirements
 - 5. Service Contracts and Field Start-up Reports
 - 6. Cleaning, Certification, and Test Reports
 - 7. System Information
 - 8. Warranties

PRODUCT TABLE	Operation & Maintenance Information							
	1	2	3	4	5	6	7	8
Volume Dampers		X						
Turn Vanes		X						
Fire Dampers - Include installation instruction with wall framing requirements	X	X	X	X		X		X
Backdraft Dampers	X	X		X				
Flexible Duct Connectors		X						
Twist-lock Fittings		X						
Sound Attenuators	X	X		X				

PART 2 - PRODUCTS

2.01 VOLUME DAMPERS

- A. Volume Dampers, up to 10 inch width, internally lined or uninsulated ducts:
 - 1. Blade: Minimum 22 ga. galvanized steel.
 - 2. Regulator: Quadrant type, 1/4 inch square shaft, hex nut lock, indicator dial marked "open" and "shut".
 - 3. Bearings: 1/4 inch square shaft, spring-lock on tail bearing.
 - 4. Regulator/Bearing Set Manufacturer: Duro-dyne SRHS-148, or approved.
- B. Volume Dampers, up to 10 inch width, externally insulated ducts:
 - 1. Blade: Minimum 22 ga. galvanized steel.
 - 2. Regulator: Quadrant type, 1/4 inch square, hex nut lock, indicator dial marked "open" and "shut", 1-1/2 inch standoff bracket.
 - 3. Bearings: 1/4 inch square shaft, spring-lock on tail bearing.

4. Regulator/Bearing Set Manufacturer: Duro-dyne SRST 1-1/2-148 standoff with SRHS-148 regulator, or approved.
- C. Volume Dampers, 11 inch to 20 inch width, internally lined or uninsulated ducts:
1. Blade: Minimum 18 ga. galvanized steel. Use multiple blades for height over 12 inches.
 2. Regulator: Quadrant type, 3/8 inch square shaft, hex nut lock, indicator dial marked "open" and "shut".
 3. Bearings: 3/8 inch square shafts, spring-lock on tail bearing.
 4. Regulator/Bearing Set Manufacturer: Duro-dyne SRHS-388, or approved.
- D. Volume Dampers, 11 inch to 20 inch width, externally insulated ducts:
1. Blade: Minimum 18 ga. galvanized steel. Use multiple blades for height over 12 inches.
 2. Regulator: Quadrant type, 3/8 inch square shaft, hex nut lock, indicator dial marked "open" and "shut", 1-1/2 inch standoff bracket.
 3. Bearings: 3/8 inch square shafts, spring-lock on tail bearing.
 4. Regulator/Bearing Set Manufacturer: Duro-dyne SRST 1-1/2-388 standoff with SRHS-388 regulator, or approved.
- E. Volume Dampers, 21 inch to 30 inch width, internally lined or uninsulated ducts:
1. Blade: Minimum 16 ga. galvanized steel. Use multiple blades for height over 12 inches.
 2. Regulator: Quadrant type, 1/2 inch square shaft, hex nut lock, indicator dial marked "open" and "shut".
 3. Shafts: 1/2 inch square, each end.
 4. End Bearing: Cast alloy, 1/2 inch square shaft size.
 5. Regulator/Bearing Set Manufacturer: Duro-dyne SRHS-128 regulator and SB-112 end bearing, or approved.
- F. Volume Dampers, 21 inch to 30 inch width, externally insulated ducts:
1. Blade: Minimum 16 ga. galvanized steel. Use multiple blades for height over 12 inches.
 2. Regulator: Quadrant type, 1/2 inch square shaft, hex nut lock, indicator dial marked "open" and "shut", 1-1/2 inch standoff bracket.
 3. Shafts: 1/2 inch square, each end.
 4. End Bearing: Cast alloy, 1/2 inch square shaft size.
 5. Regulator/Bearing Set Manufacturer: Duro-dyne SRST 1-1/2-128 standoff with SRHS-128 regulator and SB-112 end bearing, or approved.
- G. Volume Dampers, over 30 inch width:
1. Blade: Minimum 16 ga. galvanized steel, with stiffeners as required. Use multiple blades for height over 12 inches.
 2. Regulator: Quadrant type, 1/2 inch square shaft size, wing nut lock, indicator dial marked "open" and "shut".
 3. Shaft: 1/2 inch square, continuous across damper width.
 4. End Bearing: Cast alloy, 1/2 inch square shaft size.
 5. Regulator/Bearing Set Manufacturer: Duro-dyne K-5 regulator and SB-112 end bearing, or approved.
- H. Opposed Blade Volume Dampers:
1. Damper Assembly:
 - a. Type: V-crimped galvanized steel.
 - b. Blade Action: Opposed blade as noted on Drawings.
 - c. Blades: 6 inches wide, v-crimped, 16 ga. galvanized steel.
 - d. Frames: 16 ga. galvanized steel or extruded aluminum.
 - e. Blade-to-blade Linkage: Concealed within frame.
 - f. Blade Axles: 1/2 inch square zinc-plated steel.
 - g. Bearings: Oil-impregnated sintered bronze or molded synthetic.
 - h. Control Shaft: 1/2 inch square, extends 6 inches beyond frame.
 - i. Performance Ratings: Certified in accordance with AMCA Standard 500.
 - j. Manufacturer: Ruskin, Greenheck, Cesco, or approved. Similar to Ruskin CD35.
 2. Regulator: Quadrant type, 1/2 inch square shaft size, wing nut lock, indicator dial marked "open" and "shut". Duro-dyne K-5, or approved.

