Project Manual
For

BEAVERTON SCHOOL DISTRICT

ERROL HASSELL ES HVAC UPGRADE

PERMIT / BID SET

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DIVISION 23 MECHANICAL

HVAC MATERIALS AND METHODS

PART 1 - GENERAL

1.1 DESCRIPTION

A. The provisions of the General Requirements, Supplementary Requirements, and Division 1 apply to the HVAC work specified in this Division.

B. The requirements of this Section apply to the HVAC systems specified in these Specifications and in other Division 23 sections.

C. Provide all items, articles, materials, equipment, operations and/or methods listed, mentioned, shown and/or scheduled on the Drawings and/or in these Specifications, including all labor, supervision, services, permits, fees, and incidentals necessary and required to provide a complete and operable facility with complete systems as shown, specified, and required by applicable codes.

D. The work shall include, but not be limited to, the following systems:
1. Modification of air distribution system for control upgrades.
2. Installation of digital control system per drawings.
3. Modification of existing air handling systems for new control and restoration.

E. Advise subcontractor, suppliers, and vendors involved in the work specified in this Section of the applicable requirements.

1.2 QUALITY ASSURANCE

A. All work and materials shall conform to all applicable local and state codes and all federal, state and other applicable laws and regulations. All clarifications and modifications which have been cleared with appropriate authorities are listed under the applicable sections. All electrical products shall bear the label of a recognized testing laboratory such as UL or CSA..

B. Whenever the requirements of the Specifications or Drawings exceed those of the applicable code or standard, the requirements of the Specifications and Drawings shall govern.

C. Codes and Standards: Comply with the provisions of the following referenced codes, standards and specifications:
1. Federal Specifications (FS)
2. American National Standards Institute (ANSI)
3. National Electrical Manufacturer's Association (NEMA)
4. National Fire Protection Association (NFPA)
5. Underwriters Laboratories, Inc. (UL)
6. Factory Mutual (FM)
7. International Building Code (IBC) with State and Local Amendments
8. International Mechanical Code (IMC) with State and Local Amendments
9. Uniform Plumbing Code (UPC) with State and Local Amendments
10. American Society for Testing and Materials (ASTM)
11. Americans with Disabilities Act (ADA)
12. International Fire Code (IFC) with State and Local Amendments
13. Energy Policy Act (EPAct)
14. Manufacturers Standardization Society (MSS)
15. American Gas Association (AGA)

D. Each piece of equipment furnished shall meet all detailed requirements of the Drawings and Specifications and shall be suitable for the installation shown. Equipment not meeting all requirements will not be acceptable, even though specified by name. Where two or more units of the same class of equipment are furnished, use product of the same manufacturer; component parts of the entire system need not be products of same manufacturer. Furnish all materials and

equipment, new and free from defect and of size, make, type and quality herein specified or approved by the Architect. All materials shall be installed in a neat and professional manner.

E. All apparatus shall be built and installed to deliver its full rated capacity at the efficiency for which it was designed.

F. Commissioning shall be performed on this project. Commissioning agent is an agent of the Owner. See Section 23 08 00 for systems to be commissioned.

G. The Drawings and Specifications are complementary. What is called for by one shall be as though called for by both.

H. Drawings: Do not scale drawings for roughing-in measurements, nor use as shop drawings. Make field measurements and prepare shop drawings. Coordinate work with shop drawings of other specification divisions.

I. Field Wiring: It is the intent of these specifications that all systems shall be complete and operable. Refer to all drawings and specifications, especially the electrical drawings, to determine voltage, phase, circuit ampacity and number of connections provided. Provide all necessary field wiring and devices from the point of connection indicated on the electrical drawings. All equipment shall be installed in compliance with the Electrical Code and the equipment's UL listing. Bring to the attention of the Architect in writing, all conflicts, incompatibilities, and/or discrepancies prior to bid or as soon as discovered.

1.3 WORK OF OTHER CONTRACTS

A. Work under this contract shall be conducted in a manner to allow for the future installations of such equipment or items listed in other sections of this Specification.

B. See 23 08 00 for commissioning.

1.4 WORK OF OTHER DIVISIONS

A. Work under this Division shall be conducted in a manner to cooperate with the installation of such equipment or items as specified in other Divisions.

B. Plumbing piping systems and fixtures and fire suppression piping systems are specified under other Divisions of these Specifications except for provisions or items specifically noted on the Drawings or specified herein.

C. Consult all Drawings and Specifications in this project and become familiar with all equipment to be installed. Coordinate all aspects of the construction with the other trades on the job to ensure that all work and materials required to provide a complete and operational facility are included in the bid.

D. All sections of Division 23 are interrelated and shall be considered in their entirety when interpreting any material, method, or direction listed in any section of Division 23. Individual sections are not written for specific Subcontractors or Suppliers but for the General Contractor.

1.5 SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES (SUBMITTALS)

A. Submit in accordance with Division 1 full technical and descriptive shop drawing data on proposed materials and equipment as detailed in each section.

B. The Contractor shall verify that all equipment submitted can be delivered and installed within the time constraints of the construction period.

C. Include the manufacturer, type, style, catalog number, complete specification, certified

dimensions, and description of physical appearance for each item and option submitted. Reproduction of catalog data sheets shall be clean and legible to show all details, including gauge of metal used.

D. Include only information on exact equipment to be installed, not general catalogs of the manufacturer. Where sheets show proposed equipment as well as other equipment, identify proposed equipment with rubber stamp arrow or similar concise method.

E. Submit with each copy a transmittal letter verifying that all included equipment submittals have been carefully considered for quality, dimensions, function, and have been coordinated with the Drawings and Specifications. Guarantee that proposed materials will meet or exceed the quality and function of those specified.

F. Include field wiring diagrams and connection diagrams for all control and/or low voltage systems, including floor plans.

G. Submittal Review: The submittal review process is a means to provide quality control. The action noted to be taken (or where conflicts with the contract documents are not noted) shall not be interpreted by the Contractor as automatic "change orders." Approval of the data for substitution and shop drawings shall not eliminate the Contractor's responsibility for compliance with Drawings or Specifications, nor shall it eliminate the responsibility for freedom from errors of any sort in the data discovered prior to or after the review process. Deviations, discrepancies, and conflicts between the submittals and the Contract Documents shall be called to the Architect's attention in writing at the time of transmittal of the data.

H. Submittals shall be uploaded to e-Builder (Beaverton School Districts electronic project management software / system). Submittals shall be in the form of PDF documents. Arrange submittals numerically with specification sections identified in tabs. All required sections shall be submitted at one time. **Partial submittals will be rejected without review.**

1.6 PRODUCT SUBSTITUTION

A. Materials other than those specified may be approved for this project providing a written request is submitted to the Architect prior to bid in accordance with Instructions to Bidders. Requests shall include complete specifications, dimensions, manufacturer and catalog number for each item for which approval is desired. If, in the opinion of the Architect, the material is not complete or if it is not an acceptable substitute, he may reject it. The Architect's evaluation will be based solely on the material submitted.

1.7 CHANGE ORDERS

A. All supplemental cost proposals by the Contractor shall be accompanied by a complete itemized breakdown of labor and materials without exception. At the Architect's request, the Contractor's estimating sheets for the supplemental cost proposals shall be made available to the Architect. Labor must be separated and allocated for each item of work.

1.8 RECORD DOCUMENTS

A. Project Record (As-Installed) Drawings:
   1. Maintain a set of record drawings on the job site as directed in Division 1.
   2. Keep Drawings clean, undamaged, and up to date.
   3. Record and accurately indicate the following:
      a. Depths, sizes, and locations of all buried and concealed piping dimensioned from permanent building features.
      b. Locations of all valves with assigned tag numbers.
      c. Locations of all fire dampers and other airflow control devices.
      d. Changes, additions, and revisions due to change orders, obstructions, etc. Eradicate extraneous information.

e. Model numbers of installed equipment.

4. Make Drawings available when requested by Architect for review.
5. Submit as part of the required Project Closeout documents. Final submittal will be in the form of reproducible drawings.
6. Quality of entire set of project record drawings to match the quality of the contract documents; quality to be judged by Architect. Computer-aided design drafting (CADD) shall be used to complete project record drawings. Use standards set in contract documents. Note field modifications, all addenda, and change order items on project record drawings. If deficiencies are found in either the quality or the accuracy of the drawings, they will be returned unapproved. Additional review of subsequent submissions shall be at the Contractor's expense.

B. Operating and Maintenance Manuals: Submit Operating and Maintenance Instructions, including manufacturer's service data, wiring diagrams, and parts lists and vendors for all serviceable items of equipment, valve charts, balancing data, final control diagrams showing final set points, duct and piping pressure test reports, equipment startup records, and any additional equipment added by change order. Provide any performance curves, data, and model numbers from submittals. Comply with provisions of Division one where applicable to the mechanical work. Submittal shall be in the form of a PDF file per specification section. Arrange submittals numerically with equipment type or classification identified in tabs. Manufactures O&M manuals shall be provided as a single PDF file that can be hyper-linked by Owner for reference. O&M manuals that are a series of PDF files will not be accepted.

1.9 WARRANTY

A. Furnish, prior to application for final payment, a written and signed guarantee effective a period of one year from date of completion and acceptance of entire project; agree to correct, repair and/or replace defective materials and/or equipment or the results of defective workmanship without additional expense to the Owner. Where no response satisfactory to the Owner has occurred within three working days from the written report of a warranty covered defect, the Contractor shall agree to pay for the cost of repair of the reported defect by a Contractor of the Owner's choice. Note that warranty is only for new devices added or modifications to existing installations made under this contract.

B. Where the manufacturer's guarantee exceeds one year, the longer guarantee shall govern and include the Contractor's labor.

PART 2 - PRODUCTS

2.1 GENERAL

A. General: Provide all new materials and equipment, identical to apparatus or equipment in successful operation for a minimum of two years. Provide materials of comparable quality omitted here but necessary to complete the work. Maximum allowable variation from stated capacities, minus 5% to plus 10% as approved in each case.

B. Compatibility: Provide products which are compatible with other portions of the work and provide products with the proper or correct power and fuel-burning characteristics, and similar adaptations for the project.

C. Efficiency: Heating and cooling equipment shall comply with ASHRAE Standard 90.1-2019 and the State Energy Code. Where equipment efficiencies are indicated, the use of alternate or substitute manufacturer's equipment with lower efficiencies is not permitted.

D. Storage and Handling:
1. Delivery: Deliver to project site with manufacturer's labels intact and legible.
2. Handling: Avoid damage.
3. Storage: Inside protected from weather, dirt and construction dust. Where necessary to

store outside, elevate well above grade and enclose with durable, waterproof wrapping.

2. 2 DRIVES

A. Acceptable Manufacturers: Dayton, Gates, Browning.

B. General: "V" section belt drives, multiple as required, sized on 1.5 times installed motor horsepower. See drawings for installation of adjustable and fixed pitch sheaves. Final installation shall be with fixed pitch sheaves. Use standard section belts and no sheave smaller than cataloged industry standard.

2.3 VALVES

A. General: Provide factory fabricated valves of the type, body material, temperature and pressure class, and service indicated. Bronze gate, globe and check valves shall comply with MSS-SP-80. Ball valves shall comply with MSS-SP-110. Iron gate and globe valves shall comply with MSS-SP-70. Iron check valves shall comply with MSS-SP-71. Butterfly valves shall comply with MSS-SP-67. Valve size same as connecting pipe size.

B. Acceptable Manufacturers: Milwaukee, Crane, Grinnell, Nibco, Hammond, Stockham, Legend, Watts, and Walworth. Grooved end valves Victaulic, Gruvlock, or accepted substitute. NIBCO numbers are given except as noted. Where possible, provide valves from a single manufacturer.

C. Valve Styles: See individual Division 23 sections for valve styles.

D. Butterfly Valve Operators: Locking lever for shut-off service; "Memory Stop" for lever handle with 10-position throttling plate for throttling service; gear operator with babbitt sprocket rim for chain-operated valves and gear operators on all 8" or larger valves.

E. Butterfly Valve Style: Lug-type with cap screws for all valves utilized for equipment isolation for servicing. Lug and grooved style valves shall be capable for use as isolation valves and recommended by manufacturer for dead-end service at full system pressure.

F. Insulated Valves: Install extended-stem valves in all piping specified as insulated, and arrange in the proper manner to receive insulation.

G. Mechanical Actuators: Provide mechanical actuators with chain operators where indicated, where valves 4" and larger are mounted more than 7' above the floor, and where manual operation is difficult because of valve size, pressure differential or other operating conditions. Drop chains to 6'-6" above the floor.

H. Selection of Valve Ends (Pipe Connections): Select and install valves with ends matching the types of pipe/tube connections.

2.4 HANGERS AND SUPPORTS

A. General: Provide factory-fabricated horizontal piping hangers, clamps, hanger rod, inserts, supports, etc., of the indicated MSS type and size. The Manufacturers Standardization Society (MSS) of the Valve and Fittings Industry Practice SP-58 and SP-69 are referenced in this section. Seismic pipe support details shall be designed and sized by a professional engineer licensed in the State of Oregon. Design shall comply with ISSC Chapter 16.

B. Manufacturers: B-Line, Carpenter & Paterson, Grinnell, Michigan, Superstrut, Tolco, Erico, or accepted substitute. Grinnell figure numbers in parentheses where applicable (or other manufacturers as noted).

C. Corrosion Protection: Provide materials which are zinc plated or factory painted to prevent corrosion. Prevent electrolysis in the support of copper tubing by the use of hangers and supports

which are copper plated, plastic coated, or by other recognized industry methods.

D. Seismic Requirements: Provide seismic restraints in accordance with OSSC Section 1613. Design restraint systems in accordance with "Seismic Restraint Manual: Guidelines for Mechanical Systems," Second Edition, 1998, SMACNA, or "A Practical Guide to Seismic Restraint" ASHRAE RP-812, 1999.

E. Horizontal Piping Hangers and Supports:
1. Adjustable Clevis Hanger: MSS Type 1 (Fig. 260).
2. Adjustable Band Hanger: MSS Type 7 (Fig. 97), fabricated from steel.
3. Adjustable Swivel-Band Hanger: MSS Type 10 (Fig. 70).
4. Clamp: MSS Type 4 (Fig. 212, 216).
5. Double-Bolt Clamp: MSS Type 3 (Fig. 295A, 295H), including pipe spacers.
6. Adjustable Saddle-Support: MSS Type 36 (Fig. 258) and MSS Type 37 (Fig. 259), including saddle, pipe and reducer. Fabricate base-support from steel pipe and include cast-iron flange or welded-steel plate.
7. Channel Support System: Galvanized, 12 gauge channel and bracket support systems, single or double channel as indicated on the Drawings or as required by piping and equipment weights. Grinnell "Power Strut" channel. Acceptable Manufacturers: Super Strut, Globestrut, Bee, Kindorf or Unistrut.

F. Vertical Pipe Clamps:
1. Two-Bolt Riser Clamp: MSS Type 8 (Fig. 261).
2. Four-Bolt Riser Clamp: MSS Type 42 include pipe spacers at inner bolt-holes.

G. Hanger Attachment:
1. Hanger Rod: Rolled threads, zinc plated. Right hand threaded.
2. Turnbuckles: MSS Type 13 (Fig. 230).
3. Weldless Eye-Nut: MSS Type 17 (Fig. 290).
4. Malleable Eye-Socket: MSS Type 16 (Fig. 110R).
5. Clevises: MSS Type 14 (Fig. 299).

H. Building Attachments:
1. Concrete Inserts: MSS Type 18 (Fig. 282), steel or Grinnell Power-Strut PS349 continuous channel. Acceptable Manufacturers: Michigan Hanger, Globestrut, Unistrut, Super Strut.
2. Clamps: MSS Type 19 (Fig. 285, 281), Type 20, 21 (Fig. 225, 226, 131), Type 23 (Fig. 86, 87, 88), Type 25 (Fig. 227), Type 27 through 30 where applicable.

2.5 IDENTIFICATION MARKERS

A. Pipe Markers:
1. Adhesive pipe markers of width, letter size and background color conforming to ANSI A13.1.
2. Acceptable Manufacturers: Brady B946 with arrow banding tape or similar Seaton, Zeston, MSI.

B. Duct Markers:
1. Adhesive duct markers 2¼"x14" with black text indicating contents on white background with directional flow arrow.
2. Acceptable Manufacturers: Brady B946 or similar Seaton, Zeston, MSI.

C. Nameplates:
1. Engraved nameplates, 1/16" thick, laminated 3-ply plastic, bottom ply white, outer ply black, letters formed by exposing bottom ply.
2. Size: 3" by 5" nameplates with 1/4" high letters.
3. Tags on ceiling grid to be 1" tall with ¼" high letters.

D. Valve Tags:
1. 2" diameter, 18-gauge polished brass tags with 3/16" chain hole and 1/4" high stamped, black-filled service designation.
2. Acceptable Manufacturers: Seaton, Brady, MSI.

PART 3 - EXECUTION

3.1 LAYOUT AND COORDINATION

A. Site Examination: Before starting work, carefully examine site and all contract Drawings. Become thoroughly familiar with conditions governing work on this project. Verify all indicated elevations, building measurements, roughing-in dimensions and equipment locations before proceeding with any of the work.

B. Utility Locations: The location of existing utilities, wires, conduits, pipes, ducts, or other service facilities are shown in a general way only on the Drawings and are taken from existing records. Ascertain whether any additional facilities other than those shown on the plans may be present and determine the exact location and elevations of all utilities prior to commencing installation.

C. Sleeves, Inserts, Cast-in-Place Work: Provide sleeves, inserts, anchoring devices, cast-in-place work, etc. which must be set in concrete sequenced at the proper time for the project schedule.

D. Coordination:
1. The drawings are based on equipment of a certain manufacturer and may be identified as such. Where alternate manufacturers or approved substitutes are incorporated into the work, any required design changes are the responsibility of the Contractor. Such changes may include changes in utility or system connection sizes, location, or orientation, service clearances, structural support or acoustic considerations.
2. In areas where space is limited and coordination with other trades are required, prepare accurate AutoCAD shop drawings showing the actual physical dimensions required for the installation for duct work, piping and mechanical devices. Submit drawings prior to purchase/fabrication/installation of any of the elements involved in the coordination. Provide drawing files to other trades for coordination.
3. Cooperate with other trades in furnishing material and information for sleeves, bucks, chases, mountings, backing, foundations and wiring required for installation of mechanical items.
4. Coordinate all work with other trades and determine in advance where interfacing of the mechanical work and other work are required to be connected together. Provide all materials and equipment to make those connections. Submit shop drawings showing required connections where special conditions exist.
5. Coordinate the integration of the VRV control system into the BAS.

E. Discrepancies: Report immediately any error, conflict or discrepancy in Plans, Specifications and/or existing conditions. Do not proceed with any questionable items of work until clarification of same has been made. Should rearrangement or re-routing of piping be necessary, provide for approval the simplest layout possible for that particular portion of the work.

3.2 UTILITY COORDINATION

A. Utility Coordination: Coordinate all aspects of the incoming utility services indicated with the city engineer, serving utility, and the off-street improvements Contractor. Requirements of the utility company which exceed the provisions made on the Drawings or covered by these Specifications shall take precedence. Provisions made on the Drawings or Specifications in excess of the utility company's requirements shall take precedence. No additional compensation will be allowed the Contractor for connection fees or additional work or equipment not covered in the Drawings or Specifications which are a result of policies of the serving utilities.

3.3 MECHANICAL EQUIPMENT WIRING

A. Provide all mechanical equipment motors, automatic temperature, limit, float and similar control devices required, with wiring complete from power source indicated on Electrical Drawings.

B. Provide properly rated motor overload and undervoltage protection and all manual or automatic motor operating devices for all mechanical equipment.

C. Equipment and systems shown on the Drawings and/or specified, are based upon requirements of specific manufacturers which are intended as somewhat typical of several makes which may be approved. Provide all field wiring and/or devices necessary for a complete and operable system including controls for the actual selected equipment/system.