2.02 TURN VANES

- A. Turn Vanes, 20 inch and less duct width:
 - 1. Arrangement: Stationary vanes fixed to side rails installed in 90 degree square elbows.
 - 2. Vane and Rail Material: Galvanized steel.
 - 3. Vanes: Double wall, minimum 26 gauge, 90 degree, 2-inch throat radius.
 - 4. Rails: Minimum 24 gauge, 1-1/2 inch on center vane spacing.
 - 5. Manufacturer: Durodyne, Ductmate, Hardcast, Ward Industries, Cain, or approved. Similar to Durodyne Junior Vane Rail JVR2.
- B. Turn Vanes, greater than 20 inch duct width:
 - 1. Arrangement: Stationary vanes fixed to side rails installed in 90 degree square elbows.
 - 2. Vane and Rail Material: Galvanized steel.
 - 3. Vanes: Double wall, minimum 24 gauge, 90 degree, 4-1/2 inch throat radius.
 - 4. Rails: Minimum 24 gauge, 3-1/4 inch on center vane spacing.
 - 5. Manufacturer: Durodyne, Ductmate, Hardcast, Ward Industries, Cain, or approved. Similar to Durodyne Vane Rail VR2.

2.03 FIRE DAMPERS

- A. Fire Dampers, at wall and floor penetrations:
 - 1. Type: Galvanized steel, folding curtain, with fusible link.
 - 2. Free Area: 100 percent, blades out of airstream.
 - 3. Approvals: Comply with UL Standard 555.
 - 4. Closure Rating: Static.
 - 5. Fire Resistance Rating: 1-1/2 hour.
 - 6. Duct Connection Collars: Rectangular, round, or oval, as required to match ducts indicated on Drawings.
 - 7. Sealant: Dampers with round or oval duct connection collars shall have factory applied sealant at collar connections and at all seams.
 - 8. Mounting Position: Vertical or horizontal, as indicated on Drawings. Provide spring closure and latches for horizontal mount dampers.
 - 9. Manufacturer: Ruskin, Greenheck, Air Balance, Cesco, Prefco, Safe Air, Nailor, or approved. Similar to Ruskin IBD Series.

2.04 BACKDRAFT DAMPERS

- A. Backdraft Damper:
 - 1. Frame: Extruded aluminum channel.
 - 2. Blades: Extruded aluminum.
 - 3. Seals: Vinyl edge.
 - 4. Manufacturer: Ruskin, Cesco, Dowco, Greenheck, or approved. Similar to Ruskin type BD6.

2.05 FLEXIBLE DUCT CONNECTORS

- A. Flexible Duct Connectors:
 - 1. Assembly: Two 3 inch wide strips of metal connected to 3 inch wide strip of fabric with continuous crimped seams.
 - 2. Metal Strips: 24 gauge galvanized steel.
 - 3. Fabric Strip:
 - a. Indoor: Glass fabric with black DuPont Neoprene coating, flame resistant, approximately 30 ounces per yard.
 - b. Outdoor: Glass fabric with white DuPont Hypalon coating, flame resistant, UV resistant, approximately 26 ounces per yard.
 - 4. Manufacturer: Ventfabrics, Durodyne or approved. Similar to Durodyne "Metal-Fab".

2.06 TWIST LOCK FITTINGS

- A. Twist Lock Fittings:
 - 1. Type: Straight-neck "spin-in" for round take-off from rectangular duct.

2. Damper: None. Volume dampers shall be separate from twist-lock fitting. Refer to volume damper specification in this Section.
3. Manufacturer: Genflex, Flexmasterwest, Gensco, Western Stats, or approved. Similar to Flexmaster FL.

2.07 SOUND ATTENUATORS

- A. Sound Traps, Rectangular (ST-1):
 1. General: Unit shall be air tight and free of vibration and buckling at negative static pressures up to 8 inches water gauge and operational velocities up to 2000 fpm.
 2. Casing: Minimum 22 gauge galvanized steel, or Aluminum 18 gauge sheet with integral flanges for connection to ductwork.
 3. Interior Partitions: Construct from a single piece with die formed rounded entrance and exit shapes. Attachment of interior partitions to outer casing shall be made using welded tracks and nose clips.
 - a. Partition Material:
 - 1) Supply units: Minimum 26 gauge galvanized perforated steel, or 22 gauge perforated aluminum.
 - 2) Return/Exhaust Units: Minimum 24 gauge perforated galvanized steel.
 - 3) Perforations: Maximum 5/32 inch diameter holes.
 - 4) Total Perforation Area: limited to 25 percent free area.
 4. Filler Material: Inorganic glass fiber meeting requirements of NFPA 90A.
 - a. Inorganic glass fiber meeting requirements of NFPA 90A.
 - b. Density: As required to meet scheduled acoustic performance.
 - c. Packing Compression: Minimum 5 percent.
 - d. Combustion Ratings: Tested in accordance with ASTM E 84, NFPA Standard 255, or UL No. 723.
 - 1) Flame spread classification maximum 25.
 - 2) Smoke Development rating maximum 25.
 - e. Facing: Glass fiber cloth.
 5. Acoustical Performance: Certified in accordance with ASTM E 477. Refer to schedule on Drawings for performance requirements.
 - a. Acoustic rating shall include: Dynamic Insertion Loss (DIL), and Self-Noise (SN) power levels for both forward and reverse sound flow.
 6. Pressure Drop: Not to exceed indicated value through unit at design air quantity. Refer to schedule on drawings.
 7. Certified Test Data: At the request of the Engineer, or Owner's Representative, submit certified test data on DIL and SN power levels, and aerodynamic performance.
 8. Manufacturer: Vibro-Acoustics, IAC, TranSonic Inc., Commercial Acoustics, DynaSonic Systems Inc., or approved.
 9. Execution

2.08 GENERAL

- A. Install products in accordance with manufacturer's recommendations.

2.09 FIRE DAMPERS

- A. Fire Dampers:
 1. Install fire dampers in accordance with manufacturer's printed installation drawings. It is the Contractor's responsibility to obtain complete manufacturer's instructions, including requirements for wall opening preparation. Installation instructions shall be included with shop drawing submittal. Coordinate with other trades for proper construction of openings.

2.10 FLEXIBLE DUCT CONNECTORS

- A. Provide flexible duct connectors where shown on Drawings and at connections to fans which are not internally spring isolated.

2.11 SOUND ATTENUATORS

- A. Open ends of sound traps shall be capped at the factory to prevent entrance of dirt, water, or other debris. Caps shall remain in place until unit is installed.

END OF SECTION

SECTION 23 3400

FANS

PART 1 - GENERAL

1.01 RELATED SECTIONS

- A. Section 20 1000 - General Mechanical Provisions
- B. Section 20 2000 - Mechanical Operation and Maintenance Manuals
- C. Section 20 5100 - Motors

1.02 SHOP DRAWINGS, PRODUCT DATA, OPERATION & MAINTENANCE DATA

- A. Submittals required for the products listed in the Product Table, in accordance with Section 20 1000. Operation & Maintenance Information required as indicated in the Product Table in accordance with Section 20 2000.
- B. Operation & Maintenance Information requirements indicated by number designation as follows. Refer to Section 20 2000 for a description of each type of information.
 - 1. Shop Drawings (submittal data)
 - 2. Product Data (submittal data)
 - 3. Manufacturer's Operation Manuals
 - 4. Manufacturer's Service and Lubrication Requirements
 - 5. Service Contracts and Field Start-up Reports
 - 6. Cleaning, Certification, and Test Reports
 - 7. System Information
 - 8. Warranties

PRODUCT TABLE	Operation & Maintenance Information							
	1	2	3	4	5	6	7	8
Exhaust Fans	X	X	X	X				X
Equipment Curbs	X	X						

PART 2 - PRODUCTS

2.01 DOWNBLAST ROOF MOUNTED BELT DRIVE EXHAUST FANS (EF-1):

- A. Description: Curb-mounted, downblast belt drive exhauster complete with top cap, baffle and base.
- B. Performance and Certification Ratings: U.L. listed and bear AMCA rating seal for air and sound performance.
- C. Sound: Fan selection shall not exceed the maximum sones shown on the drawing schedule.
- D. Construction: 16 gauge spun aluminum, bolted to aluminum support base with continuously welded curb cap corners. Fan shall have specified lift points for roof-top installation.
- E. Electrical Chase: Integral conduit chase in motor compartment for wiring through curb.
- F. Fan Wheel: Aluminum, backward-inclined centrifugal, statically and dynamically balanced. Wheel shall be balanced in accordance with AMCA standard 204-96, balance quality and vibration levels for fans.
- G. Drive: ECM motor.
- H. Vibration Isolation: Fan support assembly isolated from unit with neoprene vibration isolators.
- I. Fan Bearings: Regreasable, cast pillowblock, specified for air handling application by fan manufacturer, minimum L50 life of 200,000 hours.
- J. Disconnect: NEMA 3R, rainproof, exterior service, factory wired to motor.
- K. Birdguard: Rigid wire mesh screen.

- L. Backdraft Damper: Gravity style. Extruded aluminum frame, aluminum blades, aluminum pins and brass bushings.
- M. Performance: Refer to schedule on Drawings.
- N. Manufacturer: Greenheck, Cook, Penn Ventilator, Carnes, or approved. Similar to Greenheck G series.

2.02 EQUIPMENT CURBS FOR ROOF MOUNTED FANS

- A. Body Construction: Minimum 18 gauge galvanized steel, continuous welded seams, cant.
- B. Insulation: 1½" thick, 3 pound density fiberglass on interior of curb wall.
- C. Damper Shelf: To fit backdraft damper where required in curb.
- D. Manufacturer: Listed fan manufacturers, Roof Products & Systems, Custom Curbs, Inc., or approved.