D. Provide all starters for mechanical motors. Review Electrical Specifications and Drawings to determine which mechanical motor starters will be provided under the Electrical Specification Sections and provide all others.

3.4 GENERAL INSTALLATION

A. Locating and Positioning Equipment: Observe all Codes, Regulations and good common practice in locating and installing mechanical equipment and material so that completed installation presents the least possible hazard. Maintain adequate clearances for repair and service to all equipment and comply with Code requirements.

B. Arrangement: Arrange piping parallel with primary lines of the building construction, and with a minimum of 7' overhead clearance in all areas where possible. Unless indicated otherwise, conceal all piping. Locate operating and control equipment properly to provide easy access, and arrange entire mechanical work with adequate access for operation and maintenance. Give right-of-way to piping which must slope for drainage. Set all equipment level or as recommended by manufacturer. Under no conditions shall beams, girders, footings or columns be cut for mechanical items. Casting of pipes into concrete is prohibited unless so shown on Drawings.

C. Drip Pans: Provide drip pans under all above ceiling in-line pumps and cooling coils. Locate pan immediately below piping and equipment, and extend a minimum of 6" on each side and lengthwise 18" beyond equipment being protected. Fabricate pans 2" deep, of reinforced 20 gauge galvanized sheet metal with watertight seams and rolled or hemmed edges. Provide 3/4" drainage piping, properly discharged to over floor drain or as shown on the Drawings. Comply with Mechanical Code for overflow protection and pipe sizing.

D. Access Panels: Provide access panels with proper backing reinforcement for all equipment, dielectric unions, valves and items requiring service and installed above ceilings, behind walls, or in furring, complete with correct frame for type of building construction involved. Exact size, number and location of access panels are not necessarily shown on Drawings. Use no panel smaller than 12" by 12" for simple manual access or smaller than 16" x 20" where personnel must pass through.

E. Adjusting: Adjust and calibrate all automatic mechanical equipment, temperature controls, float devices, etc. Adjust flow rates at each piece of equipment or fixture.

F. Building Vapor Barrier: Wherever the building insulation vapor barrier is penetrated by piping, hangers, conduits, etc., provide clear self-adhesive tape recommended by the insulation manufacturer around the penetrations.

G. Housekeeping Pads: Construct minimum 6" thick with chamfered edges using 3000 psi concrete. Provide #4 reinforcing bars 8" on center in each direction and within 4" of each edge, centered in pad thickness. Provide ½" dowel with 3" embedment into floor slab for each 2 square feet of pad area. Dowels and equipment anchor bolts shall be spaced a minimum of 6" from pad edges.

3.5 VALVE INSTALLATION

A. General: Comply with the following requirements:
   1. Install valves where required for proper operation of piping and isolation of equipment, including valves in branch lines where necessary to isolate sections of piping, and where shown on the drawings. Install valves at low points in piping systems that must be drained for service or freeze protection.
   2. Locate valves in accessible spaces (or behind access panels) and so that separate support can be provided when necessary.
   3. Install valves with stems pointed up, in the vertical position where possible, but in no case with stems pointed downward from a horizontal plane.

B. Insulated Valves: Install extended-stem valves in all piping specified as insulated, and arrange in the proper manner to receive insulation.

C. Valve Access: Provide access panels to all valves installed behind walls, in furring or otherwise inaccessible.

3.6 INSTALLATION OF HANGERS AND SUPPORTS

A. General: Proceed with the installation of hangers, supports and anchors only after the required building structural work has been completed in areas where the work is to be installed. Correct inadequacies including (but not limited to) the proper placement of inserts, anchors and other building structural attachments.
   1. Install hangers, supports, clamps, and attachments to support piping and equipment properly from the building structure. Use no wire or perforated metal to support piping, and no supports from other piping or equipment. For exposed continuous pipe runs, install hangers and supports of the same type and style as installed for adjacent similar piping.
   2. Prevent electrolysis in the support of copper tubing by the use of hangers and supports which are copper plated or by other recognized industry methods.
   3. Arrange supports to prevent eccentric loading of joists and joist girders. Locate supports at panel points only.
   4. Only use hangers approved for acoustic deck application. See part 2 for specifics.
   5. Do not support any devices from lower cord of trusses.

B. Provisions for Movement:
   1. Install hangers and supports to allow controlled movement of piping systems and to permit freedom of movement between pipe anchors, and to facilitate the action of expansion joints, expansion loops, expansion bends and similar units. Install specified seismic restraints to restrict excessive movement.
   2. Install hangers and supports so that equipment and piping live and dead loading and stresses from movement will not be transmitted to connected equipment.
   3. Install hangers and supports to provide the indicated pipe slopes, and so that maximum pipe deflections allowed by ANSI B31 are not exceeded. Comply with the following installation requirements:
      a. Clamps: Attach clamps, including spacers (if any), to piping outside the insulated piping support. Do not exceed pipe stresses allowed by ANSI B31.
      b. Insulated Pipe Supports: Insulated pipe supports shall be supplied and installed on all insulated pipe and tubing.
      c. Load Rating: All insulated pipe supports shall be load rated by the manufacturer based upon testing and analysis in conformance with ASME B31.1, MSS SP-58, MSS SP-69 and MSS SP-89.
      d. Support Type: Manufacturer's recommendations, hanger style and load shall determine support type.
      e. Insulated Piping Supports: Where insulated piping with continuous vapor barrier or where exposed to view in finished areas is specified, install hard maple wood insulation shields (Elcen Fig. 216) or steel pipe covering protection shields (MSS type 39) at each hanger.

C. Pipe Support:

1. Vertical Spacing: Support at base, at equivalent of every floor height (maximum 10' as required by Code) and just below roof line.
2. Screwed or Welded Steel or Copper Piping: Maximum hanger spacing shall be as follows:

	Steel	Copper
1-1/4" and smaller	7' span	6' span
1-1/2" pipe	9' span	6' span
2" pipe	10' span	10' span
2-1/2" & larger	12' span	10' span

3. Install additional hangers or supports at concentrated loads such as pumps, valves, etc. to maintain alignment and prevent sagging.
4. Support Rod: Hanger support rods sized as follows:

Pipe and Tube Size		Rod Size	
Inches	mm	Inches	mm
1/2" to 4"	12.7 to 101.6	3/8"	9.5
5" to 8"	127.0 to 203.2	1/2"	12.7
10" to 12"	254.0 to 304.8	5/8"	15.9

D. Adjust hangers and supports to bring piping to proper levels and elevations.

E. Provide all necessary structural attachments such as anchors, beam clamps, hanger flanges and brackets in accordance with MSS SP-69. Attachments to beams wherever possible. Supports suspended from other piping, equipment, metal decking, etc., are not acceptable.

F. Horizontal banks of piping may be supported on common steel channel member spaced not more than the shortest allowable span required on the individual pipe. Maintain piping at its relative lateral position using clamps or clips. Allow lines subject to thermal expansion to roll axially or slide. Size channel struts for piping weights.

G. Installation of drilled-in concrete anchors shall comply with the manufacturer's instructions for working load, depth of embedment, and spacing between anchors and from the edge of the slab. Use only wedge-style anchors.

H. Seismic Restraints: Install restraints where recommended in SMACNA "Seismic Restraint Manual" and as required by code. Show analysis of supporting structure, anchorages, and restraints in accordance with OSSC Section 1613 and reference ASCE standard. Seismic restraint system components shall be approved by the California Office of Statewide Health Planning and Development (OSHPD). Acceptable Manufacturers: Amber/Booth, Mason Industries, Tolco, or approved.

3.7 HVAC SYSTEM IDENTIFICATION

A. Piping System: Indicate each pipe system by its generic name (abbreviated) as shown/scheduled/specified. Comply with ANSI A13.1 for marker locations, letter sizes, and colors. Include arrows to show direction of flow and "Electric Traced" signs to identify heat cable wrapped piping. Locate pipe labels in accessible areas as follows:

1. Near each valve, meter, gauge, or control device.
2. Near equipment such as pumps, heat exchangers, water heaters, etc.
3. At piping branch connections.
4. At penetrations (each side) of walls, ceilings, and floors.
5. At access panels and doors.
6. At 25 foot maximum intervals. Provide a minimum of one label above each room where lift-out ceiling is installed. Reduce intervals in congested areas such as mechanical rooms.

B. Valve Identification: Tag all valves with brass disc and chain. Prepare valve charts indicating valve number, size, location, function and normal position. Use no duplicate numbers in Plumbing and Heating systems. Mount glazed frames containing one set of valve charts in the building mechanical room.

C. Equipment: Provide engraved plastic-laminate signs at locations of major equipment such as heat exchangers, pumps, etc. Identify equipment in field same as on drawings. Permanently mount in an appropriate and effective location. Provide tags on ceiling grid to denote location of devices above ceiling requiring service or access.

D. Operation Tags: Where needed for proper and adequate information on operation and maintenance of mechanical systems, provide tags of plasticized card stock, either pre-printed or hand printed to convey the message; example: "DO NOT CLOSE THIS VALVE EXCEPT WHEN THE PUMP IS OFF."

3.8 EQUIPMENT CONNECTIONS

A. Provide complete connections for all items of equipment requiring such connections, including incidental piping, fittings, trim and labor necessary for a finished working installation.

B. Verify the rough-in and finish requirements for all equipment provided under other Divisions of the work and requiring HVAC piping or duct connections with equipment supplier and installer prior to rough-in.

3.9 PROTECTION

A. Protect all work and materials against loss or damage. Close all pipe openings with caps or plugs. At final completion, thoroughly clean and deliver all work and equipment in an unblemished new condition. Keep all motors and bearings in watertight and dustproof covers during entire course of installation.

B. Protect floors, walls, framing and sheathing where pipe cutting and threading operations are conducted with plastic sheeting under plywood sheets. Extend plastic sheeting beyond the plywood. Clean-up metal cuttings, oil, etc., daily or as necessary to prevent debris from being tracked beyond the protected area. Damages, as determined by the Architect, due to the pipe cutting/threading operation shall be repaired by the responsible trade.

3.10 CUTTING AND PATCHING

A. General: Comply with the requirements of Division 1 for the cutting and patching of other work to accommodate the installation of mechanical work. Do all necessary cutting and patching of existing building and yard surfaces required for completion of the mechanical work. Patch to match finish and color of adjacent surfaces. Coordinate work in remodel and new areas to avoid cutting of new finished surfaces.

3.11 DEMOLITION AND SALVAGE

A. Owner shall have first right of refusal for all salvaged control devices and mechanical equipment.

B. All existing digital control devices no longer used shall be set aside for Beaverton School District to inspect and take as they wish.

C. All devices, pipes, and materials not desired by Beaverton School District are the property of the Contractor to recycle or dispose of properly off site.

3.12 RESTORATION OF EXISTING HVAC EQUIPMENT

A. General: Where restoration or other type of work is indicated, include the following as minimum required work.

1. Replace motors as noted, belts (matched set on multiple belt systems), sheaves, and bearings. Motors shall be per 23 05 00 with shaft grounding at VFD driven motors. Belts and sheaves per 23 05 00.
2. Bearings shall be manufactured by SKF, Fafnir or Dodge. Provide submittal. Bearings shall have zone harden path for bearing surface and 120º set screws. Do not use eccentric collar bearings. Provide with new housing (pillow block, side casing flange) etc. Match bearing housing style currently installed. Prior to any replacement work at air handlers complete a vibration analysis of fan, drive, bearing and shaft. Firm completing the analysis shall specialize in this service. (OTS Precision Balancing or approved). Technician completing the bearing replacement shall specialize in this service. If after the bearing replacement is complete fan operation is noisy, or vibrates to a level determined by Engineer to be unacceptable, replacement of all rotating devices shall be at the Contractors expense.
3. Replace flex connectors and supply and return, OSA, and relief duct connections.
4. Replace magnetic starter(s) and overload protective devices. See Section 23 05 00 for VFD or starter. See Drawings for where VFD's are required.
5. Replace filter media provided by the Owner.
6. Where missing, provide filter close off panels to bridge the gap between air handler wall and nominal filter sizes. Close off panels shall be no wider than 2".
7. Clean unit casing(s), plenum(s), fan scroll(s) and damper blades.
8. Vacuum clean entire air handler enclosure.
9. At air handlers clean fan wheels from low pressure and high pressure side with same method as coil above. Ensure fans are installed correctly if removed for cleaning.
10. Clean damper surfaces and adjust linkage to ensure dampers close/open properly.
11. Clean existing return air ductwork re-used, see Section 23 30 00 for more information.

3.13 EXISTING HVAC UNIT CLEANING

A. Clean the entire interior of the air handler or fan cabinet. Clean fan wheel(s), coils and dampers.

B. Detailed Duct and Equipment Cleaning.
   1. The ACR NADCA Standard 2013 will be referenced in this procedure. References made to that standard by default include the supporting information (definitions, terms, etc.) of that document. References to NADCA reference the standard. Comply with Sections 2 and 3 of NADCA Procedure.
   2. Service Openings: Service openings may be needed to perform assessment, cleaning and restoration (ACR) procedures. Below are the minimum requirements for service openings.
      a. Service openings installed into the system shall not degrade the structural, thermal, or functional integrity of the system.
      b. Service openings shall be created in a manner that allows for proper closure.
      c. Service openings shall not hinder, restrict, or alter the airflow within the air duct.
      d. Service opening construction materials and methods shall be in compliance with industry standards and local codes, using materials acceptable under those standards and codes.
   3. Materials used in the fabrication of duct access doors and permanent panels shall be those classified for flammability and smoke spread if the material is exposed to the internal airstream. These materials are classified as having a flame-spread rating of not over 25 without evidence of continued progressive combustion and a smoke-developed rating of not over 50, as determined by UL 723.
   4. All tapes used in the installation and closure of service openings shall meet the requirements of UL 181A.
   5. All service openings shall comply with applicable UL, SMACNA and NFPA standards, as well as local, regional, and state codes.
   6. Service Panels:
      a. Service panels used for closing service openings in the HVAC system shall be of an equivalent gauge or heavier so as to not compromise the structural integrity of the duct.
      b. Service panels used for closing service openings shall be mechanically fastened

(screwed or riveted) at minimum every 4" on center. The panel shall overlap the ductwork surfaces by a minimum of 1" on all sides.

c. It is recommended that service panels used for closing service openings be sealed with gaskets, duct sealants, mastic, or tape.

7. Prefabricated Duct Access Doors: The gauge of the duct access door shall be based on the pressure class of the duct system and shall be installed according to manufacturer's specifications.
8. Drilled 1" Service Openings: Drilled 1" service openings shall be closed with materials meeting UL 181 for smoke generation and flame spread.
9. Flexible Duct Systems: Service openings shall not be made in flexible ductwork.
10. Cleaning and Restoration of HVAC Systems: HVAC systems shall be cleaned by using a suitable agitation device to dislodge contaminants from the HVAC component surface and then capturing the contaminants with a vacuum collection device.
11. Wet Cleaning, Power Washing, and Steam Cleaning: Wet cleaning, power washing, steam cleaning and any other form of wet process cleaning of HVAC system components shall not damage or result in subsequent damage to the components. Cleaning agents or water shall never be applied to electrical, fibrous glass or other porous HVAC system components.
12. Vacuum Collection Equipment: Vacuum collection equipment shall be operated continuously during cleaning. The collection equipment shall be used in conjunction with agitation tools and other equipment to convey and collect debris and prevent cross-contamination of dislodged particulate during the mechanical cleaning process. Maintain capture velocities per NADCA 4.5.
13. Confined Space Cleaning: When working inside a confined space, health and safety concerns shall be a priority. The duct support system, internal components, configuration and confined space concerns shall be evaluated for safety prior to entry. It is recommended that a Certified Safety Professional be consulted as needed.
14. Air-Handling Unit (AHU) Cleaning: It is recommended that air-handling coils, fans, condensate pans, drains and similar non-porous surfaces be wet cleaned in conjunction with mechanical methods.
    a. Efforts to control water extraction shall be sufficient to collect debris and prevent water damage to the HVAC components and surrounding equipment and structure.
    b. The capture, containment, testing and disposal of waste water generated while performing wet cleaning shall be in accordance with applicable local, regional, state, and federal regulations.
15. Post-Cleaning Inspection: If debris still remains on the coil after cleaning, the process shall be repeated.
16. Remediation of Mold Contamination: Remediating mold shall be performed in accordance with the IICRC S520 Standard for Professional Mold Remediation and the cleaning/restoration of the HVAC system provisions as outlined within this Standard.
17. Surface Treatments: Surface treatments may be used to restore the integrity of material surfaces as an alternative to replacement. Surface treatments shall only be applied after confirming the system has been cleaned and has passed the specified level of cleanliness verification.
18. Removal of Mold Contaminated Porous Materials: It is recommended that porous materials with mold growth (Condition 3) be properly removed and replaced. This task shall be followed by surface cleaning using mechanical cleaning methods.
    a. The mechanical cleaning methods selected for duct liner or fibrous glass duct board shall not create abrasions, breaks, or tears to fibrous glass liner or duct board surfaces.
19. Resurfacing Fibrous Glass Surfaces: Resurfacing may be considered when thermal acoustic fibrous glass components, including air duct liner or duct board in the HVAC system, are considered friable, or exhibit visual signs of abrasion, degradation, or other undesirable conditions. Resurfacing may also be considered when the project work plan requests smoothing fiber glass surfaces to reduce future particulate collections within the HVAC system.
    a. If resurfacing is to be performed, an assessment shall be made to determine

whether the surface of the component will provide a strong, bondable surface for the coating material after undergoing proper mechanical cleaning.

b. If fibrous glass materials are beyond restoration and deemed unsuitable to support the proper application of a surfacing product or unable to provide a long-term bondable surface, resurfacing shall not be performed.

20. Damaged Fibrous Glass Material: When there is evidence of damage, deterioration, delaminating, friable material, such that cleaning or resurfacing cannot restore fibrous glass materials, replacement is recommended. Call to the attention of the Engineer.
21. HVAC System Repair: HVAC components found to have pre-existing damage during the cleaning process shall be documented and brought to the attention of the Engineer.
22. After return air and exhaust air ducts have been cleaned operate the fan system at full speed for a minimum of 8 hours. Then proceed to cleaning air handler unit and supply air ductwork.
23. In the event that engineer does not agree that the air handler system or fan system is clean additional cleaning shall be provided to the satisfaction of the engineer within boundaries of the ACR NADCA Standard 2013.

3.14 HVAC WORK CLOSEOUT

A. General: Refer to the Division 1 sections for general closeout requirements. Calibrate all equipment requiring same. Complete each system as shown or specified herein and place in operation except where only roughing-in or partial systems are called for. Each system shall be tested and left in proper operation free of leaks, obstructions, or contamination.

B. See Section 23 08 00 for Commissioning.

C. Record Drawings: Submit record set of drawings required in **Division 1** as previously specified in this Section.

D. Closeout Equipment/Systems Operations: Sequence operations properly so that work of project will not be damaged or endangered. Coordinate with seasonal requirements. Operate each item of equipment and each system in a test run of appropriate duration with the Architect present, and with the Owner's operating personnel present, to demonstrate sustained, satisfactory performance. Adjust and correct operations as required for proper performance. Clean and lubricate each system and replace dirty filters, excessively worn parts and similar expendable items of the work.

E. Operating Instructions: Conduct a walk-through instruction seminar for the Owner's personnel who are to be involved in the continued operation and maintenance of the HVAC equipment and systems. Provide written instructions outlining and explaining the identification system, operational diagrams, emergency and alarm provisions, sequencing requirements, seasonal provisions, security, safety, efficiency and similar features of the systems.

END OF SECTION

TESTING, ADJUSTING AND BALANCING

PART 1 - GENERAL

1.1 DESCRIPTION

A. Work Included: After completion of the work of installation, test and regulate all components of the new heating, air conditioning and ventilating systems to verify air volumes and heating-cooling flow rates indicated on the Drawings.