PART 3 - EXECUTION

3.01 GENERAL

- A. Install products in accordance with manufacturer's recommendations.
- B. Do not operate fans during construction.

END OF SECTION

**SECTION 23 3600
AIR TERMINAL UNITS**

PART 1 - GENERAL

1.01 RELATED SECTIONS

- A. Section 20 1000 - General Mechanical Provisions
- B. Section 20 2000 - Mechanical Operation and Maintenance Manuals

1.02 SHOP DRAWINGS, PRODUCT DATA, OPERATION & MAINTENANCE DATA

- A. Submittals required for the products listed in the Product Table, in accordance with Section 20 1000. Operation & Maintenance Information required as indicated in the Product Table in accordance with Section 20 2000.
- B. Operation & Maintenance Information requirements indicated by number designation as follows. Refer to Section 20 2000 for a description of each type of information.
 - 1. Shop Drawings (submittal data)
 - 2. Product Data (submittal data), including documentation of ORS 453.005 (7) (e) compliance.
 - 3. Manufacturer's Operation Manuals
 - 4. Manufacturer's Service and Lubrication Requirements
 - 5. Service Contracts and Field Start-up Reports
 - 6. Cleaning, Certification, and Test Reports
 - 7. System Information
 - 8. Warranties

PRODUCT TABLE	Operation & Maintenance Information							
	1	2	3	4	5	6	7	8
Air Terminal Units	X	X	X	X				X

1.03 QUALITY ASSURANCE

- A. Products shall comply with the requirements of Oregon Revised Statute (ORS) 453.005 (7) (e), effective January 1, 2011. The referenced statute limits the use of three types of brominated fire retardant chemicals, which are defined as hazardous substances.

PART 2 - PRODUCTS

2.01 AIR TERMINAL UNITS

- A. Terminal Units:
 - 1. Type: Single duct, pressure independent, variable volume, with electric reheat coils.
 - 2. Casing: Minimum 22 gauge galvanized steel, with access panel on bottom of unit.
 - 3. Internal Liner Insulation: Fibre-Free, 1½ lb. density, engineered polymer closed cell foam complying with UL-181 and NFPA 90A. Exposed fiberglass is not acceptable.
 - 4. Damper:
 - a. Maximum leakage rate of 1% at 3 inch w.g. inlet static pressure.
 - b. Shaft: Steel.
 - 5. Heating Coil: Factory installed, electric resistance, UL listed, airflow interlock, primary and secondary thermal cutouts, magnetic contactors, control transformer, panel enclosure with terminal strip for controls interface.
 - 6. Air Flow Sensor: Multiple point, averaging differential pressure sensor, compatible with control system.
 - 7. Flow Measuring Taps: External taps and calibration chart for field measurement of airflow.
 - 8. Controls:
 - a. Refer to Section 23 09 00 for DDC terminal unit controller and damper actuator.
 - b. Provide factory connection of airflow sensor to DDC controller.

- c. Provide factory installed metal panel enclosure with hinged door for DDC controller.
- d. Factory test assembled units before shipment.
- 9. Duct Outlet Connection: Slip and drive.
- 10. Control Panel Access: All control connections and the control panels shall be accessible from the same side, right hand or left hand, as shown on Drawings.
- 11. Performance Data: Rated in accordance with ARI standards 880-94.
- 12. Capacity: Refer to schedule on Drawings.
- 13. Manufacturer: Price, Carnes, Krueger, Nailor, Tempmaster, Trane, Titus, Tuttle & Bailey, or approved. Similar to Price SDV.

PART 3 - EXECUTION

3.01 GENERAL

- A. Install products in accordance with manufacturer's recommendations.

END OF SECTION

**SECTION 23 3700
AIR OUTLETS AND INLETS**

PART 1 - GENERAL

1.01 RELATED SECTIONS

- A. Section 20 1000 - General Mechanical Provisions
- B. Section 20 2000 - Mechanical Operation and Maintenance Manuals
- C. Section 20 9100 - Testing, Adjusting, and Balancing

1.02 SHOP DRAWINGS, PRODUCT DATA, OPERATION & MAINTENANCE DATA

- A. Submittals required for the products listed in the Product Table, in accordance with Section 20 1000. Operation & Maintenance Information required as indicated in the Product Table in accordance with Section 20 2000.
- B. Operation & Maintenance Information requirements indicated by number designation as follows. Refer to Section 20 2000 for a description of each type of information.
 - 1. Shop Drawings (submittal data)
 - 2. Product Data (submittal data), including documentation of ORS 453.005 (7) (e) compliance.
 - 3. Manufacturer's Operation Manuals
 - 4. Manufacturer's Service and Lubrication Requirements
 - 5. Service Contracts and Field Start-up Reports
 - 6. Cleaning, Certification, and Test Reports
 - 7. System Information
 - 8. Warranties

PRODUCT TABLE	Operation & Maintenance Information							
	1	2	3	4	5	6	7	8
Grilles	X	X						
Diffusers	X	X						

1.03 QUALITY ASSURANCE

- A. Products shall comply with the requirements of Oregon Revised Statute (ORS) 453.005 (7) (e), effective January 1, 2011. The referenced statute limits the use of three types of brominated fire retardant chemicals, which are defined as hazardous substances.