B. Related Work: The requirements of Section 23 05 00, Common HVAC Materials and Methods, also apply to this section.

C. Balancing Organization:
1. Balancing of the Heating and Air Conditioning Systems: Performed by a firm providing this service established in the State of Oregon.
2. Balancing Organization: Approval by Architect. Air Balancing Specialties, Air Introduction & Regulation, Northwest Engineering Services, Neudorfer Engineers, or approved.
3. Provide all necessary personnel, equipment, and services.

1.2 QUALITY ASSURANCE

A. Balancing of the Heating and Air Conditioning Systems: Agency shall be a current member of NEBB or AABC specializing in the adjusting and balancing of systems specified with a minimum of 10 years documented experience.

B. Testing, adjusting, and balancing shall be performed under direct field supervision of a Certified NEBB Supervisor or a Certified AABC Supervisor.

C. See section 23 08 00 for systems to be commissioned.

1.3 SUBMITTALS

A. Balancing Data: Include the following minimum information in the Operation and Maintenance Data, as specified in Section 23 05 00.
1. Names or initials of personnel performing the balancing.
2. Dates balancing was performed.
3. List of balancing instruments utilized.
4. Weather conditions at the time of the test.
5. Mechanical system descriptions.
6. All motor rated voltages, amps, starter and overload protective device sizes.
7. All motor operating data.
8. Fan cfm, rpm, operating static pressures, driven and motor sheave data, and all drive changes necessitated to obtain design capacities. List actual minimum outside air volumes measured for each system.
9. All supply, return and exhaust air outlet cfm readings.
10. Heating section entering and leaving air temperatures.
11. CO2 controller set points – minimum CO2 setpoint (ppm), maximum CO2 setpoint (ppm)(setting for min OSA at full occupancy).
12. OSA intake damper settings at min CO2 and max CO2 set point.
13. Building pressure at each area.
14. Heat exchanger inlet and outlet conditions.
15. Air side heat exchanger pressure drop.
16. Operate fan systems with VFD’s at maximum air flow and minimum air flow (or at airflow for when hood fans are on or off). Record speeds for Control Contractor and balancing.
17. Domestic hot water recirculating pump flow rate and branch balance valve flow rates.

PART 2 - PRODUCTS

-- NOT USED --

PART 3 - EXECUTION

3.1 INSTALLATION TOLERANCES

A. Air Handling Systems: Adjust to within plus 10 percent or minus 5 percent of design for supply systems and +/- 10 percent of design for return and exhaust systems.

B. Air Outlets and Inlets: Adjust total to within plus 10 percent or minus 5 percent of design to space. Adjust outlets and inlets in space to within +/- 10 percent of design.

C. Hydronic Systems: Adjust to within +/- 10 percent of design.

3.2 ADJUSTING

A. Ensure recorded data represents actual measured or observed conditions.

B. Permanently mark settings of valves, dampers, and other adjustment devices allowing settings to be restored. Set and lock memory stops.

C. After adjustment, take measurements to verify balance has not been disrupted or that such disruption has been rectified.

D. Leave systems in proper working order, replacing belt guards, closing access doors, closing doors to electrical switch boxes, and restoring thermostats to specified settings.

E. At final inspection, recheck random selections of data recorded in report. Recheck points or areas as selected and witnessed by the Owner.

3.3 AIR SYSTEM PROCEDURE

A. Adjust air handling and distribution systems to provide required or design supply, return, and exhaust air quantities.

B. Make air quantity measurements in ducts by Pitot tube traverse of entire cross sectional area of duct.

C. Measure air quantities at air inlets and outlets.

D. Adjust noise distribution system to obtain uniform space temperatures free from objectionable drafts and noise.

E. Use volume control devices to regulate air quantities only to the extent that adjustments do not create objectionable air motion or sound levels. Effect volume control by duct internal devices such as dampers and splitters.

F. Vary total system air quantities by adjustment of fan speeds. Provide drive changes required. Vary branch air quantities by damper regulation.

G. Provide system schematic with required and actual air quantities recorded at each outlet or inlet.

H. Measure static air pressure conditions on air supply units, including filter and coil pressure drops, and total pressure across the fan. Make allowances for 50 percent loading of filters.

I. Adjust outside air automatic dampers, outside air, return air, and exhaust dampers for design

conditions.

J. Measure temperature conditions across outside air, return air, and exhaust dampers to check leakage.

K. Where modulating dampers are provided, take measurements and balance at extreme conditions. Balance variable volume systems at maximum air flow rate, full cooling, and at minimum air flow rate, full heating.

L. Measure building static pressure and adjust supply, return, and exhaust air systems to provide required relationship between each to maintain approximately 0.02" (12.5 Pa) positive static pressure near the building entries.

M. For variable air volume system powered units, set volume controller to air flow setting indicated. Confirm connections are properly made and confirm proper operating for automatic variable air volume temperature control. Adjust drives to maximum airflow for highest static condition.

N. Space pressure Control, Return Fan Speed Endpoints: For variable air volume system with terminal unit zoning, attain return fan speed control endpoints based on the following values for the given operating mode. Coordinate with the HVAC control contractor for system setup and provide values when determined.

Return Fan Speed Endpoint Values				
Mode	**Supply Fan Speed Hi/Lo Reset Limits**	**Desired Space Pressure (InH2O)**	**Economizer Position**	**Return Fan Speed**
Full Heating (All terminal units are operating at heating flow setpoints)	TBD – Noted during the full heating condition	**Ideal - 0.02** Acceptable Test Range: 0.01 – 0.03	Min-Min (25% of the minimum ventilation requirement)	Minimum Return Fan Speed-TBD
Full Cooling (All terminal units are operating at cooling flow setpoints)	TBD – Noted during the full cooling condition	**Ideal - 0.02** Acceptable Test Range: 0.01 – 0.03	Min-Max (100% of the minimum ventilation requirement)	Maximum Return Fan Speed-TBD

O. CO_2 controller set points – minimum CO_2 setpoint (ppm), maximum CO_2 setpoint (ppm)(setting for min OSA at full occupancy).

P. Outside air intake damper settings at minimum CO_2 and maximum CO_2 setpoint.

3.4 WATER SYSTEM PROCEDURE

A. Adjust water systems to provide required or design quantities. Coordinate with Control Contractor to determine pressure setpoint for new differential pressure sensor in new construction.

B. Use calibrated Venturi tubes, orifices, or other metered fittings and pressure gauges to determine flow rates for system balance. Where flow metering devices are not installed, base flow balance on temperature difference across various heat transfer elements in the system.

C. Adjust systems to provide specified pressure drops and flows through heat transfer elements prior to thermal testing. Perform balancing by measurement of temperature differential in conjunction with air balancing.

D. Effect system balance with automatic control valves fully open to heat transfer elements.

E. Effect adjustment of water distribution systems by means of balancing cocks, valves, and fittings. Do not use service or shut-off valves for balancing unless indexed for balance point.

F. Where available pump capacity is less than total flow requirements or individual system parts, full flow in one part may be simulated by temporary restriction of flow to other parts.

3.5 SCHEDULES

A. Equipment Requiring Testing, Adjusting, and Balancing:
1. Unit Ventilators
2. Fin Pipe units
3. Air handling units
4. Fans
5. Air filters
6. Air terminal units
7. Air inlets and outlets

B. Report:
1. Summary Comments:
   a. Design versus final performance
   b. Notable characteristics of system
   c. Description of systems operation sequence
   d. Summary of outdoor and exhaust flows to indicate amount of building pressurization
   e. Nomenclature used throughout report
   f. Test conditions
2. Instrument List:
   a. Instrument
   b. Manufacturer
   c. Model number
   d. Serial number
   e. Range
   f. Calibration date

C. Electric Motors:
1. Manufacturer
2. Model/frame
3. HP/BHP
4. Phase, voltage, amperage; nameplate, actual, no load
5. RPM
6. Service factor
7. Starter size, rating, heater elements
8. Sheave make/size/model

D. V-Belt Drives:
1. Identification/location
2. Required driven RPM
3. Driven sheave, diameter, and RPM
4. Belt, size, and quantity
5. Motor sheave diameter and RPM
6. Center to center distance, maximum, minimum, and tested

E. Cooling Coils:
1. Identification/number
2. Location
3. Service
4. Manufacturer
5. Air flow, design and actual
6. Entering air DB temperature, design and tested
7. Entering air WB temperature, design and tested

8. Leaving air DB temperature, design and tested
9. Leaving air WB temperature, design and tested
10. Air pressure drop, design and tested
11. Saturated suction temperature, design and tested

F. Gas or Electric Heating Section:
1. Identification/number
2. Location
3. Service
4. Manufacturer
5. Air flow, design and tested
6. Entering water temperature, design and tested
7. Leaving water temperature, design and tested
8. Entering air temperature, design and tested
9. Leaving air temperature, design and tested
10. Air pressure drop, design and tested

G. Air Moving Equipment:
1. Location
2. Manufacturer
3. Model number
4. Serial number
5. Arrangement/Class/Discharge
6. Air flow, specified and tested
7. Return air flow, specified and tested
8. Outside air flow, specified and tested
9. Total static pressure (total external), specified and tested
10. Inlet pressure
11. Discharge pressure
12. Sheave make/size/bore
13. Number of Belts/Make/Size
14. Fan RPM

H. Return Air/Outside Air:
1. Identification/location
2. Supply air flow, design and tested
3. Return air flow, design and tested
4. Outside air flow, design and tested
5. Return air temperature
6. Outside air temperature
7. Mixed air temperature, design and tested

I. Exhaust Fans:
1. Location
2. Manufacturer
3. Model number
4. Serial number
5. Air flow, specified and tested
6. Total static pressure (total external), specified and tested
7. Inlet pressure
8. Discharge pressure
9. Sheave Make/Size/Bore
10. Number of Belts/Make/Size
11. Fan RPM

J. Duct Traverses:
1. System zone/branch
2. Duct size

3. Area
4. Design velocity
5. Design air flow
6. Test velocity
7. Test air flow
8. Duct static pressure
9. Air temperature
10. Air correction factor

K. Terminal Device:
1. Manufacturer
2. Type, constant, variable, single, dual duct
3. Identification/number
4. Location
5. Model number
6. Size
7. Minimum static pressure
8. Minimum air flow, design and tested
9. Maximum air flow, design and tested
10. Inlet static pressure, design and tested

L. Air Distribution Tests:
1. Air terminal number
2. Room number/location
3. Terminal type
4. Terminal size
5. Area factor
6. Design velocity
7. Design air flow
8. Test (final) velocity
9. Test (final) air flow
10. Percent of design air flow

M. Hot Water Heating Section:
1. Identification/number
2. Location
3. Service
4. Manufacturer
5. Air flow, design and tested
6. Entering water temperature, design and tested
7. Leaving water temperature, design and tested
8. Entering air temperature, design and tested
9. Leaving air temperature, design and tested
10. Air pressure drop, design and tested
11. Water flow rate design and tested.

3.6 DETAILED REQUIREMENTS

A. Adjusting and Balancing:
1. Adjust and balance all portions of the mechanical systems to produce indicated results within limits of minus 5 or plus 10 percent or as subsequently directed by the Architect.
2. Balancing data may be spot checked with instruments similar to that used by the balancing firm. Allow Engineer to witness any tests (up to 25% of the systems). Coordinate when testing work is to be conducted with Engineer to allow scheduling of site visit. Allow two weeks prior to conducting work.
3. If, in the judgment of the Architect, the discrepancies warrant additional adjustment, readjust and rebalance the systems at no additional project cost.
4. See drawings for requirements related to testing fans with adjustable sheaves and then

replacing with fixed pitch. Note these requirements will necessitate two balancing efforts at each air handler.

5. Perform balancing work to the satisfaction of and in the presence of commissioning agent.

END OF SECTION

HVAC INSULATION

PART 1 - GENERAL

1.1 DESCRIPTION

A. The requirements of this section apply to the insulation of mechanical equipment specified elsewhere in these specifications.

B. Related Work: The requirements of Section 23 05 00, Common HVAC Materials and Methods, also apply to this section.

1.2 QUALITY ASSURANCE

A. Insulation Thickness and Thermal Performance: Comply with Chapter 13 provisions of the State of Oregon Structural Specialty Code (Oregon Energy Code).

B. Composite (Insulation, Jacket or Facing and Adhesives) Fire and Smoke Hazard Ratings: Not to exceed a flame spread of 25 or smoke development of 50.

C. Component Ratings of Accessories (Adhesives, Mastics, Cements, Tapes, Finishing Cloth for Fittings): Same as "B" requirements above and permanently treated. No water soluble treatments.

1.3 PRODUCT DELIVERY, STORAGE AND HANDLING

A. General: In addition to the requirements specified in Section 23 05 00, the following apply:
1. Deliver insulation, coverings, cements, adhesives and coatings to the site in factory-fabricated containers with the manufacturer's stamp or label affixed showing fire hazard ratings of the products. Store insulation in original wrappings and protect from weather and construction traffic.
2. Protect insulation against dirt, water, chemical and mechanical damage. Do not install damaged insulation. Remove such insulation from project site.

1.4 SUBMITTALS

A. Submit catalog data and performance characteristics for each product specified.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Insulating Manufacturers: Johns Manville, Knauf, Armstrong, Owens-Corning, Pittsburgh Corning, Pabco, Imcoa or Certain Teed. Johns Manville products are listed unless indicated otherwise.

B. Adhesive Manufacturers: Foster, 3M, Insul-Coustic, Borden, Kingco or Armstrong.

2.2 PIPING INSULATION

A. Pipe Temperatures Minus 30 to 180 Deg. F: Flexible, preformed, pre-slit, self-sealing elastomeric pipe insulation up to 2-1/8" ID, thermal conductivity of 0.27 BTU/hr. sq. ft./in. at 75 deg. F and vapor transmission rating of 0.2 perms/inch. Apply in thickness necessary to prevent condensation on the surface at 85 deg. F and 70% RH. Armstrong "Armaflex 2000" or, in concealed locations, Imcoa or Nomaco also approved.

B. Exterior Installations: Same as for interior installations except 0.016" aluminum finish jacket.

C. Interior and Exterior Piping Systems 50 to 850 Deg. F: Glass fiber preformed pipe insulation with

a minimum K-value of 0.23 at 75 Deg. F, a minimum density of 3.5 pounds per cubic foot within all-service vapor barrier jacket, vinyl or pre-sized finish and pressure sensitive seal containing less than 0.1% by weight deca-PDE fire retardant.

2.3 DUCT INSULATION

A. Interior Above Grade Ductwork: Glass fiber formaldehyde-free blanket with "FSK" facing, k value = 0.31 at 75 deg. F, 0.2 perms, and UL 25/50 surface burning rating. Johns Manville "Microlite."

2.4 EQUIPMENT INSULATION

A. Equipment Temperatures Below 70 Deg. F: Flexible, closed cell, elastomeric sheet insulation of 5.5 #/cubic feet density and 0.27 thermal conductivity at 75 deg. F. Armstrong "Armaflex."

B. Equipment Temperatures From 70 to 450 Deg. F: Glass fiber 3 pound density insulation with a 0.23 thermal conductivity at 75 deg. F. Johns Manville "814 Spin-Glas" with "FSK" jacket or finished as recommended by manufacturer.

2.5 INSULATION ACCESSORIES

A. Insulation Compounds and Materials: Provide rivets, staples, bands, adhesives, cements, coatings, sealers, welded studs, etc., as recommended by the manufacturers for the insulation and conditions specified except staples not permitted on chilled water lines.

B. Interior Tanks and Equipment Insulation Covering: Finished metal jacket or as recommended by the manufacturer for insulation material specified.

C. PVC Protective Jacketing and Valve and Pipe Fitting Covers: Johns Manville Zeston 2000, Proto LoSmoke, or Ceel-Co Ceel-Tite 100 Series with precut fitting fiberglass insulation or approved.

D. Jacket Lap Sealing Adhesives: Foster Drion 85-75 contact cement or approved substitute.

E. Saddles and Shields: Unless otherwise indicated and except as specified in piping system specification sections, install the following types:
1. Steel Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
2. Protection Shields (MSS Type 40): Of length recommended by manufacturer to prevent crushing insulation.
3. Thermal-Hanger Shield Inserts: For supporting insulated pipe, 360-degree insert of high-density, 100-psi (690-kPa) minimum compressive strength, water-repellent-treated calcium silicate or cellular-glass pipe insulation, same thickness as adjoining insulation with vapor barrier and encased in 360-degree sheet metal shield.

PART 3 - EXECUTION

3.1 PIPING INSULATION

A. General: Do not insulate underground piping except at joints and fittings on preinsulated piping unless indicated otherwise.

B. Heating Water Piping: Insulate with glass fiber or elastomeric pipe covering:

Size	Thickness
1/2" to 1-1/2"	1-1/2"
2" to 3"	2"
4" and larger	2-1/2"

C. Pipe Fittings:

1. Insulate and finish all fittings including valve bodies, bonnets, unions, flanges and expansion joints with precut fiberglass insulation and preformed PVC covers sealed to adjacent insulation jacket for continuous vapor barrier covering over all fittings.
2. Provide removable/reusable insulation covers on 4" and larger valves, unions, flanges, pump casings, strainers and similar fittings or equipment requiring periodic service.

D. Protective Covering: Install continuous protective PVC or metal covering on all piping and fittings in mechanical rooms, accessible tunnels, attic spaces, accessible ceilings, etc., where insulation may be subject to damage. Install with rivets or cement seams and joints.

E. Insulated Piping: Comply with the following.
1. Maintain continuous insulation except at seismic support. Provide shield at insulation bearing point to support and allow minor thermal expansion.
2. Install MSS SP-58, Type 39 or Type 40 protection saddles, if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
   a. Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 (DN100) and larger if pipe is installed on rollers.
3. Shield Dimensions for Pipe: Not less than the following.
   a. NPS 1/4 to NPS 3-1/2 (DN8 to DN90): 12 inches (305 mm) long and 0.048 inch (1.22 mm) thick.
   b. NPS 4 (DN100): 12 inches (305 mm) long and 0.06 inch (1.52 mm) thick.
   c. NPS 5 and NPS 6 (DN125 and DN150): 18 inches (457 mm) long and 0.06 inch (1.52 mm) thick.
   d. NPS 8 and NPS 14 (DN200 and DN350): 24 inches (610 mm) long and 0.075 inch (1.91 mm) thick.
   e. NPS 16 and NPS 24 (DN400 and DN600): 24 inches (610 mm) long and 0.105 inch (2.67 mm) thick.
4. Insert Material: Length at least as long as protective shield.
5. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

F. Piping Insulation Lap Seams and Butt Joints: Install insulation jacket in accordance with manufacturer's recommendation. Where jacket joint and lap seams have not adhered, remove affected section of insulation and reinstall or apply lap sealing adhesive in accordance with manufacturer's instructions.

3.2 DUCTWORK INSULATION

A. Ductwork: Insulate the following:
1. All supply ductwork.
2. All supply and return ductwork in systems routed in unconditioned spaces or exposed to the outside conditions.
3. All outside air intake ducts.
4. All ductwork required to be insulated by code.

B. Insulation Thickness: Select board and blanket insulation of thickness required to provide the following installed R-value.
1. All heating or cooling system supply and return ducts located on the exterior of the insulated building envelope and all outside air intake ducts.
   a. R-8
2. All heating and cooling system supply ducts located inside of building envelope or in unconditioned spaces, R-3.5.
3. All heating and cooling system return ducts located in vented spaces, R-8.

C. Fittings: Wire and duct adhesive as required. To prevent sagging on all rectangular or square ducts over 24" wide, install Gramweld or equal welding pins on the bottom. Maximum spacing 18" on center in both directions.

D. Installation: Applied with butt joints, all seams sealed with vapor seal mastic or taped with 2"

wide vapor-proof, pressure-sensitive tape. Seal all penetrations with vapor barrier adhesive.

E. Internally Lined Ductwork: Where internally lined ductwork is indicated on the Drawings and/or specified, no exterior insulation is required. Select duct lining to provide the required R-value. Carefully lap the ends of the exterior insulation a minimum of 6" past the interior insulation unless otherwise shown. Seal the end of vapor barrier jacket to the duct with mastic where the vapor barrier is required. Duct lining is specified in Section 23 30 00.

3.3 EQUIPMENT ROOM ITEMS

A. Materials:
1. 1-1/2" calcium silicate blocks applied with wire or bands as required. Finish with 1/2" thick smoothing coat of insulating cement and with glass cloth.
2. For equipment and piping systems operating below 350 deg. F., a 3 pound per cubic foot, 1-1/2" thick spun glass fiber blanket with organic binders and aluminum sheet metal exterior jacket may be substituted for the above insulation.
3. Install tank head finish per manufacturer's recommendations.

END OF SECTION

HVAC COMMISSIONING REQUIREMENTS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes general requirements that apply to implementation of commissioning of HVAC systems and components. It will assist operating staff training and familiarization with new systems. It will serve as a tool to reduce post-occupancy critical systems operational difficulty or failure. It will also be used to develop test protocol and record the associated test data to advance the building systems from a state of substantial completion to operation.

B. All mechanical systems in the project shall perform in accordance with the design intent and the Owner's operational needs.

C. Commissioning Process Overview: The following narrative provides a brief overview of the typical commissioning tasks during construction and the general order in which they occur.

1. Equipment and system submittals pertaining to the commissioning scope are reviewed by the Commissioning Provider, concurrently with the Design Team, during the construction submittal process.
2. Commissioning during construction will include a controls integration meeting conducted by the Commissioning Provider where the controls plan is reviewed with the Commissioning Team members.
3. The Trade Contractor schedules and coordinates a start-up plan for selected equipment with review by the Commissioning Provider. The Commissioning Provider develops commissioning checklists from the approved submittals.
4. The Commissioning Provider performs periodic construction observations and provides updates to the Commissioning Team members.
5. The Trade Contractor, under their own direction, execute and document the manufacturer start-up procedure while performing manufacturer start-up and initial checkout. The Commissioning Provider documents that the start-up was completed through spot witnessing and reviewing Trade Subcontractor's completed manufacturer startup reports.
6. The Commissioning Provider creates a Deficiency Log to track equipment or system installation or function which is non-compliant with the contract documents.
7. Testing and balancing is performed for dynamic systems by the Trade Contractor. The Commissioning Provider documents that the testing and balancing was completed through spot witnessing and reviewing Trade Contractor's completed balancing reports.
8. The Commissioning Provider develops specific written equipment and system functional test procedures pertaining to the commissioned scope.
9. The functional test procedures are executed by the Trade Contractor, under the direction of, and documented by the Commissioning Provider for most equipment.
10. Items of non-compliance in installation or function are corrected by the Trade Contractor and the equipment or system is re-tested.
11. The Commissioning Provider reviews the controls O&M for clarity, accessibility and completeness.
12. The Commissioning Provider reviews and assists in coordinating the training provided by the Trade Contractor and verifies that is completed.

D. Systems to be commissioned:

1. HVAC system controls shall be commissioned, including, but not limited to:
    a. Building Controls as added or brought into new for the below existing equipment.
        1) Boiler plant
        2) VFD hydronic system pumps
        3) Air handling units
        4) Associated condensing units
        5) Heat pump rooftop unit serving computer lab
        6) Existing rooftop modular air handling units

7) VAV terminal units
8) Fan coil units
9) Makeup air units
10) Duct coils
11) Exhaust fans
12) Unit heaters

b. Review of re-balancing efforts

1.2 RESPONSIBILITIES

A. Overview: The responsibilities of the commissioning team members in the commissioning process are summarized in the following. Their responsibilities are listed here to further clarify the commissioning process.

B. Architect, Design Engineers of Record:
1. All tasks of the designers are applicable only if it is within their contracted scope of services.
2. Construction Phase:
a. Attend the commissioning kick-off meeting and selected commissioning team meetings, including the controls coordination meeting, as necessary.
b. Perform normal submittal review, construction observation, O&M manual review.
c. Review the coordination drawings.
d. Assist in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
e. Witness selected testing.
f. Coordinate resolution of commissioning deficiencies and warranty issues identified during commissioning, as necessary.
g. Provide an overview of system design and function during selected operator trainings.

C. Commissioning Provider:
1. Construction Phase:
a. The primary role of the Commissioning Provider is to develop and coordinate the execution of the process of improved equipment installation and checkout and to verify and document that systems are functioning in accordance with the Contract Documents. The Commissioning Provider is not responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating, or construction management, unless specifically stated otherwise in the Contract Documents. The Commissioning Provider may assist with problem-solving non-conformance or deficiencies, but ultimately that responsibility resides with the Trade Contractors.
b. Coordinate the commissioning work with the Contractor Team to ensure that commissioning activities are being scheduled into the master schedule.
c. Revise, if necessary, the construction phase commissioning plan developed during design.
d. Plan and conduct commissioning meetings including the kick-off meeting and controls integration meeting, as needed, and distribute minutes.
1) Pre-balancing Meeting: After initial pre-balancing a meeting may be required to review pre-balance report.
2) Controls Integration Meeting: Coordinate the final approval process for the control system submittal via a meeting attended by the Controls Contractor, Owner, and Mechanical Engineer. The meeting shall occur after the controls submittal is issued for initial review, but prior to final approval.
e. Review normal Trade Subcontractor submittals applicable to systems being commissioned concurrent with the A/E reviews for compliance with

commissioning.

f. Review requests for information and change orders for impact on commissioning.

g. Write and distribute commissioning checklists for commissioned equipment.

h. Perform site visits, as necessary, to observe component and system installations. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction meeting minutes for items relating to the commissioning process.

i. Write step-by-step functional test procedures for commissioned equipment and systems. Functional test procedures will include active testing, and may include energy management control system trending and stand-alone data-logger monitoring.

j. Coordinate functional testing for all commissioned systems. Witness and document functional tests performed for all commissioned systems, except: a) some smaller equipment may be tested and documented by the Trade Contractors, at the Commissioning Provider's discretion, b) electrical equipment testing and regulated testing may be directed and documented by the Trade Subcontractor with only spot witnessing and report review by the Commissioning Provider. The functional testing shall include operating the system and components through each of the written sequences of operation, and other significant modes and sequences, including start-up, shutdown, unoccupied mode, “Hand” mode, staging, miscellaneous alarms and interlocks with other systems or equipment. Sensors and actuators shall be calibrated during checkout by the installing Trade Contractors, and verified by the Commissioning Provider during testing. Analyze performance trend logs and monitoring data to verify performance, if necessary. Coordinate retesting as necessary until satisfactory performance is achieved.

k. After functional testing and initial deficiency resolution is complete, monitor system operation and performance for selected data points for up to 2 weeks by requesting trend logs from the Trade Contractor from the building automation system. Analyze monitored data to verify operation and performance.

l. Maintain a Deficiency Log. Report all issues as they occur. Provide directly to the project team written progress reports and test results.

m. Verify the training of the facility operating personnel.

n. Review the O&M manuals for commissioned equipment.

o. Compile a commissioning report.

2. HVAC and Mechanical-Specific Tasks of the Commissioning Provider

a. Review air and water systems balancing by selected site observation, by reviewing completed reports and by spot testing.

D. Owner/Owner Representative:

1. Construction Phase:

a. Furnish a copy of all construction documents, addenda, requests for information, change orders and approved submittals and shop drawings related to commissioned equipment to the Commissioning Provider for their permanent retention.

b. Facilitate the coordination of the commissioning work by the Commissioning Provider.

c. Participate in deficiency resolution as necessary.

d. Provide final approval for the completion of the commissioning work.

E. Trade Contractors:

1. Construction Phase.

a. Coordinate with the Commissioning Provider to facilitate the commissioning work.

b. Be proactive in seeing that commissioning processes are executed and that the requirements of the Commissioning Provider for the commissioning work are coordinated into the over-all construction schedule.

c. Participate in the controls integration meetings coordinated by the Commissioning Provider, prior to finalizing the controls submittal.
d. The Trade Contractors shall respond to deficiencies identified during the commissioning process, making required corrections or clarifications and returning prompt notification to the Commissioning Provider.
e. When completion of a task or other issue has been identified as holding up any commissioning process, particularly functional testing, the Trade Subcontractor shall notify the Commissioning Provider and provide an expected date of completion or resolution of the issue. It is not the responsibility of the Commissioning Provider to obtain this status information through meeting attendance, asking questions or field observation.
f. The Trade Subcontractor shall provide the Commissioning Provider additional documentation necessary for the commissioning process, when requested.
g. Assist in clarifying the operation and control of commissioned equipment or systems in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed functional testing procedures.
h. During the start-up and initial checkout process, document the execution of manufacturer start-up and initial checkout with parties having direct knowledge of the equipment or system and provide a copy to the Commissioning Provider.
i. During construction, maintain red-line documents for Trade Contractors-generated coordination drawings. Update after completion of commissioning (excluding deferred seasonal testing).
j. Record all deficiencies that arise during the testing, adjusting and balancing work, such as damaged or missing duct or insulation, sensors, wiring, valves, dampers, controls, programming, equipment, components, etc. or items that will reduce the effectiveness of the installation or prevent accurate air and water balancing or systems or building control.
k. Review functional test procedures developed by the Commissioning Provider to ensure feasibility.
l. Execute functional testing for selected systems under the direction of, and documented by the Commissioning Provider.
m. Assist and cooperate with the Commissioning Provider by putting all commissioned equipment and systems into operation and continuing the operation during each working day of testing, as required.
n. Remedy outstanding Architect “punch list” items that may affect equipment operation before testing. Air and water testing adjusting and balancing shall be completed with discrepancies and problems remedied before functional testing of the respective air- or water-related systems.
o. Provide all tools or the use of tools to start, check-out and functionally test equipment and systems, except for portable data-loggers, which shall be supplied and installed by the Commissioning Provider.
p. Provide skilled technicians and perform testing under the direction of the Commissioning Provider for equipment and systems specified for testing in this section. In particular, the individual tasked with operating the controls system during functional testing shall be familiar with this building and control strategy. Ensure that they are available and present during the agreed upon schedule and for a sufficient duration to complete necessary functional tests, adjustments and problem-solving. For larger mechanical equipment, provide the services of the manufacturer start-up technician for the beginning of the testing of the equipment.
q. Provide assistance to the Commissioning Provider in interpreting apparent system performance problems from monitored and test data.
r. Respond in writing to each deficiency. Correct deficiencies (differences between specified and observed performance) as interpreted by the Commissioning Provider and retest the equipment.
s. Train facility operating personnel using expert qualified personnel according to the Contract Documents.

t. Prepare O&M manuals, according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions and submit a copy to the Commissioning Provider for review.

1.3 SUBMITTALS

A. Other Equipment and System Information.
1. When not included with the standard submittals, the Trade Contractors shall provide to the Commissioning Provider requested shop drawings, the manufacturer's printed installation and detailed start-up procedures, full sequences of operation, O&M data, performance data, any performance test procedures and control drawings. In addition, the manufacturer installation and checkout materials that are shipped inside the equipment and the field checkout forms to be used by the factory or field technicians shall be submitted to the Commissioning Provider. This documentation may be required prior to the normal O&M manual submittals.

B. All equipment and system documentation requested by the Commissioning Provider shall be included by the Trade Contractors later in the O&M manuals.

C. The Trade Contractors shall submit startup forms and procedures.

1.4 QUALITY ASSURANCE

A. Test Equipment:
1. All standard testing equipment required for the Trade Contractors to perform installation, start-up and initial checkout and required functional testing shall be provided by the Trade Contractors.
2. Special tools and instruments, only available from vendor, specific to a piece of equipment, required for testing equipment according to these Contract Documents shall be provided.
3. Instrumentation will be provided by the Subcontractor. Instruments used for measurements shall be accurate. Calibration histories for each instrument shall be available for examination. Calibration and maintenance of instruments shall be in accordance with the requirements of NEBB or AABC Standards.
4. Application of instruments and accuracy of measurements shall be in accordance with NEBB or AABC Standards.
5. The Trade Contractors shall provide datalogging equipment for setting up and testing of cold rooms, clean room certification, fume hoods and lab room pressurization and equipment required to perform specified electrical equipment testing.
6. Datalogging equipment required for testing equipment in support areas shall be provided and used by the Commissioning Provider.

1.5 COORDINATION

A. Commissioning Team: The members of the commissioning team consist of the Commissioning Provider, the Owner/Owner Representative, the Architect and Design Engineers, the testing adjusting and balancing Contractor, the Controls Contractor, any other installing contractors or suppliers of commissioned equipment or systems and the facility or plant operator/engineer.

PART 2 - PRODUCTS NOT USED

PART 3 - EXECUTION

3.1 MEETINGS

A. Kick-off Meeting: The Commissioning Provider will schedule, plan and conduct a commissioning kick-off meeting with the entire commissioning team in attendance, including the controls, mechanical, adjusting and balancing and other appropriate Trade Contractors and the facility

operator or Owner Representative in attendance. Prior to this meeting, the commissioning plan will be distributed to all members. The commissioning plan, the overall commissioning process and general responsibilities of each team member, reporting and communication protocols and next steps will be discussed. Meeting minutes will be distributed to all parties by the Commissioning Provider.

B. Miscellaneous Meetings: Deficiencies identified through the commissioning process shall be discussed, as needed, in portions of regular construction meetings. Meetings dedicated to deficiencies or commissioning: status, coordination and planning shall also be conducted, if needed. The Commissioning Provider will plan, conduct and take minutes at commissioning meetings. When practical, commissioning meetings will be an appendage to regular construction meetings. All commissioning meetings shall be attended by the mechanical and the controls subcontractor. Selected meetings shall require the attendance of the TAB or other trades of commissioned systems.

C. Controls Integration Meeting: The Commissioning Provider coordinates the meeting to go over the control drawings, sequences of operation included in the controls submittal. This meeting is held prior to the approval of the controls submittal. The intent is to clarify control related issues for the Controls Contractor, mechanical, facility staff and Commissioning Provider prior to startup, testing and balancing and functional testing.
   1. The Controls Contractor shall attend the meeting. The Mechanical Contractor shall attend when issues regarding equipment they are responsible for are discussed. The control technicians attending the meetings must be the same technicians that are/will install and program the DDC system.
   2. Primary issues discussed and clarified are:
      a. Control drawing content
      b. Point database (points (monitored points, software points, naming conventions, alarms, report format)
      c. Sequences of operation and setpoints
      d. Interlocks to packaged controls and other systems
      e. Operator workstation graphics
      f. Field sensor and panel locations
   3. The Commissioning Provider takes minutes at these meetings.

3.2 COMMISSIONING CHECKLISTS, START-UP, AND INITIAL CHECKOUT

A. The following procedures apply to all equipment and systems to be commissioned:
   1. Commissioning Checklists:
      a. Contractor Team and Trade Contractors are to execute pre-functional system checks using the Commissioning Provider's created forms on the web-based commissioning software Buildup.
      b. The Commissioning Provider develops and completes the commissioning checklists and procedures for commissioned equipment and systems.
      c. Calibrations: The construction checklists will contain requirements for calibrations when applicable. The Trade Contractors is responsible to calibrate all field-installed sensors and actuators using checkout documentation methods approved by the Commissioning Provider.
   2. Manufacturer Installation and Startup Procedures:
      a. A start-up plan shall be developed and submitted by the installing Subcontractor. Start-up plan to include the following:
         1) New admin area fan coil unit start-ups
         2) New condensing unit start-ups
         3) New motor VFD start-ups
      b. The Trade Contractors shall complete the pre-start procedures in the manufacturer startup forms prior to starting equipment, including but not limited to verification of completion of wiring, safeties, lubrication, drive rotation and proper electrical test readings. Startup shall be conducted under supervision of responsible manufacturer representatives for major pieces of equipment. The

Contractor Team shall notify the Commissioning Provider at least 5 days in advance of any equipment start-up, providing the Commissioning Provider a copy of the start-up plan at that time.

c. The Commissioning Provider shall observe startup and checkout of selected systems.

d. The Trade Contractors and manufacturer representatives shall execute start-up and provide the Commissioning Provider with a signed and dated copy of the completed start-up documentation. The Trade Contractors shall clearly note any items that have not been completed and the plan for their completion.

e. The Trade Contractors shall operate each commissioned device or system to the full extent of its capability, from minimum to maximum, under automatic and manual control and verify that the equipment, system and assembly is functioning according to the specifications, manufacturer recommendations and good operating practice.

f. The manufacturer startup reports and procedures for a given system shall be successfully completed and submitted prior to testing, adjusting and balancing of the equipment.

g. The Commissioning Provider will review startup documentation and identify incomplete areas.

h. The Trade Contractors shall correct all areas that are deficient or incomplete in the startup documentation in a timely manner.

3. Designated systems requiring test and balance work shall have this activity commence after systems have successfully completed start-up. System and equipment deficiencies observed during this activity is to be noted and corrected.

3.3 FUNCTIONAL TESTING

A. Functional Performance Testing begins after operational testing, adjusting, and balancing of the systems have been completed by the Subcontractors. Functional tests for a given system shall not be conducted until they are fully operational under normal and reliable control with control calibrations, programming and control system graphics complete and checked out and the Trade Contractors have submitted completed, applicable startup reports, satisfactory to the Commissioning Provider.

B. The objective of the Functional Performance Testing is to advance the building systems from a state of substantial completion to full dynamic operation in accordance with the specified design requirements and design intent.

C. Any test ports, gauges, test equipment, etc., needed to accomplish the functional performance tests shall be provided by Subcontractors.

D. Subcontractors shall provide to the Commissioning Team documentation of calibration of controls. Documentation shall include dates, setpoints, calibration coefficients, control loop verification, and other data required to verify system check-out. Documentation shall be dated and initialed by field engineer or technician performing the work.

3.4 DEFICIENCIES AND NON-CONFORMANCE

A. Deficiency Management

1. The Commissioning Provider will record the results of document reviews, field observations, tests conducted or reviewed and trend logs or monitoring. All deficiencies will be recorded on a Deficiency Log kept by the Commissioning Provider. The Deficiency Log will be kept updated by the Commissioning Provider.
2. All deficiencies will be tracked using the online commissioning software Buildup. A current copy of the Deficiency Log will be provided to the Contractor Team and Owner/Owner Representative on a regular basis, as requested. New deficiencies will be identified.
3. Items that are incomplete or are requiring Designer input will be sent to the Designer and

Owner/Owner Representative by the Commissioning Provider via appropriate channels.

4. When completion of a deficiency has been identified by the Commissioning Provider as holding up or is likely to delay any commissioning process, particularly functional testing, the Contractor Team, shall be required to notify the Commissioning Provider providing the planned actions and an expected date of completion. The Contractor Team shall notify the Commissioning Provider listing the actions taken to resolve the issue. It is not the responsibility of the Commissioning Provider to obtain this status information through meeting attendance, asking questions or field observation.
5. The Commissioning Provider documents resolutions in the Deficiency Log and schedules retesting and backchecking as needed.
6. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the Commissioning Provider will not be pressured into overlooking deficient work or loosening acceptance criteria to satisfy scheduling or cost issues, unless there is an overriding reason to do so.
    a. The time for the Commissioning Provider to direct, document and evaluate any retesting required because a specific construction checklist or start-up test item, reported to have been successfully completed, but determined during testing to be faulty, will be charged to the Contractor Team.
    b. The Contractor Team shall reimburse the Commissioning Provider for costs when a scheduled test cannot be completed due to:
        1) Failure of the Contractor Team to schedule the test with all parties required to perform the test or with regulatory authorities required to witness the test.
        2) Failure of the Contractor Team to provide required notice for tests that have been cancelled or rescheduled.
        3) Failure of the Contractor Team or Trade Contractors to have in place test equipment, support equipment, instrumentation, permits, or other ancillary equipment or systems required for successful execution of the test.
        4) Failure of the Trade Contractors to complete pre-start or start-up procedures or other work required as a prerequisite for execution of the test.
7. The Contractor Team shall respond in writing to the Commissioning Provider at least as often as commissioning meetings are being scheduled concerning the status of each outstanding deficiency identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.