PART 2 - PRODUCTS

2.01 GRILLES, REGISTERS, AND DIFFUSERS

- A. General:
 - 1. Refer to Drawings for types, neck sizes, and blow patterns.
- B. Supply Diffuser Ceiling (SDC-1):
 - 1. Type: Louvered face.
 - 2. Material: Steel or aluminum.
 - 3. Face: Square, removable multi-louvered vane assembly.
 - 4. Blow Pattern: As indicated on Drawings.
 - 5. Frame Type: Lay-In 24x24 module.
 - 6. Neck: Square.
 - 7. Finish: White.
 - 8. Manufacturer: Titus, Kreuger, Carnes, Tuttle & Bailey, Anemostat, Price, or approved. Similar to Titus TDC.
- C. Supply Diffuser Ceiling (SDC-2):
 - 1. Type: Louvered face.

2. Material: Steel or aluminum.
 3. Face: Square, removable multi-louvered vane assembly.
 4. Blow Pattern: As indicated on Drawings.
 5. Frame Type: Surface-mount.
 6. Neck: Square.
 7. Finish: White.
 8. Manufacturer: Titus, Kreuger, Carnes, Tuttle & Bailey, Anemostat, Price, or approved. Similar to Titus TDC.
- D. Supply Grille Wall (SGW-1):
1. Type: Double deflection, individually adjustable blades.
 2. Material: Steel or aluminum.
 3. Border: 1-1/4 inch wide, countersunk screw holes, gasket.
 4. Front Blades: Maximum 3/4 inch on center, parallel to long dimension.
 5. Rear Blades: Maximum 3/4 inch on center, parallel to short dimension.
 6. Finish: White.
 7. Manufacturer: Titus, Kreuger, Carnes, Tuttle & Bailey, Anemostat, Price, or approved. Similar to Titus 300RL.
- E. Return Grille Ceiling (RGC-1):
1. Type: Perforated face, lay-in.
 2. Material: Steel or aluminum.
 3. Face: 24x24 module, removable, perforated, with 3/16 inch diameter holes on staggered 1/4 inch centers.
 4. Frame Type: Lay-In.
 5. Neck: As indicated on Drawings.
 6. Finish: White.
 7. Manufacturer: Titus, Kreuger, Carnes, Tuttle & Bailey, Anemostat, Price, or approved. Similar to Titus PAR.
- F. Return Grille Ceiling (RGC-2):
1. Type: Perforated face, lay-in.
 2. Material: Steel or aluminum.
 3. Face: 48x24, removable, perforated, with 3/16 inch diameter holes on staggered 1/4 inch centers.
 4. Frame Type: Surface-mount.
 5. Neck: As indicated on Drawings.
 6. Finish: White.
 7. Manufacturer: Titus, Kreuger, Carnes, Tuttle & Bailey, Anemostat, Price, or approved. Similar to Titus PAR.
- G. Return Grille Ceiling (RGC-3):
1. Type: Perforated face, surface.
 2. Material: Steel or aluminum.
 3. Face: 12x12, removable, perforated, with 3/16 inch diameter holes on staggered 1/4 inch centers.
 4. Frame Type: Surface-mount.
 5. Neck: As indicated on Drawings.
 6. Finish: White.
 7. Manufacturer: Titus, Kreuger, Carnes, Tuttle & Bailey, Anemostat, Price, or approved. Similar to Titus PAR.
- H. Exhaust Grille Ceiling (EGC-1):
1. Type: Perforated face, surface.
 2. Material: Steel or aluminum.
 3. Face: 12x12 module, removable, perforated, with 3/16 inch diameter holes on staggered 1/4 inch centers.
 4. Frame Type: Surface.
 5. Neck: As indicated on Drawings.

6. Finish: White.
7. Manufacturer: Titus, Kreuger, Carnes, Tuttle & Bailey, Anemostat, Price, or approved. Similar to Titus PAR.

PART 3 - EXECUTION

3.01 GENERAL

- A. Install products in accordance with manufacturer's recommendations.
- B. Secure grilles and registers with flat head, countersunk screws, flush with borders, painted to match borders. Hex head and/or bright finish screws are not acceptable.
- C. Install outlets and inlets tight to mounting surfaces.
- D. Center outlets and inlets between lights and in ceiling tiles, as shown on Architectural reflected ceiling plans.
- E. Install outlets and inlets plumb and square with walls and ceilings.
- F. Install return air grilles so that blades block vision through grille.
- G. Paint ductwork visible behind outlets and inlets matte black.

END OF SECTION

**SECTION 23 7410
PACKAGED AIR CONDITIONING UNITS**

PART 1 - GENERAL

1.01 RELATED SECTIONS

- A. Section 20 1000 - General Mechanical Provisions
- B. Section 20 2000 - Mechanical Operation and Maintenance Manuals

1.02 SHOP DRAWINGS, PRODUCT DATA, OPERATION & MAINTENANCE DATA

- A. Submittals required for the products listed in the Product Table, in accordance with Section 20 1000. Operation & Maintenance Information required as indicated in the Product Table in accordance with Section 20 2000.
- B. Operation & Maintenance Information requirements indicated by number designation as follows. Refer to Section 20 2000 for a description of each type of information.
 - 1. Shop Drawings (submittal data)
 - 2. Product Data (submittal data), including documentation of ORS 453.005 (7) (e) compliance.
 - 3. Manufacturer's Operation Manuals
 - 4. Manufacturer's Service and Lubrication Requirements
 - 5. Service Contracts and Field Start-up Reports
 - 6. Cleaning, Certification, and Test Reports
 - 7. System Information
 - 8. Warranties

PRODUCT TABLE	Operation & Maintenance Information							
	1	2	3	4	5	6	7	8
Air Conditioning Units	X	X	X	X	X		X	X
Roof Curbs	X	X						
Thermostats		X	X					X

1.03 QUALITY ASSURANCE

- A. Products shall comply with the requirements of Oregon Revised Statute (ORS) 453.005 (7) (e), effective January 1, 2011. The referenced statute limits the use of three types of brominated fire retardant chemicals, which are defined as hazardous substances.

PART 2 - PRODUCTS

2.01 AIR CONDITIONING UNITS (RTU-1)

- A. General:
 - 1. Weatherproof, downflow or horizontal arrangement including complete factory assembled wiring, open protocol microprocessor based controls, and refrigerant piping and refrigerant charge.
 - 2. Units constructed for installation on a roof curb providing full perimeter support under air handler section and pedestal support under condenser section.
 - 3. Cooling capacity ratings shall be based on ARI Standard 360 requirements.
 - 4. Units shall be factory tested and shipped in one piece.
- B. Casing:
 - 1. Phosphated, galvanized steel coated with baked-on enamel which meets and exceeds 600 hours of salt spray test in accordance with ASTM B117.
 - 2. Insulation: 1-inch thick 3/4 lb density neoprene coated glass fiber secured to all panels, including access doors, with adhesive and mechanical fasteners.
 - 3. Floor to have sheet metal liner.

4. Access doors: 17-gauge galvanized steel hinged access doors with single lever, single action staggered engagement latching mechanism. Provide access doors on both sides of each air handling section.
- C. Frame and Base:
1. Construction: 15-gauge galvanized steel.
 2. Base: Overhangs roof curb with formed recess to provide a watertight seal.
 3. Lifting Brackets: Provide heavy duty lifting brackets on the unit base with lifting holes to accept cable or chains hooks. Lifting brackets to be used for seismic restraint, see Part 3, Execution.
- D. Supply and Return Fan Assembly:
1. Assembly statically and dynamically balanced by, including final trim balance.
 2. Bearings: 200,000 hour greasable ball bearings.
 3. Fans: Class II airfoil style, constructed from heavy gauge aluminum with fan blades continuously welded to back plate and end rim.
 4. Motor: High efficiency, open drip proof, with greasable ball bearings.
 5. Drive and Sheaves: Belt drives with factory installed fixed sheaves with adjustable base for alignment and belt tension adjustment.
 6. Vibration Isolators: Seismically restrained spring vibration isolators sized by manufacturer.
- E. Condensing Section:
1. Compressors: Copeland Discus reciprocating semi-hermetic, hermetic scroll type, or approved.
 2. Capacity control: Cylinder unloading to provide 0/50/100 capacity steps and hot gas bypass for intermediate control and frost protection.
 3. Vibration Isolation: Seismically restrained, spring vibration isolators on compressor with vibration eliminators on suction and discharge lines.
 4. Condenser Fans: Propeller type, vertical discharge, direct drive fans with steel blades, and totally enclosed three phase motors. Fans shall be statically balanced. Motors shall be permanently lubricated, with built-in current and thermal overload protection in a weathertight casing.
 5. Condenser Coils: Multi-row copper tubes mechanically bonded to aluminum fins.
 6. Each refrigerant circuit: Sight-glass, filter-drier or replacement core filter drier, manual shutoff valve, and spring type high pressure relief. Sub-cooler circuit to provide 15 degrees of liquid sub-cooling.
 7. Electrical: Each compressor and condenser fan motor furnished with contactors and inherent thermal overload protection.
- F. Cooling Coil Section:
1. Coils: Direct expansion (DX), 5/8-inch copper tubes mechanically expanded to aluminum fins.
 2. Coil circuiting: Interlaced two circuit with multi-row design. Evaporator circuit fed by adjustable thermal expansion valve with equalizer.
 3. Drain Pan/s: Stainless steel pan extending beyond the leaving side of coil and underneath the cooling coil connections. Minimum 1/8-inch per foot slope to ensure positive draining. Threaded stainless steel drain connection.
- G. Economizer/ Return Air Fan Section:
1. Factory installed, outside air intake hood, fully modulating zero to 100% return air/outside air damper and motor, barometric relief damper, minimum outside air position setting, fixed dry bulb control, capable of simultaneous economizer and compressor operation.
- H. Building Static Pressure Control:
1. Provide keypad programmable offset and parameters to allow field adjustment of the supply and return fan volumes.
- I. Filters:
1. Filter Media Type/Thickness: Medium Efficiency Filters (25-30%, MERV 7), 2-inch.