B. Approval and Acceptance: The Commissioning Provider will note each satisfactorily demonstrated function on the test form. Functional testing or acceptance of a system is indicated after all testing and monitoring is complete and there are no outstanding deficiencies for that equipment or system in the Commissioning Provider's Deficiency Log.

3.5 DEFERRED TESTING

A. Unforeseen Deferred Tests: If any functional test cannot be completed due to the building structure, required occupancy condition or other deficiency, execution of functional testing may be delayed.

3.6 ADDITIONAL DOCUMENTATION

A. Documentation required of the Trade Contractors shall consist of the following:
1. Pre-balancing, re-balancing reports
2. Startup and initial checkout forms completed.
3. Record of deficiencies and incomplete items for tests they are responsible to document.
4. Training record.

B. O&M Documentation Completion and Review:

1. Prior to substantial completion, the Commissioning Provider shall review the controls O&M manuals for systems that were commissioned to verify compliance with the specifications. The Commissioning Provider will communicate deficiencies in the manuals to the Commissioning Team.
2. This work does not supersede the Design Team's review of the O&M manuals.

3.7 TRAINING OF FACILITY PERSONNEL

A. The Trade Contractors are responsible to provide training for facility personnel per the Contract Documents. The Trade Contractors shall work with the Commissioning Provider to develop appropriate training and orientation agendas for equipment and systems and provide skilled trainers for the sessions. The Commissioning Provider will verify that the Trade Contractors execute training per the Contract Documents.

END OF SECTION

DDC CONTROLS

PART 1 - GENERAL SYSTEM DESCRIPTION

1.1 GENERAL REQUIREMENTS

A. Drawings and general provisions of the Contract, including General and other Conditions and other Division 1 – General Requirements sections, apply to the work specified in this Section.

1.2 BASIC SYSTEM

A. Building Automation System (BAS) system shall utilize DDC to control valve and damper actuators for all mechanical equipment as specified in the sequence of operation and in the drawings for all systems.

B. The control system shall be fully integrated and installed as a complete package of controls and instruments in a manner that provides maximum benefit to the end user.

C. The system shall include all computer software and hardware, control unit hardware and software, operator input/output devices, sensors, control devices, and miscellaneous devices required for complete operation and future modifications. Documentation for all software and hardware devices shall be provided.

D. Provide engineering, installation, calibration, commissioning, acceptance testing assistance, software programming, and checkout for complete and fully operational DDC.

E. Where existing devices are shown to remain those may be retained if manufactured by Johnson Controls or a manufacture normally used by JCI installation firm. The devices must be tested for operation and compatible with the new system.

1.3 SCOPE OF SERVICES (OVERVIEW OF SECTION 23 09 23)

A. Work under this section of the specification shall include, but not limited to, the following:
1. Furnish and install a complete sensor, actuator, wiring and piping system for all air handling and related equipment as shown on the plans and specified in this section. Install all necessary sensors and actuators as required by the plans and specifications and equipment schedules.
2. Label all sensors, control devices, and control units.
3. Furnish and install conduit, wire, branch circuit protection, etc. as required to bring 120 VAC power to control panel locations and equipment (actuators, sensors, control devices, etc.) as shown on the drawings and described in the specifications.
4. All line drivers, signal boosters, and signal conditioners etc. shall be provided as necessary for proper data communication.
5. Coordination as required with other sections of the specification for the proper and complete installation of the wiring system, control devices, dampers, valve, actuators, etc.
6. Furnish and install Direct Digital Control Equipment (DDC) as required by the point list, plans, and specifications including, control units, software, database development, check-out, and debugging. Provide points necessary for a complete and operable system.
7. Install the sequence of operations specified in the drawings and in this section.
8. Software testing requirements shall include testing in the field of all logic sequences including actual simulation of different processes and events and observing program response to the process or event. All deviations from the requirements of the sequence as specified on the drawings or this specification shall be corrected immediately at no additional cost to the Owner.
9. Provide documentation of software system testing before acceptance testing.
10. Provide staff for acceptance testing procedures. Modify hardware and software errors/problems at no additional cost to the Owner.
11. Provide a series of training classes for Owner staff.

12. Setup trending data before and after system acceptance.
13. Attend a series of meetings with the Engineer and Owner to agree on system setup and operating parameters.
14. Provide detailed documentation of system configuration including control units and all control devices.
15. Provide all software (with hardware connections) and software license for district computer as required.
16. Read this section in it entirety for specific details.
17. If the Control Contractor cannot comply with any of these specifications, then the Control Contractor must explain in writing the reasons for non-compliance and provide an alternative approach that satisfies these requirements.
18. Provide all equipment and personnel to complete system commission per previous section and as listed further in specification.

1.4 QUALITY ASSURANCE AND SYSTEM OVERVIEW

A. The BAS system shall be designed, installed, commissioned, and serviced by qualified Contractor.
   1. The Contractor shall be pre-qualified per Beaverton School District Control Contractor review process.
   2. Control Contractor shall operate a local branch facility within 75 miles of the job site.
   3. Emergency service shall be available 24/7.

B. Acceptable Control System Contractors and Manufacturers: Control systems shall be BTL listed across the line of product controllers (BACnet advanced application controller B-AAC, BACnet Building Controller (B-BC) controllers and BACnet application specific controllers) B-ASC as defined by BACnet International testing standards.

C. All products proposed for this contract shall have been in continuous and successful use for at least two (2) year (not including beta testing).

D. All materials and equipment used shall be standard components, regularly manufactured for this and/or other systems and not custom designed specially for this project.

E. The control system shall be forward compatible with future versions of the manufacturer's hardware, firmware, and software. Future versions of the manufacturer's hardware, firmware, and software shall be backward compatible with the installed control system. Forward and backward compatibility shall be guaranteed for at least five (5) years from the time of system acceptance. Any hardware, firmware, or software modifications or replacements required within that period because of incompatibility with new hardware, firmware, or software installed in the same facility shall be at no cost to the Owner.
Note: Equipment (controllers and software) should be provided by single manufacturer. All other products (e.g., sensors, valves, dampers, and actuators) need not be manufactured by the control manufacturer.

F. System shall be web based.

G. Commissioning of the new mechanical devices and control system shall be completed. Coordinate with Owners Commissioning Contractor.

1.5 CONTROL CONTRACTOR/MANUFACTURER QUALIFICATIONS

A. The Control Contractor shall have WEB based programming tools required to program and modify the BAS controllers.

B. Proprietary programming tools are not allowed

C. All programming tools shall be supplied to the Owner for future use.

D. See Basic System Requirements (1.02) for additional requirements.

E. The Controls Contractor shall be regularly engaged in the engineering, programming, installation, and service of Control Systems by the selected manufacturer and shall have a minimum of five years' experience with the complete, turn-key installation of Controls by the same manufacturer of similar size and technical complexity. If portions of the installation will be performed by a Subcontractor, the Controls Contractor will submit to BSD, two sample installations performed by Subcontractor which are similar to the current project. The Controls Contractor shall have a local branch facility within a 75-mile radius of the job site. Emergency service shall be available on a 24-hour, 7-day-a-week basis. Acceptable Controls Contractors:
1. Johnson Controls, Inc., 4011 S.E. International Way #605, Milwaukie, OR 97222.
2. Northwest Control Contractors, 8750 SE McLoughlin Blvd, Milwaukie, OR 97222
3. Or selected Johnson Controls Inc. Authorized Building Controls Specialist (ABCS), and their designated agents.
4. Selection of Controls Contractors is subject to approval by BSD.
Controls Contractors not currently approved by the District shall provide a list of five comparable projects that have Controls with the features as specified for this project. These projects must be on-line and functional.

F. No installer or programmer substitutions will be made without written approval from the Owner.

G. All materials, products, and equipment used for this contract shall be standard components that have been in full production with continuous and successful use for at least two years.

H. The Controls architecture shall consist of the products of a manufacturer regularly engaged in the production of Controls, and shall be the manufacturer's latest proven standard design. Controllers and DDC (Direct Digital Control) system components shall be current production products.

I. All other equipment shall be the products of the CONTROLS manufacturer or of an approved manufacturer regularly engaged in production of specialized Controls materials or equipment.

J. The Controls Manufacturer will provide a written guarantee to the Owner that the system and technology being provided will be supported for a minimum of ten years following the completion and acceptance of the project.

K. Johnson Control System shall be the current version used by Beaverton School District. Graphics shall match the quality, type, and operability of the current graphics used by Beaverton School District. All devices, controls, graphics, and programming shall be compatible with current Beaverton School District standards.

1.6 RELATED SECTIONS

A. Drawings and general provisions of Contract, including General and Supplementary Conditions, Mechanical Special Conditions, Electrical Special Conditions and Division - 1 Specification.

B. Coordination with Other Trades:
1. This section specifies cooperation of the Control Contractor (the combination of installer and programmer hence forth) with other trades and including balancing firm to assure proper arrangement of control items. Control valves, dampers, wiring, thermostat wells, and other control devices that are to be built into the field assembled ductwork, piping, or wiring systems shall be furnished by the Control Contractor and installed under other sections of the specification as directed by the Control Contractor and indicated in other portions of the specifications and drawings.
2. The Control Contractor shall insure that the DDC system communicates successfully with other equipment (e.g., air handling units, packaged rooftop units, heat pumps, motors, actuators, etc.). Note: the equipment supplier is responsible for the proper performance of their equipment (assuming the proper signals are sent/received from the BAS). The Control Contractor is responsible for all system sensors, including those

which are factory installed.

3. Electrical Wiring: All wiring required for work under this section of the specification shall be provided under this section of the specification unless otherwise specified.
4. Electrical wiring - power for control panels, control devices, and sensors
   a. Power for control units, control devices and sensors shall be coordinated with the air handling manufacturer for the project and/or the Owner.
   b. Contact locations in starter control circuits. All contacts controlling motor starters, including overload contacts, shall be located on the hot side of the coil (ungrounded control power leg). Coordinate this requirement with the air handling manufacturer for the project.
   c. Extend power to damper actuators.
      1) Actuators will be powered at 24 VAC.
      2) At each auxiliary panel location, furnish and install a 24 VAC transformer with 20 VA of capacity for each actuator installed and served from the panel.
      3) Furnish and install a fused terminal in the +24 VAC lead and a disconnecting terminal in the neutral lead of the power cable to each actuator.
5. Testing, Adjusting and Balancing: If necessary, The Controls Contractor shall operate the BAS to assist the TAB Contractor.

1.7 QUALITY CONTROL – CODES AND STANDARDS

A. All work, materials, and equipment shall comply with the rules and regulations of all codes and ordinances of the local, state, and federal authorities. Such codes, when more restrictive, shall take precedence over these plans and specifications, As a minimum, the installation shall comply with the current editions in effect 30 days prior to receipt of bids for the following codes:
   1. National Electric Code (NEC)
   2. Uniform Building Code (UBC), Oregon Structural Specialty Code
   3. Uniform Mechanical Code (UMC), Oregon Mechanical Specialty Code
   4. Underwriters Laboratories (UL)
   5. National Electric Manufacturers' Association (NEMA)
   6. National Fire Prevention Association (NFPA)
   7. American Society Of Heating, Refrigeration, And Air Conditioning Engineers (ASHRAE)
   8. Instrument Society Of America (ISA)
   9. National Institute of Standards and Technology (NIST).

B. Meet all of the local authorities and State Fire Marshal code requirements for normal operating and smoke mode functions.

1.8 SUBMITTALS

A. Shop drawing submittals are required for the following, in accordance with Section 23 05 00. The Contractor shall not start the project until the Shop Drawings have been submitted and approved. Shop drawings shall include:
   1. All submittals should be provided on paper (with legible font type and size).
   2. All drawings should be labeled TC (temperature control) rather than being referenced within the mechanical or electrical divisions. Sheets shall be consecutively numbered
   3. One drawing per air handler or system (e.g., boiler plant). Drawing should include point descriptors (DI, DO, AI, AO), addressing, and point names. Each point names should be unique (within a system and between systems). For example, the point named for the mixed air temperature for AH#1, AH #2, and AH #3 should not be MAT but could be named AH #1 MAT, AH #2 MAT, and AH #3 MAT. The point names could be logical and consistent between systems and AHs. The abbreviation or short hand notation (e.g., MAT) should be clearly defined in writing by the Control Contractor. See Section 5 for Naming Standard.
   4. Floor plans depicting all BAS control devices (control units, control devices, gateways,

LAN interface devices, actuators, sensors, motor control centers, etc.) in relation to mechanical rooms, HVAC equipment, and building footprint.

5. DDC System Engineer diagram indicating schematic location of all Control Units, workstations, LAN Interface devices, gateways, etc. Indicate address and type for each Control Unit. Indicate protocol, baud rate, and type of LAN (per Control Unit).
6. For each drawing, include a schematic flow diagram of each air and water system showing fans, coils, dampers, valves, pumps, heat exchange equipment, control devices, etc. Label each control device with setting or adjustable range of control. Label each input and output with the appropriate range.
7. Electrical wiring diagrams shall include both ladder logic type diagrams for motor start, control, and safety circuits and detailed digital interface panel control point termination diagrams with all wire numbers and terminal block numbers identified. Indicate all required electrical wiring. Provide panel termination drawings on separate drawings. Ladder diagrams shall appear on system schematic. Clearly differentiate between portions of wiring that are existing, factory-installed and portions to be field-installed.
8. Show all electric connections of the controls system to equipment furnished by others complete to terminal points identified with manufacturer's terminal recommendations.
9. Control Contractor shall provide one complete drawing that shows the equipment (fan unit, boiler, chiller, etc.) manufacturers wiring diagram with the Control Contractors wiring diagram superimposed on it.
10. Provide sequence of operation based on sequence in these documents, as discussed with Engineer and Owner and as modified based on site conditions and normal programming protocol. Provide details such as levels controlled to and point designations. Simply copying the sequence from these documents is not sufficient.
11. Provide complete panel drawings that are
    a. Clearly labeled.
    b. Drawn to scale
    c. Show the internal and external component arrangement so that the operators can identify the components by their position if the labels come off
    d. Wiring access routes should also be identified so that Class 1 wiring is separated from Class 2 and 3 and so high voltage wiring is segregated from low voltage wiring and tubing.
12. Cataloged cut sheets of all equipment used. This includes, but is not limited to, the following: DDC panels, peripherals, sensors, actuators, dampers, control air system components, and so forth.
    a. Range and scale information for all transmitters and sensors. This sheet shall clearly indicate one device and any applicable options. Where more than one device to be used is on a single sheet, submit two sheets, individually marked.
    b. Manufacturer's installation, operation and maintenance data for all equipment.
13. Training course outlines for each four-hour session.
14. Hardware data sheets for all operator workstations, local access panels, and portable operator terminals.
15. Software manuals for all applications programs to be provided as a part of the operator workstations, portable operator terminals, programming devices, and so forth for evaluation for compliance with the performance requirements of this Specification.
16. Initial project team Quality Assurance compliance report.
17. Bill of materials for each system with part numbers.
18. Provide all necessary BACnet-compliant hardware and software to meet the system's functional specifications. Provide Protocol Implementation Conformance Statement (PICS) for Windows-based control software and every controller in system, including unitary controllers.
19. Damper schedule should include:
    a. Action (normally open or closed)
    b. Direct or reverse actuation
    c. Manufacturer make and model
    d. Design pressure drop at full flow
    e. Leakage rate
    f. Operating range

g. Flow rate
h. Actuator requirements
i. Actuator spring range
j. Special construction features (U.L. listed smoke damper, etc.)

20. A set of drawings showing the details of the valve and valve actuator installation for each valve, required for operation and maintenance manuals only. This should include:
    a. Action (normally open or closed)
    b. Manufacturer make and model
    c. Cv
    d. Close off rating
    e. Flow rate
    f. Actuator spring range
    g. Cavitation coefficient (where applicable)
    h. Special construction features
21. Shop drawings submitted are required within 21 days of contract award.
22. Submittals for this phase of work shall include the remaining portions of the DDC that is being retained. The existing documents shall be included as a scanned PDF provided by the Owner or by the Contractor that completed the last phase of the work. The intention is to provide a single document for all current digital controls at this school.

B. Record Documents:

1. Provide a complete set of control drawings with as-installed equipment and operating sequences on paper and in electronic format (AutoCAD). “As-built” (i.e., as-installed and debugged and after system acceptance) documentation shall include the following as minimum:
    a. All data specified in the shop drawings section in its final "as-built" form.
    b. Schematic outline of the overall control system for quick reference
    c. Adequate record of the work as installed, including exact location of control panels and the wiring route (using TC documents, section 1.8-3).
    d. Blue prints shall include sequence of operation.
    e. System hardware specification data which provides a functional description of all hardware components.
    f. System engineering information which provides all of the information for the system set-up, definition and application.
    g. System database information that provides the point names and application data programmed into the system.
    h. All of the information, data, procedures and drawings shall be supplied in the form of manuals.
2. Provide as-installed (after system acceptance) control logic diagrams showing all points (real and virtual).
3. DDC systems that use line-based programming must reference line code number with control logic diagrams and/or with sequence of operation text. Control Contractor shall discuss final format with Owner.
4. Provide licensed electronic copies of all software for each workstation and laptop. This includes, but is not limited to: project graphic images, project database, trouble-shooting and debugging programs, project-specific application programming code and all other software required to operate and modify the programming code (including software at system level, primary control units, secondary control units, and all communication software). Any hardware devices (cables, protection devices) required to operate the software/hardware shall also be provided.
5. The Control Contractor shall document deviations from the shop drawing submittals. Documentation should include what equipment was changed and the reason for the change.
6. Provide copy of final test reports.
7. Provide within 21 days of substantial completion.
8. Documents shall be provided as a PDF file. See O & M for number of hard copies.

C. Operating and Maintenance Materials:

1. Submit three sets of each manual within three weeks (21 calendar days) of Substantial Completion.
   a. Include the following documentation in the Hardware Manual:
      1) General description and cut sheets for all components.
      2) Detailed wiring and installation illustrations and complete calibration procedures for each field and panel device.
      3) Complete trouble-shooting procedures and guidelines.
      4) Complete operating instructions for all systems.
      5) Maintenance Instructions: Document all maintenance and repair/replacement procedures.
   b. Include the following documentation in the DDC Software Manual:
      1) Sequence of Operations
      2) Program Listing of Software Source Code OR Flow Chart Diagrams of Programming Objects.
      3) Printed listing of controller and operator workstation database files.
      4) Software Point Name Abbreviation List. Include Name, Description, Controller Where Located, Point Type and Point ID.
      5) I/O Point List. Include Point Name, Controller Location, Point Number, Control Device, Range and Span.
      6) Printouts of the following; Reports, Group Listings and Alarm Messages.
      7) Index of all DDC point names with documentation, manual page number references.
   c. Provide all English language manufacturers manuals covering the installed system. This shall include, as a minimum:
      1) System Engineering Manual
      2) System Installation Manual
      3) Programming Manual
      4) Engineering and Troubleshooting Bulletins
      5) Operator Workstation Software Manual
      6) All other pertinent manuals published by the control system manufacturer.
2. All manuals shall be provided in an editable PDF file with tabs and an index for each device or system. Copyrighted factory manuals may be in a PDF file.

1.9 WARRANTY

A. Material:
   1. The Control System shall be free from defects in material and workmanship under normal use and service. If within thirty six (36) months from the date of substantial completion any of the equipment herein described is defective in operation, workmanship or materials, it will be replaced, repaired or adjusted at the option of the Controls Contractor free of charge.

B. Installation:
   1. The Control System shall be free from defects for a period of one year from acceptance. The Controls Contractor shall, free of charge, correct any defects in workmanship within one week of notification in writing by the Owner.

C. System Compatibility
   1. The Controls Manufacturer will provide a written guarantee to the Owner that the system and technology being provided will be supported for a minimum of ten years.

1.10 DELIVERY AND STORAGE

A. Provide factory-shipping cartons for each piece of equipment and control device not factory installed. Provide factory applied plastic end caps on each length of pipe and tube. Maintain cartons and end caps through shipping, storage, and handling as required to prevent equipment and

pipe-end damage, and to eliminate dirt and moisture from equipment and inside of pipe and tubes. Store equipment and materials inside and protected from weather.

1.11 DEMOLITION

A. Remove all pneumatic devices, tubing compressor, air dryer, and wire no longer used.

B. Remove all digital control devices no longer used.

C. Owner shall have first right of refusal of all digital control devices, and compressor and air dryer. Gather control devices and secure. Let Owner review devices. Those devices not desired by the Owner are to be recycled or disposed of by the Contractor off site.

1.12 DISCREPANCIES

A. Any items not included in the specification but referred to in the Appendix and/or Drawings in reference to this project and any other incidentals not referred to but required as a basic element to the overall performance and/or successful completion of the work shall be installed as part of this contract.

PART 2 - PRODUCTS

2.1 BASIC MATERIALS, CONTROL DEVICES, SENSORS

A. Installation of some of the equipment in this section may be the responsibility of other Contractors (see 1.5).

B. All sensors and equipment related to or connected to the DDC system shall be installed according to manufacturer's recommendations.

2.2 WIRING, CONDUIT, AND HANGERS

A. To supply, install and connect all conduits, boxes and wires between all the different components related in this section including all line voltage to the equipment.

B. Provide all necessary field wiring and devices from the point of connection indicated on the drawings. Bring to the attention of the Engineer in writing, all conflicts, incompatibilities, and/or discrepancies prior to bid or as soon as discovered.

C. Field Wiring: It is the intent of these specifications that all systems shall be complete and operable. Refer to all drawings and specifications to determine voltage, phase, circuit ampacity and number of connections provided.

D. All wiring and fiber optic cable in the central plant, tunnels, and plenums to be supported by B-line Bridle rings or equal. All wiring and fiber optic cable in the hallways, rooms, and other public areas shall be in conduit unless noted otherwise in section H.

E. All wires in Bridle Rings or conduit shall follow building lines (i.e., wires in plenum space shall run within several inches of the wall and shall NOT run in the middle of the space). Those areas of the building with RA plenum ceilings where wire is routed above that wire shall be plenum rated or routed in conduit.

F. Wire:
1. Wire and cable of the sizes and types shown on the plans and/or hereinafter specified shall be furnished and installed by the Control Contractor. All wire and cable shall be new soft drawn copper and shall conform to all the latest requirements of the National Electrical Code, IPCEA, and shall meet the specifications of the ASTM.
2. All control wiring to be copper stranded TEW-105, with appropriate gauge in accordance

with the Codes. The minimum gauge used to be 16 AWG.

3. Input/Output Wiring: Wiring serving inputs and outputs from the BAS shall be cables consisting of single or multiple twisted individually shielded pairs. Each pair shall have an independent shield with drain wire. Cables installed without conduit shall be plenum rated and comply with NEC article 725. Where automation input/output wiring is run in cable tray furnish and install conductors or multi-conductor cable rated for use in cable trays per NEC articles 340 and/or 725. Conductors shall be minimum #18 wire gauge.
4. Power Conductors: All feeder and branch circuit wire shall be 600 V insulated of THHN type unless shown or specified to be otherwise. No wire less than No. 12 gauge shall be used except for control circuits or low voltage wiring. Wire sizes No. 14 to No. 10 shall be solid except where otherwise indicated. Wire sizes No. 8 and larger shall be stranded. All wire sizes shown are American Wire Gauge sizes. Where power conductors are run in cable tray, furnish and install conductors or multi-conductor cable rated for use in cable trays per NEC articles 340 and/or 725.
5. All the conductors used for signals from the Controllers and field sensors must be shielded two wire, 18 AWG. with a drain wire. Conductor model 8760 from Belden is to be used or approved alternative by Engineer.
6. All power wiring to be copper stranded RW 90 type, with appropriate gauge in accordance with the Codes. The following color code must be applied: line voltage to be black and/or white, ground to be green.
7. Acceptable Manufacturers: Cable and wire shall be a standard type as manufactured by General Electric Company, National Electric Company, U. S. Rubber Company, Simplex, General Cable Company, Carol, Anaconda, Rome, Southwire, Belden, Alpha, Houston Wire and Cable, or ITT Royal.

G. Wiring Installation:
1. All wires shall be continuous from outlet to outlet and there shall be no unnecessary slack in the conductors.
2. All wire terminations will be identified using rail terminal strips (see 5.11)
3. All drain wires must be grounded at the source end. The other end must be protected with a dielectric material (tape).
4. All control wiring (24 V and more) must be in a separate conduit from the shielded conductors.
5. Pull-Box and Junction Box:
   a. Pull boxes and junction boxes shall be installed where indicated on the drawings or where required to facilitate wire installation. Locate in conjunction with other trades so as to install without conflict with other materials or equipment.
   b. A pull-box will be located at every 50'.
   c. All switch, pull, junction boxes, etc., shall be hot dipped galvanized or sherardized, concrete tight, with interlocking ring or multiple point locking devices. Connectors shall be three piece. Indentation fittings are not acceptable.
   d. In suspended ceilings, all boxes must be installed on the structure.
   e. Boxes shall be attached by fasteners designed for the purpose and shall provide adequate mechanical strength for future maintenance.
   f. Junction and pull boxes not dimensioned shall be minimum 4 inch square.
6. Care shall be used to avoid proximity to heat ducts and/or steam lines. Where crossings are unavoidable, conduit shall clear covering of line by at least six inches.
7. Motor Interlock Wiring: Interlock circuit wiring shall be No. 14 solid or stranded wire. Stranded wire only shall be used where wiring is used for flexible wiring harnesses. Stranded control wire shall be provided with crimp type spade terminators. Interlock circuit wiring shall be color coded or numbered using an identical number on both ends of the conductor. Wire numbers shall be installed before conductors are pulled. Where motor interlock conductors are run in cable tray, furnish and install conductors or multiconductor cable rated for use in cable trays per NEC articles 340 and/or 725.
8. All splices, taps, and terminations shall be made at outlet, junction, or pull boxes. Wire to No.6 gauge shall be spliced using Scotchlok wire nuts. No Bakelite wirenuts shall be used. Wire No. 6 and larger shall be spliced using solderness connectors as manufactured by Penn Union Company. Splices No. 6 and larger shall be insulated by taping with

plastic vinyl tape as manufactured by Minnesota Mining and Manufacturing Company. Splices shall not be permitted in automation input and output wiring with out specific written authorization from the Engineer. If such a splice is approved, the location of the splice shall be clearly documented on the "As Built" drawings. Splices in automation wiring, if necessary, shall be made using Thomas&Betts STA-KON connectors installed per the manufacturer's directions to maintain NEMA specified voltage drops and wire retention forces.

9. Grounding:
   a. The Contractor shall extend existing equipment grounding systems. The Contractor shall use only approved grounding clamps and connectors as manufactured by Penn-Union, Burndy or O-Z Mfg. Company.
   b. The conduit system of the 480/277 and 208Y/120 volt systems shall be continuous and shall be used as the static grounding conductor, except for circuits installed in flexible conduit. Install a green grounding conductor inside all flexible conduits and extend to the nearest outlet or junction box. Install a green grounding conductor inside all non-metallic conduits or raceways.

H. Conduit:
1. Conduit Material:
   a. All wiring to be in E.M.T. type conduits unless in plenum or otherwise noted below.
      1) Above accessible ceilings open cable with bridle ring support is allowed.
      2) Routed in corridors or other finished spaces on top of exposed sheet metal ducts supported with open wire way devices attached to the center top of the duct is allowed. Wire shall not be visible under casual observation of the installation.
      3) 12 ft. or more above the floor in mechanical rooms where supported per specifications.
   b. All conduits to be a minimum of 1/2".
   c. All flexible conduits will not exceed 6' in length and are to be used only in areas where vibrations and/or expansion joints are present.
   d. Flexible conduit to be used for connecting any element to its conduit. The length of this flexible conduit will not exceed 24".
   e. Jacketed flexible steel conduit (Sealtite) shall be used where flexible conduit connections are required outdoors and at connections to all motorized equipment and motors outdoors.
   f. In damp areas, the conduit and related equipment must be suitable for the application.
   g. Electrometalic tubing shall be installed for all exposed work and for all concealed work in applications where conduit is required. For exposed locations in finished spaces (halls, classrooms, offices, gym's etc.) conduit shall be painted. See Architectural Drawings for location where painting is required.
   h. Conduit shall be by Allied, Triangle, Republic, Youngstown, Carlon, Rob Roy, or approved equal.
   i. For exposed installations where the conduit cannot be run in ceiling spaces, wall cavities or attics, EMT is required. EMT shall be painted to match wall. See Painting Specification.
2. Conduit Installation:
   a. All wiring in mechanical rooms at heights below 12 feet must be run in conduit. Otherwise, wiring in all other open areas must have conduit (at all heights). Existing conduit runs where compliant with these specifications may be re-used.
   b. All conduits to be installed in a concealed manner where possible and shall be installed parallel to the lines of the building.
   c. All exposed conduits shall be installed parallel or at right angles to the building walls or floors.
   d. Conduit bends shall be made with standard hickeys of proper size; radius of bends to be at least 6 times the diameter of the conduit. Runs between outlets

shall not contain more than the equivalent of three quarter bends. Conduit runs shall be continuous from outlet to outlet, outlet to cabinet, etc.

e. Conduits shall be installed with pitch toward outlet box wherever possible. All heavy wall conduits shall have two locknuts and a bushing at each termination outlet box, junction box, etc., except where terminated in a threaded hub. Fittings on electrometalic tubing shall be compression type.

f. A bushing shall be used where conduit enters a panel box. Bushing for No. 4 AWG or larger shall be insulated type with provisions for grounding as type "BL" made by O-Z Electric Company, or approved equal.

g. Expansion fittings shall be provided at all conduits across the building expansion joints. Fittings shall be Type "AX" or "TX" as made by O-Z Electric Company, or approved equal. Provide copper bonding jumper at each expansion fitting.

h. All ½'' conduit to be supported every 6', the supports will be located at the connector end of the conduit.

i. Exposed conduit shall be securely fastened in place on maximum 5 ft. intervals for 3/4" through 2-1/2 inch nominal sizes. Supports may be one hole malleable straps or other approved devices. No perforated metal straps will be permitted.

I. Wireway:

1. Furnish and install at all control panel locations a NEMA 1 lay-in wireway system to bring cable into and out of the panel as detailed on the drawings and specified in this section. Furnish 3-way wireways at each panel location: one for Class 1 wiring, 1 for Class 2 and Class 3 wiring. Panels at units to be NEMA 3R or better.
2. Wireway systems at locations where cables are to be run without conduit or in a cable tray shall consist of a connection to the control panel with a vertical extension to 8'-0" or the pipe rack or cable tray level, whichever is higher. The vertical section shall terminate in a 90° fitting with a closure plate. The closure plate shall be provided with a conduit nipple with locknuts and bushings as a wire entry point into the square duct. The conduit nipple shall be one size smaller than the wireway it is associated with.
3. Wireway systems at locations where cables are to be run in conduit shall consist of a horizontal section of wireway with a length equal to the control panel width and located above the control panel and connected to the control panel with three conduit nipples, locknuts, and bushings; one for tubing, one for Class 1 wiring and one for Class 2 and 3 wiring. Conduits for cable runs shall terminate on the wireway.
4. The intent of the wireway configurations outlined above is to provide a method for adding input and output wiring to the control panel without having to drill directly into the electronics enclosure after the system is on-line and running and to provide sufficient area to land field conduits while maintaining appropriate circuit segregation for wire entry into the controller enclosure. The installation of wireway shall be made with this consideration in mind.

J. Hangers and Anchors:

1. Where control system tubing is run on trapezes and/or hangers used by and or installed by other trades, supports for the trapezes shall be coordinated by all trades using the trapeze to assure that the anchor system is not overloaded and is sufficient for the load imposed including a margin of safety and seismic considerations. Under no circumstances shall a trapeze or hanger system installed by the electrical trades be used to support work by any other trade, nor shall the electrical trades use the trapezes installed by any of the other trades for the support of electrical equipment, all as required by the National Electric Code. Similarly, under no circumstances shall a trapeze or hanger system installed by the sprinkler trades be used to support work by any other trade, nor shall the sprinkler trades use the trapezes installed by any of the other trades for the support of sprinkler systems or equipment, all as required by NFPA 13, Standard For The Installation Of Sprinkler Systems.
2. Anchors to be loaded in tension for use in existing concrete structure and anchors loaded in tension and not cast in place shall be epoxy resin set anchors installed per the manufacturers recommendations for technique, size, loading, embedment, etc. Where

anchors are loaded in shear at these locations, suitably sized and installed wedge type anchors may be used.

3. In all cases, anchor loading shall be based on hanger spacing, weight of the pipe to be supported when full and insulated, weight of any additional loads imposed upon the anchor, wind loading, seismic loading, quality of the material that the anchor is being installed in, etc. The Control Contractor shall verify in the field that the anchors used and the materials that they are being installed in are suitable for the load imposed and shall bring any problems to the attention of the Engineer in writing immediately and not proceed without direction from the Engineer.
4. Wedge type anchors shall be Hilti Kwik Bolt II. Adhesive anchors shall be Hilti HVA.

2.3 UNIT CONTROL PANELS (INSTALLATION AND FABRICATION)

A. Enclosed cabinet type with hinged door for mounting all relays, switches, thermometers, and miscellaneous controls not requiring direct mounting on equipment such as sensing elements, valves and damper motors. Provide cabinet for each control unit adjacent to each system.

B. Each panel shall have power conditioners on electrical supply, Crucial Power Product MI Series.

C. Control panels shall be fabricated to match the approved shop drawings submitted by the Control Contractor. Fabrication shall be in a neat and workmanlike manner and shall facilitate repair, maintenance, and adjustment of the equipment contained therein.

D. Control panels shall be fabricated and laid out to incorporate the following features:
1. Identification of all internally and cover mounted devices. Cover mounted labels shall be engraved labels as specified in this section (5.10). Labels shall be mounted adjacent to the device they are associated with so that replacement of the device does not eliminate the label. Provide laminated control diagram at each panel.
2. Electrical wiring shall enter the panel from the top, bottom, and/or side of the left side of the panel or as required by the panel supplier to meet NEC requirements.
3. All wires entering or leaving the panel shall pass through a rail terminal strip. Where the wires are part of a current loop transmission circuit, the terminals shall be the disconnecting link type. Terminals shall be identified with a number that corresponds to the terminal number on the job wiring diagram. Rail terminal strip specifications include:
   a. General: Terminal rail assemblies shall be fabricated from components selected from the product line of one manufacturer. Sizes (heights, widths, and profiles) of each terminal shall be selected to be compatible with the other terminals on the rail. Terminal units located at the end of a rail or adjacent to terminals with a different profile (for example, where disconnecting terminals are located next to resistor terminals) shall be provided with end caps to completely close off the terminal unit interior components from the local environment. End stops shall be provided for on all rails to secure the terminals located on the rail in place.
4. All internal wiring and tubing shall be run inside plastic wiring/tubing duct as manufactured by Tyton. Wire duct shall be sized to hold the required number of wires and tubes without crimping the tubes and with sufficient space to allow wiring and tubing to be traced during troubleshooting operation.
5. Wires that pass from the panel interior to cover mounted devices shall be provided with a flex loop that is anchored on both sides of the hinge. Wiring running to cover mounted devices shall be bundled using cable ties.
6. Provide strain relief type cord and cable connectors for all cables that leave the panel as individual cables not in conduit.
7. All control panels shall be provided with removable sub panels to allow the panel enclosures to be installed at the job site during rough in while the panels are fabricated off-site for later installation.
8. Provide one under cabinet type fluorescent light with switch mounted internally in the control panel. Panels with external light hoods will also be acceptable if the light will illuminate the panel interior with the door open.
9. Provide one duplex outlet mounted inside the control panel and separately fused with a

non-time delay fuse at 15 A at any panel location containing electronic or electrical control components. This receptacle may be served from the control panel 120 VAC power source.

10. Each control panel shall be provided with a control power disconnect switch located and wired so as to disconnect all control power in the panel. The leaving side of this switch shall be wired to the panel and field components through a fuse or fuses sized and applied to protect both the components of the system as well as the wire and as required for code compliance.
11. Power to the following equipment will be have a fuse rated for applicable current and voltage. Fuses will be on rail terminal strips. Equipment includes:
    a. Each control unit
    b. Control devices
    c. Panel light
    d. Receptacle loads (e.g., modems, laptops)
12. All control panels containing electrical equipment shall be NEMA rated for the location in which they are installed. Cover mounted components, tubing penetration, and conduit penetrations shall be made in a manner consistent with the NEMA rating.
13. All wiring leaving the panel shall be separated by classification; i.e., Class 1 circuits shall not be run with Class 2 circuits, etc. Segregation shall be maintained inside the panel to the fullest extent possible. Where low voltage wires carrying low level ac and dc signals cross wires containing power and high level ac signals, the wires shall cross at a 90° angle.

E. Control panels shall be shop fabricated and tested prior to installation in the field. The panels shall be inspected and approved by the Engineer at the assembly location prior to installation in the field. The Engineer shall be given the opportunity to witness the testing of the panels.

F. Panel Location:
1. Each control panel is to be located for convenient servicing.
2. Mount panels adjacent to associated equipment on vibration isolation.

2.4 CONTROL DAMPER ACTUATORS AND VALVES

A. Damper Actuator Requirements:
1. All damper actuators shall be Belimo electric actuators.
2. Torque rating shall be based on the damper manufacturers operating torque requirements at the design flows and pressure drops or shall be based on the manufacturer's required shut-off torque to achieve the design leakage rate, whichever is greater. This higher torque rating shall be doubled. An actuator with this doubled torque rating shall be installed.
3. All damper sections which operate in sequence with each other shall have identical actuators and identical linkage arrangements to assure similar performance between all sections.
4. Modulated actuator operation shall be industry standard 0-10V.
5. Two or three position operation is not acceptable for economizers, VAV dampers, multizone dampers, or any other application specifying modulated operation. OSA Dampers to be normally closed, mixed air dampers to be normally open.
6. Spring returns on damper operators are required for OSA application.
7. Actuator quantities for dampers shall be based on the following criteria.
    a. Actuators must be outside unit enclosure.
    b. Actuators shall be installed to maximize the linearity between actuator stroke and actuated devise travel (25% actuator stroke produces approximately 25% of the desired angular rotation required; 50% stroke produces 50% angular rotation). In addition, actuators should be installed to maximize force available for useful work over the entire stroke.
8. Actuators for VAV boxes to be provided to VAV manufacturer for installation at the factory.

B. Control Valves and Actuators:

1. Provide adequate size and number of modulating or two-position action.
2. Provide positive positioning devices where shown or where sequencing cannot be accomplished by using standard spring ranges.
3. Belimo only.

C. Valve Sizing:
1. Modulating valve sizing shall be based on the following conditions.
   a. Water Valves:
      1) Minimum pressure drop-2 psi or equal to the water side pressure drop of the coil it is associated with, whichever is greater.
      2) Maximum pressure drop-3 psi
   b. Flow rates for valve sizing shall be based upon the flow rates indicated on the equipment schedules on the drawings.
   c. Valve sizing shall consider the valve cavitation coefficient. In no case shall a valve be sized so that the pressure drop through the valve causes cavitation with fluid temperatures and pressures encountered in the system during start up or normal operation.
   d. Valves on heating systems to be normally open.