- J. Discharge Plenum:
 - 1. Suitable for bottom duct connection.
- K. Electrical:
 - 1. Single point power terminal block for main power connection.
 - 2. Starters: Each Supply and return fan shall have contactors and external thermal overload protection. Each compressor and condenser fan shall have contactors and inherent thermal overload protection.
 - 3. Non-fused disconnect switch located inside control with through-the-door operation.
 - 4. Control circuit: Low voltage, circuit fusing, 115 volt control transformer, fuse, systems switches, and high temperature sensor.
 - 5. Receptacle: 115 volt convenience receptacle with separate electrical connection.
 - 6. Unit wiring: Complies with NEC requirements and with all applicable UL standards.
 - 7. Wiring and electrical components shall be number and color coded and labeled according to the unit electrical wiring diagram.
 - 8. Control panels: Provide weatherproof control panels for main unit and condensing section.
- L. Microprocessor Based Controls:
 - 1. Shall perform fan, heat, minimum ventilation, economizer and cooling control with anti-cycle protection of fans, heater and compressors.
 - 2. Controller shall accept occupied/unoccupied dry contact input from Building Automation System controls and allow monitoring of room temperature operating status.
 - 3. During occupied mode fan shall operate continuous and minimum ventilation shall be provided based on potentiometer input.
 - 4. During unoccupied mode fan shall operate only with call for night low/high limit and minimum ventilation shall be reset to zero. In unoccupied mode cooling setpoint is raised 7 degrees and heating setpoint is lowered 7 degrees.
 - 5. System shall provide automatic changeover between heating and cooling.
 - 6. Refer to Section 23 0900 and 23 1000.
- M. See Part 3, Execution, for additional requirements.
- N. Capacity and Efficiencies requirements: See schedule on Drawings.
- O. Manufacturer: Trane, York, McQuay, Carrier, or approved. Similar to Trane TCD Series.

PART 3 - EXECUTION

3.01 GENERAL

- A. Install products in accordance with manufacturer's recommendations.

3.02 PACKAGE ROOFTOP UNITS

- A. Roof Curb and Seismic Restraint:
 - 1. Refer to Architectural Drawings for curb and roof pad details. This section shall coordinate unit roof curb and roof cutting requirements with the curb installer.
 - 2. Units will be seismically restrained and installed on vibration isolation curbs as shown on the Mechanical Drawings. Provide additional hardware necessary to accomplish the restraint method of attachment detailed. Restraint attachment shall comply with seismic criteria listed under Section 20 4200.
 - 3. Units installed on concrete roof pads: Coordinate concrete duct opening sizes, locations and overall pad size with the installing contractor.
- B. Start-up and Commissioning: Unit manufacturer shall provide a factory authorized technician to start and commission the units and systems prior to final air balance. Submit certification report with Operation and Maintenance manual.
- C. This section shall provide any additional field assembly and electrical wiring of unit components not provided by the unit manufacturer.
- D. Install unit level to facilitate coil condensate drainage.

END OF SECTION

**SECTION 23 7420
PACKAGED HEAT PUMPS**

PART 1 - GENERAL

1.01 RELATED SECTIONS

- A. Section 20 1000 - General Mechanical Provisions
- B. Section 20 2000 - Mechanical Operation and Maintenance Manuals

1.02 SHOP DRAWINGS, PRODUCT DATA, OPERATION & MAINTENANCE DATA

- A. Submittals required for the products listed in the Product Table, in accordance with Section 20 1000. Operation & Maintenance Information required as indicated in the Product Table in accordance with Section 20 2000.
- B. Operation & Maintenance Information requirements indicated by number designation as follows. Refer to Section 20 2000 for a description of each type of information.
 - 1. Shop Drawings (submittal data)
 - 2. Product Data (submittal data), including documentation of ORS 453.005 (7) (e) compliance.
 - 3. Manufacturer's Operation Manuals
 - 4. Manufacturer's Service and Lubrication Requirements
 - 5. Service Contracts and Field Start-up Reports
 - 6. Cleaning, Certification, and Test Reports
 - 7. System Information
 - 8. Warranties

PRODUCT TABLE	Operation & Maintenance Information							
	1	2	3	4	5	6	7	8
Package Heat Pumps	X	X	X	X	X		X	X
Roof Curbs	X	X						
Filters	X	X						
Thermostats		X	X					X

1.03 QUALITY ASSURANCE

- A. Products shall comply with the requirements of Oregon Revised Statute (ORS) 453.005 (7) (e), effective January 1, 2011. The referenced statute limits the use of three types of brominated fire retardant chemicals, which are defined as hazardous substances.

PART 2 - PRODUCTS

2.01 HEAT PUMPS (RTU-2):

- A. Type:
 - 1. Single package, outdoor rooftop, downflow, factory assembled and wired.
 - 2. Consisting of cabinet and frame.
 - 3. Supply fan.
 - 4. Economizer.
 - 5. Electric heating coil.
 - 6. Air filters.
 - 7. Refrigerant coil, compressor, condenser coil, condenser fan reversing valve, refrigerant specialties and controls.
 - 8. Unit shall be listed and bare UL, CSA, or ETL label.