D. Valves: 1/2" to 2"
1. Equip with custom flow control modulating ball valve.
2. Two position valves shall be the full size of the pipe that they are associated with unless otherwise specified.
3. Two-way valve actuators shall be sized to close off tight against the full pump shut off head on the system upon which they are installed.
4. Three-way valve actuators shall be sized to close off tight in both directions against 2.5 times the valve pressure drop at full flow.
5. Valves shall close against differential pressures. Water control valves, acting as pressure control or pressure relief valves, shall be capable of closing against a differential pressure equal to 150% of rated pump head of each application.
6. Spring return is required at heating water valves.
7. Screwed ends on valves 2-inches and smaller. Flanged ends on valves 2-21/2 inches and larger.
8. Three-way valves where indicated on drawings, otherwise two-way valves.

E. Valves 2 1/2" and Larger
1. Butterfly valves shall be sized for modulating service at 60-70-degree stem rotation. Isolation valves shall be line-size. Design velocity shall be less than 12 feet per second when used with standard EPDM seats. Modulating Control Valve Body Size may be reduced at most two pipe sizes from the line size or not less than half the pipe size.
   a. Body is Cast Iron.
   b. Disc is Aluminum Bronze standard.
   c. Seat is EPDM standard.
   d. Body Pressure is 200 psi, -30ºF to 275ºF.
   e. Flange is ANSI 125/250.
   f. Media Temperature Range is -22ºF to 240ºF.
   g. Maximum Differential Pressure is 200 psi for 2" to 6" size.
2. Actuator Mounting for Damper and Valve arrangements shall comply to the following:
   a. Damper Actuators shall not be installed in the air stream.
   b. A weather shield shall be used if actuators are located outside. For Damper Actuators use clear plastic enclosure.
   c. Damper or valve actuator ambient temperature shall not exceed 122ºF through any combination of medium temperature or surrounding air. Appropriate air gaps, thermal isolation washers or spacers, standoff legs, or insulation shall be provided as necessary.
   d. Actuator cords or conduit shall incorporate a drip leg if condensation is possible.

Water shall not be allowed to contact actuator or internal parts. Location of conduits in temperatures dropping below dew point shall be avoided to prevent water from condensing in conduit and running into actuator.

3. Valve Mounting Arrangements Shall Comply to the following:
   a. Unions shall be provided on all ports of two-way and three-way valves.
   b. Install three-way equal percentage Characterized Control Valves in a mixing configuration with the "A" port piped to the coil.
   c. Install 2 1/2" inch and above, Three-way Globe Valves, as manufactured for mixing or diverting service to the coil.
   d. Two-way Valve shall be piped in the return side of the coil in order to minimize ambient heat at the coil.

F. Valve Actuators:
   1. Electronic actuators shall be manufactured by Belimo for all valves.
   2. Torque shall be rated at twice the required load.
   3. Modulated actuator shall be industry standard 0-10V, floating point is not allowed.

2.5 SENSORS

A. Shall be manufactured by Johnson Controls, Mamac, Kele, Setra, Veris, or Penn only.

B. All sensing inputs shall be provided industry standard signals.

C. Temperatures, humidities, differential pressure signals, and all other signal inputs shall be industry standard variable voltage or amperage.

D. All signal inputs shall be compatible with the controllers used and with the requirement for readout of variables as specified.

E. If sensors are not linear, then software will linearize sensor output.

F. Controls and sensors for VAV boxes to be provided to VAV manufacturer for installation at the factory.

G. Minimum sensor accuracy (as compared to a test standard) and range are listed in Table. Accuracy is not the same as resolution (the ability of the DDC to measure incremental change). Resolution is specified in "Part 3. DDC Hardware."
   1. All accuracy values should be combined effect numbers taking into account thermal drift, interchangeability, hysteresis, etc.

Sensor Type	Range	Min. Accuracy
Duct/Air Handling Unit Temperature	40 – 130°F	± 0.5 Degree F
Room Temperature	50 – 85°F	± 1 Degree F
Outside Air Temperature	- 20 to 120°F	± 0.5 Degree F
Chilled Water Temperature	32 – 80°F	± 0.1 to ± 0.5 Degree F
Hot Water Temperature	80 – 220°F	± 0.1 to ± 0.5 Degree F
Water flow	Sized for application	± 5% of reading
Humidity	0 to 100% RH	± 3% RH
Duct Static Pressure	0 to 3″ w.c.	± 1% full scale per 50°F
Space Static Pressure	- 0.25″ to 0.25″ w.c.	± 1% full scale per 50°F
High Limit Static	0-5" w.c.	± 1% full scale per 50ºF
Steam Pressure	Sized for application	± 1% full scale
Current Sensor	Sized for application	± 1% full scale
Power (kWh)	Sized for application	± 2.5% full scale (at 0.5 PF) ± 2% full scale (at 1.0 PF)

Air flow	700 to 4,000 fpm	± 2% full scale
CO_2 sensors	0 to 2,000 PPM	± 3% full scale
Freeze Stat	34ºF to 68ºF	± 1ºF

Sensors shall not drift more than 1% of full scale per year

2.6 TEMPERATURE SENSORS/THERMOSTATS

A. All sensors shall be completely electronic. The temperature sensor shall be of the resistance type, and shall be either two-wire 1000 ohm nickel RTD, or two-wire 1000 ohm platinum RTD.

B. Duct/ Air Handling Unit type temperature sensor (mixed, discharge/supply, and return air):
1. The probe of the duct sensor shall be 12" in length, and be made of Stainless Steel. Applications where the smallest dimension of the duct is less than 24", the probe shall be sized to reach the center of the duct.
2. Large systems above 9 square feet may require an averaging probe if sufficient mixing of the air stream is not possible.
3. Mount the sensor far enough down stream to allow mixing of the air stream, this is most important on Hot and Cold Deck applications where the coil is placed after the fan.
4. Sensors for mounting on insulated ducts or casings are to be equipped with brackets for mounting clear of the isolation.
5. Do not locate sensors in dead air spaces or in positions with obstructed air flow.
6. Provide separate duct flange for each sensing element.
7. Temperature sensing elements shall be thermally isolated from brackets and supports.
8. Securely seal ducts where elements or connections penetrate duct.
9. Mount sensor enclosures to allow for easy removal and servicing without disturbance or removal of duct insulation.

C. Immersion Type Temperature Sensor:
1. The probe of the sensor shall be constructed of stainless steel and pressure rating consistent with system pressure and velocity.
2. The well shall be constructed of stainless steel and sized to reach into the center of the pipe. Pipes with small diameters shall have the well mounted at a 90 degree elbow to allow sufficient contact with the fluid.
3. Locate wells to sense continuous flow conditions.
4. Do not install wells using extension couplings.
5. Wells shall not restrict flow area to less than 70 percent of line-size-pipe normal flow area. Increase piping size as required to avoid restriction.
6. Provide thermal transmission material within the well.
7. Provide wells with sealing nuts to contain the thermal transmission material and allow for easy removal.

D. Room Type Temperature Sensor:
1. All thermostat locations shall be submitted for approval before installation.
2. Provide all sensors without CO_2 function with blank wall plate, vandal-proof covers that are flush with wall. Mamac TE-205-P Series are equal.
3. Coordinate sensor location with light switches, and mount 60" above the floor. Verify location before installation, so that no direct sunlight or influences from heat and cooling sources will be imposed on the sensor.
4. At classrooms or other systems required to include CO_2 monitoring a combination sensor is allowed. JCI CD-WOO-XO-2 Series only.
5. Metal guards shall be provided as shown on Drawings.
6. Insulation shall be installed between the temperature sensor and open conduit to eliminate false temperature readings due to cold drafts.

E. Outside Air Sensors
1. Outside air sensors shall be designed to withstand the environmental conditions to which they will be exposed. They shall also be provided with a solar shield.
2. Sensor's exposed to wind velocity pressures shall be shielded by a perforated plate that

surrounds the sensor element.

3. Temperature transmitters shall be of NEMA 3R construction and rated for ambient temperatures.

F. Averaging Sensors

1. For ductwork greater in any dimension that 48 inches and/or where air temperature stratification exists, an averaging sensor with multiple sensing points shall be used.
2. For plenum applications, such as mixed air temperature measurements, a string of sensors mounted across the plenum shall be used to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12-foot long segment.
3. Capillary supports at the sides of the duct shall be provided to support the sensing string.

2.7 AIR PRESSURE SENSORS

A. Static Pressure and Velocity Controllers:

1. Static pressure sensors shall be of either the diaphragm or rigid element bellows, electronic type, photo helic.
2. Each sensor shall be provided with connections, i.e., stop cock and tubing, for attaching a portable pressure gauge.
3. Sensors for mounting on insulated ducts or casings are to be equipped with brackets for mounting clear of the insulation.
4. The transmitter shall be a two-wire type and provide a 4-20 mA signal which is proportional and linear over the calibrated pressure range.
5. The transmitter shall be capable of operating from an unregulated 18-30 VDC power supply.
6. The device housing shall provide 1/4" barbed brass fitting for the connection of the pressure lines. Pressure ranges shall suit the application so that normal operation will occur at mid range of the sensor span.
7. The location of the indoor measurement shall be remote from doors and openings to the outside, away from elevator lobbies, and shielded from air velocity effects. See Drawings for location.

2.8 WATER PRESSURE SENSORS

A. The device shall be capable of withstanding an over pressure of two times its calibrated span without any damage to the sensing element.

B. Typical ranges: 0-150 psig.

C. The device enclosure shall be a NEMA 4 type and provide rugged mounting feet. All wetted parts shall be stainless steel so that a wide variety of fluids may be measured.

D. The transmitter shall be capable of operating from an unregulated 18-30 VDC power supply.

E. Pressure sensors for liquid or pressurized applications shall be installed with shut off valve to that the system must not be shut down or drain to install or service the sensor.

2.9 FREEZE PROTECTION THERMOSTAT

A. Length: one linear foot of sensing element per square foot of coil or duct area.

B. Low temperature cutout control, snap acting, normally closed contacts.

C. Sensing element contacts will open when any 16-inch portion of the element sensing at or lower than setpoint.

D. Autorest with manual alarm reset.

E. Temperature sensing elements shall be thermally isolated from brackets and supports.

F. Reset temperature 5°F above setpoint.

2.10 TRANSFORMERS

A. Transformers selected and sized for appropriate VA capacity and installed and fused according to applicable Codes.

2.11 CO_2 SENSORS

A. Self-calibrating sensors are acceptable but, sensor must easily allow field calibration with test gas. Sensors must retain accuracy for between 3 - 5 years without requiring calibration. Sensors that require annual calibration are not acceptable. Provide CO_2 sensor calibration tool with system. Sensors must be calibrated at system start-up. Calibration tool is to be turned over to Owner along with instructions for use at close-out.
   1. CO_2 sensor output shall be 4 – 20 mA or 2 – 10 VDC proportional over the specified range. Minimum sensor accuracy and range:
   2. The transmitter shall be capable of operating from an unregulated 18 – 30 VDC power supply.
   3. Acceptable Manufacturers: Veris Industries, Johnson Controls.

2.12 POWER MONITORING DEVICES

A. Current Measurement (Amps)
   1. Current measurement shall be by a combination current transformer and a current transducer. The current transformer shall be sized to reduce the full amperage of the monitored circuit to a maximum 5 Amp signal, which will be converted to a 4-20 mA DDC compatible signal for use by the Controls.
   2. Current Transformer – A split core current transformer shall be provided to monitor motor amps.
      a. Operating frequency – 50 - 400 Hz.
      b. Insulation – 0.6 Kv class 10Kv BIL.
      c. UL recognized.
      d. Five amp secondary.
      e. Select current ration as appropriate for application.
      f. Acceptable manufacturers: Veris Industries
   3. Current Transducer – A current to voltage or current to mA transducer shall be provided. The current transducer shall include:
      a. 6X input over amp rating for AC inrushes
      b. Manufactured to UL 1244.
      c. Accuracy: +.5%, Ripple +1%.
      d. Minimum load resistance 30kOhm.
      e. `Input 0-20 Amps.
      f. Output 4-20 mA.
      g. Transducer shall be powered by a 24VDC regulated power supply (24 VDC +5%).
      h. Acceptable manufacturers: Veris Industries

2.13 SURGE PROTECTION

A. All equipment shall be protected from power surges and voltage transients. If failure occurs from surges and transients during the warranty period, then the contractor shall repair surge protection equipment and other equipment damaged by the failure at no cost to the Owner.

B. Isolation shall be provided at all peer-to-peer network terminations, as well as all field point terminations to suppress induced voltage transients, and shall be consistent with IEEE standards

587-1980.

2.14 FACTORY MOUNTED DEVICES

A. Sensors as required shall be provided by Control Contractor to the manufacturer for installation. All materials and labor beyond this is the responsibility of the Control Contractor.

PART 3 - DIRECT DIGITAL CONTROLS – HARDWARE

3.1 SYSTEM ARCHITECTURE

A. Extend existing JCI BACnet system to modified systems in the 100 building area, 300 building area, and boiler room equipment. Provide new controllers as required. Extend network as required to devices not on the BACnet system in 200 building area. Modify programming as required.

3.2 NETWORK CONTROLLER/SUPERVISOR

A. The Network Controller shall be a fully user-programmable supervisory controller. The Network Controller shall monitor and communicate the network of distributed primary, secondary, application-specific control units, provide global strategy and direction, and communicate on a peer-to-peer basis with other Network Controllers/Supervisors.

B. Controllers shall be microprocessor-based with a maximum program scan rate of one (1) second. They shall be multi-tasking, multi-user, and real-time digital control processors. Controller size and capability shall be sufficient to fully meet the requirements of this Specification.

C. Each Network Controller/Supervisor shall support/communicate with a minimum of 100 control units.

D. Each controller shall have sufficient memory to support its own operating system, databases, and control programs, and to provide supervisory control for all control units. In addition, if memory for historical data trending is not on primary and/or secondary control units, then sufficient memory is required on the network controller to capture and record historical trending data. Memory size shall be at least 1 gigabyte.

E. Network Controller/Supervisor speed shall be between 300 bps to 115K bps.

F. Network Controller/Supervisor shall interact with printers, pagers, and host workstations.

G. The controller shall have an integrated real-time clock.

H. Error detection, correction, and re-transmission to guarantee data integrity. (Optional. Low cost is of greater importance.)

I. The NC shall provide at least one Ethernet port 10/100 mdps, one RS-232/485 port. Controllers shall allow temporary use of portable devices without interrupting the normal operation.

J. The NC shall support standard Web browser access via the Internet. It shall support a minimum of 15 simultaneous users.

K. The NC shall provide alarm recognition, storage, routing, management and analysis to supplement distributed capabilities of equipment or application specific controllers.

L. The NC shall be able to route any alarm condition to any defined user location whether connected to a local network or remote via dial-up, telephone connection, or wide-area network.
1. Alarm generation shall be selectable for annunciation type and acknowledgement requirements including but not limited to:

a. Alarm,
b. Return to normal,
c. To default.

2. Alarms shall be annunciated in any of the following manners as defined by the user:
   a. Screen message text,
   b. Email of complete alarm message to multiple recipients.
   c. Pagers via paging services that initiate a page on receipt of email message.
   d. Graphics with flashing alarm object(s).
3. The following shall be recorded by the NC for each alarm (at a minimum):
   a. Time and date
   b. Equipment (air handler #, accessway, etc.)
   c. Acknowledge time, date, and user who issued acknowledgement.

M. Programming software and all controller "Setup Wizards" shall be embedded into the NC.

N. Controller shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The network controller shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failures to establish communication.

O. In the event of the loss of normal power, there shall be an orderly shutdown of all controllers to prevent the loss of database or operating system software. Nonvolatile memory shall be incorporated for all critical controller configuration data and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.
1. During a loss of normal power, the control sequences shall go to the normal system shutdown conditions.
2. Upon restoration of normal power and after a minimum off-time delay, the controller shall automatically resume full operation without manual intervention through a normal soft-start sequence.
3. Should a controller memory be lost for any reason, the operator workstation shall automatically reload the program without any intervention by the system operators.

P. Devices shall be JCI only.

3.3 PRIMARY CONTROL UNITS

A. Primary control units are stand-alone units able to control HVAC equipment per the specified sequence of operation.
1. Each controller shall be capable of performing all specified control functions independently. The primary control unit shall directly control all units, fans, and control devices. All control software shall be implemented in the primary control unit. The sequence of operation precisely identifies all points of monitoring and control.
2. Shall monitor specific analog and digital inputs, process the data received, and produce analog or digital outputs to control the systems specified.
3. Systems utilizing controllers that operate in a default mode only as a stand-alone will not be acceptable.

B. Minimum specifications include:
1. Microprocessor-based controllers, fully equipped with power supply, input and output terminals, internal (electronic) timeclock, and self-charging battery backup.
2. Modular multi-tasking microprocessor based direct digital controller with minimum of 1MB of EEPROM and RAM memory.
3. Minimum 10 bit Analog-to-Digital (A/D) converter.
4. Minimum 12 bit Digital-to-Analog (D/A) converter.
5. Sufficient memory for storing 288 trend values for every point (real and virtual).
6. Controllers shall have unused physical points available for future add-ons. The number of spare points shall equal 20% of all physical points (20% AI, 20% AO, 20% BI, 20% BO) or at least two spare points of each type.

7. Shall include all control strategies listed in "Part 4: DDC Software."
8. Each control loop shall be fully definable in terms of inputs and outputs that are a part of the control strategy.
9. Each control unit shall be equipped with a communication interface connection, minimum of 16 universal analog or digital inputs and outputs, and shall communicate via the LAN to the building level controller.
10. On board power supply for all sensors.
11. On board sockets for plug-in resistors.
12. Each control units shall be capable of proper operation in an ambient environment of between 32°F and 110°F and from 10% to 90% RH.
13. Control units provided for outside installation shall be capable of proper operation in an ambient environment of 0°F to 120°F, and 5 to 95% RH. If such hardware is not available, locate hardware in an accessible indoor location or as approved by the Engineer.
14. Power Failure Protection:
    a. All control panels shall be provided with automatic protection from power failure for at least 168 hours.
    b. This protection shall, at a minimum, include continuous real-time clock operation, automatic system restart upon power return, and integrity of all volatile point data.
    c. Panel outputs shall, at a minimum, be configured to remain in the last commanded state and return to the required state upon restoration of power.
15. Diagnostics: Controller shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The network controller shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failures to establish communication.
16. Power Failure: In the event of the loss of normal power, there shall be an orderly shutdown of all controllers to prevent the loss of database or operating system software. Nonvolatile memory shall be incorporated for all critical controller configuration data, and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.
    a. During a loss of normal power, the control sequences shall go to the normal system shutdown conditions.
    b. Upon restoration of normal power and after a minimum off-time delay, the controller shall automatically resume full operation without manual intervention through a normal soft-start sequence.
    c. Should a controller memory be lost for any reason, the operator workstation shall automatically reload the program without any intervention by the system operators.
17. Certification: All controllers shall be listed by Underwriters Laboratories (UL).
    a. All controllers shall be listed by Underwriters Laboratories (UL).

C. Primary control units shall be installed on:
1. Air handling units greater than 2,000 CFM
2. Air handling units with VFDs
3. Any application not listed in secondary and application control units.

D. Devices shall be JCI only.

3.4 SECONDARY CONTROL UNITS

A. Secondary control units are able to control HVAC equipment per specified by the sequence of operation.
1. Each controller shall be capable of performing specified control functions. The secondary control unit shall directly control all units, fans, dampers and control devices. All control software shall be implemented in the secondary control unit. The sequence of operation precisely identifies all points of monitoring and control.
2. Each controller shall monitor specific analog and digital inputs, process the data received,

and produce analog or digital outputs to control the systems specified.