- B. Cabinet:
 - 1. Galvanized steel with baked enamel finish
 - 2. Insulated with minimum 1/2 inch thick fiberglass coated on airside. Sloped condensate pan and drain connection.
- C. Supply Fan:
 - 1. General: Forward curved centrifugal, resiliently mounted.
 - 2. Drive: Adjustable belt drive. Provide alternate motors and drives as required to meet capacity requirements scheduled on Drawings. Premium efficient motors with permanently lubricated bearings and inherent automatic reset thermal over load protection.
- D. Filter Section:
 - 1. Provide factory fabricated filter section of the same construction and finish as unit casing with filter guides, removable double wall access doors with gasket.
 - 2. Filters shall be removable from one side of the filter section.
 - 3. See Air Cleaning Devices, Section 23 4000, for filter media to be provided with the unit.
 - 4. Filter Media Type/Thickness: Medium Efficiency Filters (25-30%, MERV 7), 2-inch.
- E. Electric Resistance Heating Coil:
 - 1. Open wire nickel-chrome elements with all necessary safety operating controls.
 - 2. UL listed and indicated on basic unit informative plate.
 - 3. SCR Control.
- F. Compressors:
 - 1. General: Direct drive, hermetic, reciprocating, internally isolated, current overload protection.
 - a. One or two compressors as scheduled, each with independent refrigerant circuit.
 - b. Two-stage cooling capacity controls on units with two compressors.
- G. Refrigeration Components:
 - 1. Refrigerant service valves and gage connections,
 - 2. Accumulator
 - 3. Reversing valve
 - 4. Pressure relief
 - 5. Expansion device
 - 6. Refrigerant filter
 - 7. R-410a refrigerant charge
- H. Evaporator and Condenser Coils: Aluminum plate fins bonded to copper tubes with all joints brazed.
 - 1. Coil Guards: Protective grilles at condenser coils.
 - 2. Condenser Fans:
 - a. Direct drive, propeller
 - b. Totally enclosed outdoor fan motor with permanently lubricated bearings and overload protection.
 - 3. Operating and Safety Controls:
 - a. Factory wired low voltage control circuit
 - b. High temperature limit,
 - c. Compressor short cycle protection,
 - d. Compressor overtemperature and pressure protection.
- I. Economizer:
 - 1. Factory installed
 - a. Outside air intake hood
 - b. Fully modulating 0% to 100% return air/outside air damper and motor
- J. Electrical: See schedule on drawings, single point power connection.

- K. Controls:
 - 1. Unit shall be complete with self-contained low-voltage control circuit.
 - 2. Unit shall incorporate an outdoor coil defrost system to prevent excessive frost accumulation during heating duty. Defrost shall be initiated on the basis of time and coil temperature. A 30/50/90-minute timer shall activate defrost cycle only if coil temperature is low enough to indicate a heavy frost condition. Defrost cycle shall terminate when defrost thermostat is satisfied and shall have a positive termination time of 10 minutes.
 - 3. Unit shall be capable of simultaneous heating during defrost cycle operation by using electric heaters.
- L. Capacity: Refer to schedule on Drawings.
- M. Manufacturer: Trane, McQuay, York, Carrier, or approved. Similar to Trane Series WSX.

2.02 THERMOSTATS

- A. Thermostats:
 - 1. Type: Programmable heating and cooling.
 - 2. Schedule Programming: 7 day programming with 2 occupied/unoccupied periods per day.
 - 3. Temperature Setpoints: Occupied heating, occupied cooling, unoccupied heating, unoccupied cooling.
 - 4. Optimal Start: Automatically optimizes start time.
 - 5. Fan Control: Continuous fan operation during occupied periods; fan only on call for heating or cooling during unoccupied periods.
 - 6. Automatic changeover from heating to cooling.
 - 7. Override: 3 hour occupied button in thermostat cover.
 - 8. Stages of Control: Single stage heating; two stage cooling.
 - 9. Battery backup.
 - 10. Manufacturer: Honeywell T7300 thermostat with Q7300 subbase.

PART 3 - EXECUTION

3.01 GENERAL

- A. Install products in accordance with manufacturer's recommendations.
- B. Roof Curb and Seismic Restraint:
 - 1. Refer to Architectural Drawings for curb and roof pad details. This section shall coordinate unit roof curb and roof cutting requirements with the curb installer.
 - 2. Units will be seismically restrained and installed on vibration isolation curbs as shown on the Mechanical Drawings. Provide additional hardware necessary to accomplish the restraint method of attachment detailed. Restraint attachment shall comply with seismic criteria listed under Section 20 4200.
 - 3. Units installed on concrete roof pads: Coordinate concrete duct opening sizes, locations and overall pad size with the installing contractor.
- C. Start-up and Commissioning: Unit manufacturer shall provide a factory authorized technician to start and commission the units and systems prior to final air balance. Submit certification report with Operation and Maintenance manual.
- D. This section shall provide any additional field assembly and electrical wiring of unit components not provided by the unit manufacturer.
- E. Install unit level to facilitate coil condensate drainage.

END OF SECTION