B. Minimum specifications include:
1. Microprocessor-based controllers, fully equipped with power supply, input and output terminals.
2. Modular multi tasking based direct digital controller with minimum of 2048 bytes of EEPROM and RAM memory.
3. Minimum 8 bit Analog-to-Digital (A/D) converter.
4. Minimum 10 bit Digital-to-Analog (D/A) converter.
5. Controllers shall have unused physical points available for future add-ons. The number of spare points shall equal 20% (20% AI, 20% AO, 20% BI, 20% BO) of all physical points or two spare points whichever is greater.
6. Shall include all control strategies listed in "Part 4: DDC Software."
7. Each control loop shall be fully definable in terms of inputs and outputs that are a part of the control strategy.
8. Each secondary control unit shall be equipped with a USB communication interface connection, minimum of 16 universal analog or digital inputs or outputs, and shall communicate via the LAN to the network front end. Each control units shall be capable of proper operation in an ambient environment of between 32°F and 110°F and from 10% to 90% RH.
9. Control units provided for outside installation shall be capable of proper operation in an ambient environment of 0°F to 120°F, and 5 to 95% RH. If such hardware is not available, locate hardware in an accessible indoor location, in a ventilated control panel or as approved by the Engineer.

C. Secondary control unit. Secondary control units are microprocessor-based devices that are less programmable and will be used on:
1. Small unitary equipment (flow rate less than 2,000 CFM)
2. Fan coil units

D. Devices shall be JCI only.

3.5 APPLICATION SPECIFIC CONTROL UNITS

A. Pressure Independent VAV Terminal Unit Controller
1. General
a. Controls shall be microprocessor based Pressure Independent Variable Air Volume Terminal Unit Controllers (VTC). The VTC shall be based on a minimum 8-bit microprocessor working from software program memory that is physically located in the VTC. The VTC controller "intelligence" shall be resident within the same enclosure that translates sensor signals into digital information.
b. The VTC shall consist of microprocessor, power supply, enclosure, pressure transducer, field terminations, field adjustments, and operating/application system software in a single integrated package. Device shall operate remote Belimo damper actuator and valve actuator.
c. All input/output signals shall be directly hardwired to the VTC. Troubleshooting of input/output signals shall be easily executed with a volt/ohm meter (VOM) or hand-held operator interface device or laptop.
2. Non-Volatile Memory
a. All control sequences programmed in the VTC shall be stored in non-volatile memory which is not dependent upon the presence of a battery to be retained.
b. Power failures shall, therefore, not cause the VTC memory to be lost, nor shall there be any need for batteries to be recharged or replaced.
3. Controller Location: To simplify controls, mechanical service and troubleshooting, all components of the VTC shall be mounted directly at the Variable Air Volume terminal box. This shall allow all controls maintenance and troubleshooting to be made while at the VTC zone location. Enclosure assembly shall be mounted and positioned so that it is

easily accessible to operational personnel.

a. The VTC shall be powered by a 24 VAC power source and shall comply with Class 2 wiring requirements.
b. For compatibility with the environment of a VAV terminal box, the VTC shall have wide ambient ratings for specified controls, sequences, and performance. VTC shall be rated for service from 40°F to 140°F.
c. Contractor shall submit description of location of VTC on VAV terminal box.
d. For compatibility of use in the supply or return air plenum, the VTC enclosure shall be constructed to comply with the requirements of UL-465.

4. Transducer
   a. Each VTC shall contain an integral flow transducer capable of measuring and controlling over a 0.05 to 2.00 WC range with an accuracy of +6% at full rated flow.
   b. Flow transducer shall contain an automatic recalibration circuit that eliminates transducer error due to temperature variations and long-term sensor drift.
   c. VAV box controllers not meeting this specification shall include their bid price the cost of sensor recalibration to factory tolerance on a quarterly basis for a minimum period of three years.
5. Actuator Operation
   a. Each VTC shall be capable of operating on VAV terminal boxes that require clockwise or counterclockwise primary damper operation.
   b. All actuators shall provide a proportional signal over the entire control range.
   c. Actuators shall stop automatically at end of travel and shall include a permanently lubricated gear train.
   d. Interface to the VAV terminal box shall be directly to the damper shaft or through electrical connection to an existing 24 VAC bi-directional motor operator.
   e. All actuators shall be Belimo. None others will be accepted.
6. Operational Features
   a. Each VTC shall have a discharge temperature sensor that provides data to the BAS.
   b. Each VTC shall support the setup of the minimum and maximum flow setpoints, the cooling setpoint as well as the heating or parallel fan start point setpoints without the need for a separate hand-held communications device. In addition, the configuration modes described earlier in this specification must also be definable at the VTC without requiring an external hand-held communications device.
   c. The set-up of the above parameters shall be permanent in the VTC, a power failure shall not require the reconfiguration of the VTC operating parameters.
7. BAS Communication/Control With VTC application control unit: BAS shall be in continual direct communication with the VTCs implemented in the facility. VTCs shall perform all control as specified in control functions for the respective VAV terminal box.

PART 4 - DIRECT DIGITAL CONTROLS – SOFTWARE

4.1 SYSTEM SOFTWARE

A. Stand-alone Digital Controller (SDC) Software:
   1. All Stand-alone controllers shall have as a standard feature, a complete library of control algorithms for DDC, Energy Management, and Facilities Management functions. These resident libraries of algorithms shall be drawn from for the creation of the application programming of each individual controller.
   2. Contractor shall provide a blueprint documentation of the software application program for each controller. Documentation provided shall include block software flowchart showing the interconnection between each of the control algorithms and sequences.
   3. For systems utilizing program listings: A program listing shall be printed onto the same blueprint, along with the program flowchart, and description of the sequence of operation. This blueprint shall be stored and maintained in each controller.

4. System acceptance shall not be completed until this documentation is provided.
5. The stand-alone software library shall include as a minimum, the following programs:
   a. Direct Digital Control Functions:
      1) Setpoint Reset
      2) Ramp
      3) Floating ON/OFF
      4) 2-Position ON/OFF
      5) PID Loop
      6) Self-tune PID Loop
      7) Linear Sequencer
      8) Rotating Sequencer
      9) Binary Sequencer
      10) High/Low Select
      11) Energy Dead Band
      12) Thermostat
   b. Energy Management Control Functions:
      1) Duty Cycle
      2) Temperature Compensated Duty Cycling
      3) Optimum Start/Stop
      4) Electric Demand Limiting
      5) Weekly Scheduling
      6) Calendar Scheduling
      7) Enthalpy Changeover
   c. Math and Logic Functions:
      1) Add
      2) Subtract
      3) Multiply
      4) Divide
      5) Square root
      6) and, or, xor, nand, nor
      7) Invert
      8) Averaging
      9) Summation
      10) Totalize
      11) Pulse Count Conversion
      12) Time Delay
      13) Sensor Curve Fit
      14) CFM Calculation
      15) BTUH Calculation
   d. Facilities Management Functions:
      1) Analog High/Low Alarm
      2) Digital Alarm
      3) Trend Log Reporting
      4) Daily EMS Report
      5) Monthly EMS Report
      6) Maintenance Time Reminders
      7) BTUH Trend
   e. HVAC Application Functions:
      1) Constant Volume Single Zone
      2) Heat Pump
      3) Multizone
      4) Variable Air Volume (Dual & Single Fan VAV Systems)
      5) Fan Tracking VAV
      6) Boiler Optimization
      7) Chiller Optimization
      8) MICROFLO /TM/ Interface
      9) MICROZONE /TM/ Interface
      10) Supply Air Optimization

11) Hot Deck Optimization
12) Cold Deck Optimization

6. Stand-alone controllers not capable of performing the above listed software programs without the host computer will not be acceptable. Programs must be maintained regardless of communication with the host computer.
7. Programs shall be provided as required to meet the sequence of operation as specified.
8. All programming resident to the stand-alone controller, including but not limited to, application programs and point database, shall be protected from loss due to power failure for a minimum of six months. Systems not providing nonvolatile memory shall provide battery backup sufficient to provide protection for six months.

4.2 SYSTEM OVERVIEW

A. The BAS Contractor shall provide system software based on server/thin-client Engineer, designed around the open standards of web technology. The BAS server shall communicate using Ethernet and TCP\IP. Server shall be accessed using a web browser over Owner network and remotely over the Internet.

B. The intent of the thin-client Engineer is to provide the operator(s) complete access to the BAS system via a web browser. The thin-client web browser Graphical User Interface (GUI) shall be browser and operating system agnostic, meaning it will support Microsoft and Netscape Navigator browsers (6.0 or later versions), and Windows as well as non-Window operating systems. No special software, other than free public domain programs such as "JAVA VIRTUAL MACHINE" shall be required to be installed on PC's used to access the BAS via a web browser.

C. The BAS server software must support at least the following server platforms (Windows, and/or Linux). The BAS server software shall be developed and tested by the manufacturer of the system stand-alone controllers and network controllers/routers.

D. The web browser GUI shall provide a completely interactive user interface and must offer and be configured with the following features as a minimum:
1. Trending
2. Scheduling
3. Electrical demand limiting
4. Duty Cycling
5. Downloading Memory to field devices
6. Real time 'live' Graphic Programs
7. Tree Navigation
8. Parameter change of properties
9. Setpoint Adjustments
10. Alarm / Event information
11. Configuration of operators
12. Execution of global commands
13. Add, delete, and modify graphics and displayed data

E. Software Components: All software shall be the most current version. All software components of the BAS system software shall be provided and installed as part of this project .BAS software components shall include:
1. Server Software, Database and Web Browser Graphical User Interface
2. System Configuration Utilities for future modifications to the system, and controllers.
3. Graphical Programming Tools
4. Direct Digital Control software
5. Application Software
6. Any required third party software
7. If licensing credits are required provide a minimum of 10% additional to as built control system requires.

F. BAS Server Database: The BAS server software shall utilize a Java DataBase Connectivity

(JDBC) compatible database such as: MS SQL 8.0, Oracle 8i or IBM DB2. BAS systems written to Non -Standard and/or Proprietary databases are NOT acceptable.

G. Database Open Connectivity: The BAS server database shall allow real time access of data via the following standard mechanisms:
1. Open protocol standard like SOAP
2. OLE/OPC (for Microsoft Client's/Server platform only)
3. Import/Export of the database from or to XML (eXtensible Mark-up Language)

H. Communication Protocol(s): The native protocol for the BAS server software shall be TCP/IP over Ethernet. Proprietary protocols over TCP/IP are NOT acceptable.

I. Thin Client – Web Browser Based: The GUI shall be thin client or browser based and shall meet the following criteria:
1. Web Browser's for PC's: Only a 5.5 or later browser (Explorer/Navigator) will be required as the GUI, and a valid connection to the server network. No installation of any custom software shall be required on the operator's GUI workstation/client. Connection shall be over an intranet or the Internet.
2. Secure Socket Layers: Communication between the Web Browser GUI and BAS server shall offer encryption using 128-bit encryption technology within Secure Socket Layers (SSL). Communication protocol shall be Hyper-Text Transfer Protocol (HTTP).

4.3 WEB BROWSER GRAPHICAL USER INTERFACE

A. Web Browser Navigation: The Thin Client web browser GUI shall provide a comprehensive user interface. Using a collection of web pages, it shall be constructed to "feel" like a single application, and provide a complete and intuitive mouse/menu driven operator interface. It shall be possible to navigate through the system using a web browser to accomplish requirements of this specification. The Web Browser GUI shall (as a minimum) provide for navigation, and for display of animated graphics, schedules, alarms/events, live graphic programs, active graphic setpoint controls, configuration menus for operator access, reports, and reporting actions for events.

B. Login: On launching the web browser and selecting the appropriate domain name or IP address, the operator shall be presented with a login page that will require a login name and password. Navigation in the system shall be dependent on the operator's role privileges, and geographic area of responsibility.

C. Navigation: Navigation through the GUI shall be accomplished by clicking on appropriate level of a navigation tree (consisting of expandable and collapsible tree control like Microsoft's Explorer program), and/or by selecting dynamic links to other system graphics. Both the navigation tree and action pane shall be displayed simultaneously, enabling the operator to select a specific system or equipment, and view the corresponding graphic. The navigation tree shall as a minimum provide the following views: Geographic, Network, Groups and Configuration.

D. Geographic View shall display a logical geographic hierarchy of the system including: cities, sites, buildings, building systems, floors, equipment and objects.

E. Groups View shall display Scheduled Groups and custom reports.

F. Configuration View shall display all the configuration categories (Operators, Schedule, Event, Reporting and Roles).

G. Action Pane: The Action Pane shall provide several functional views for each HVAC or mechanical/electrical subsystem specified. A functional view shall be accessed by clicking on the corresponding button:
1. Graphics: Using graphical format suitable for display in a web browser, graphics shall include aerial building/campus views, color building floor-plans, equipment drawings, active graphic setpoint controls, web content, and other valid HTML elements. The data

on each graphic page shall automatically refresh.

2. Graphic pages for viewing at workstations and smart devices shall differ. Smart device graphics shall be more condensed for viewing on these types of devices. Provide an option upon entering the system from a smart device for viewing full graphics version or just the smart version.
3. Properties: Shall include graphic controls and text for the following: Locking or overriding objects, demand strategies, and any other valid data required for setup. Changes made to the properties pages shall require the operator to depress an 'accept/cancel' button.
4. Schedules: Shall be used to create, modify/edit and view schedules based on the systems geographical hierarchy (using the navigation tree).
5. Alarms: Shall be used to view alarm information geographically (using the navigation tree), acknowledge alarms, sort alarms by category, actions and verify reporting actions.
6. Trends: Shall be used to display associated trend and historical data, modify colors, date range, axis and scaling
7. Logic - Live Graphic Programs: Shall be used to display' live' graphic programs of the control algorithm, (micro block programming) for the mechanical/electrical system selected in the navigation tree.
8. Other actions such as Print, Help, Command, and Logout shall be available via a drop-down window.

H. Color Graphics: The Web Browser GUI shall make extensive use of color in the graphic pane to communicate information related to setpoints and comfort. Animated .gifs or .jpg, vector scalable, active setpoint graphic controls shall be used to enhance usability. Graphics tools used to create Web Browser graphics shall be non-proprietary and conform to the following basic criteria:

1. Display Size: The GUI workstation software shall graphically display in 1024 by 768 pixels 24 bit True Color.
2. General Graphic: General area maps shall show locations of controlled buildings in relation to local landmarks.
3. Color Floor Plans: Floor plan graphics shall show heating and cooling zones throughout the buildings in a range of colors, as selected by Owner. Provide a visual display of temperature relative to their respective setpoints. The colors shall be updated dynamically as a zone's actual comfort condition changes.
4. Mechanical Components: Mechanical system graphics shall show the type of mechanical system components serving any zone through the use of a pictorial representation of components. Selected I/O points being controlled or monitored for each piece of equipment shall be displayed with the appropriate engineering units. Animation shall be used for rotation or moving mechanical components to enhance usability.
5. Minimum System Color Graphics: Color graphics shall be selected and displayed via a web browser for the following:
   a. Each piece of equipment monitored or controlled including each terminal unit
   b. Each building
   c. Each floor and zone controlled

I. Hierarchical Schedules: Utilizing the Navigation Tree displayed in the web browser GUI, an operator (with password access) shall be able to define a Normal, Holiday or Override schedule for an individual piece of equipment or room, or choose to apply a hierarchical schedule to the entire system, site or floor area. For example, Independence Day 'Holiday' for every level in the system would be created by clicking at the top of the geographic hierarchy defined in the Navigation Tree. No further operator intervention would be required and every control module in the system with would be automatically downloaded with the 'Independence Day' Holiday. All schedules that affect the system/area/equipment highlighted in the Navigation Tree shall be shown in a summary schedule table and graph.

1. Schedules: Schedules shall comply with the LonWorks standards, (Schedule Object, Calendar Object, Weekly Schedule property and Exception Schedule property) and shall allow events to be scheduled based on:
   a. Types of schedule shall be Normal, Holiday or Override
   b. A specific date,

c. A range of dates,
d. Any combination of Month of Year (1-12, any), Week of Month (1-5, last, any), Day of Week (M-Sun, Any)
e. Wildcard (example, allow combinations like second Tuesday of every month).

2. Schedule Categories: The system shall allow operators to define and edit scheduling categories (different types of "things" to be scheduled; for example, lighting, HVAC occupancy, etc.). The categories shall include: name, description, icon (to display in the hierarchy tree when icon option is selected) and type of value to be scheduled.
3. Schedule Groups: In addition to hierarchical scheduling, operators shall be able to define functional Schedule Groups, comprised of an arbitrary group of areas/rooms/equipment scattered throughout the facility and site. For example, the operator shall be able to define an 'individual tenant' group – who may occupy different areas within a building or buildings. Schedules applied to the 'tenant group' shall automatically be downloaded to control modules affecting spaces occupied by the 'tenant group'
4. Intelligent Scheduling: The control system shall be intelligent enough to automatically turn on any supporting equipment needed to control the environment in an occupied space. If the operator schedules an individual room in a VAV system for occupancy, for example, the control logic shall automatically turn on the VAV air handling unit, chiller, boiler, and/or any other equipment required to maintain the specified comfort and environmental conditions within the room.
5. Partial Day Exceptions: Schedule events shall be able to accommodate a time range specified by the operator (ex: board meeting from 6 pm to 9 pm overrides Normal schedule for conference room).
6. Schedule Summary Graph: The schedule summary graph shall clearly show Normal versus Holiday versus Override Schedules, and the net operating schedule that results from all contributing schedules. Note: In case of priority conflict between schedules at the different geographic hierarchy, the schedule for the more detailed geographic level shall apply.

J. Alarms: Alarms associated with a specific system, area, or equipment selected in the Navigation Tree, shall be displayed in the Action Pane by selecting an 'Alarms' view. Alarms, and reporting actions shall have the following capabilities:
1. Alarms View: Each Alarm shall display an Alarms Category (using a different icon for each alarm category), date/time of occurrence, current status, alarm report, and a bold URL link to the associated graphic for the selected system, area or equipment. The URL link shall indicate the system location, address and other pertinent information. An operator shall easily be able to sort events, edit event templates and categories, acknowledge or force a return to normal in the Events View as specified in this section.
2. Alarm Categories: The operator shall be able to create, edit or delete alarm categories such as HVAC, Maintenance, Fire, or Generator. An icon shall be associated with each alarm category, enabling the operator to easily sort through multiple events displayed.
3. Alarm Templates: Alarm template shall define different types of alarms and their associated properties. As a minimum, properties shall include a reference name, verbose description, severity of alarm, acknowledgement requirements, and high/low limit and out of range information.
4. Alarm Areas: Alarm Areas enable an operator to assign specific Alarm Categories to specific Alarm Reporting Actions. For example, it shall be possible for an operator to assign all HVAC Maintenance Alarm on the 1st floor of a building to email the technician responsible for maintenance. The Navigation Tree shall be used to setup Alarm Areas in the Graphic Pane.
5. Alarm Time/Date Stamp: All events shall be generated at the DDC control module level and comprise the Time/Date Stamp using the standalone control module time and date.
6. Alarm Configuration: Operators shall be able to define the type of Alarm generated per object. A 'network' view of the Navigation Tree shall expose all objects and their respective Alarm Configuration. Configuration shall include assignment of Alarm, type of Acknowledgement and notification for return to normal or fault status.
7. Alarm Summary Counter: The view of Alarm in the Graphic Pane shall provide a numeric counter, indicating how many Alarms are active (in alarm), require

acknowledgement, and total number of Alarms in the BAS Server database.

8. Alarm Auto-Deletion: Alarms that are acknowledged and closed shall be auto-deleted from the database and archived to a text file after an operator defined period.
9. Alarm Reporting Actions: Alarm Reporting Actions specified shall be automatically launched (under certain conditions) after an Alarm is received by the BAS server software. Operators shall be able to easily define these Reporting Actions using the Navigation Tree and Graphic Pane through the web browser GUI. Reporting Actions shall be as follows:
   a. Print: Alarm information shall be printed to the BAS server's PC or a networked printer.
   b. Email: Email shall be sent via any POP3-compatible e-mail server (most Internet Service Providers use POP3). Email messages may be copied to several email accounts. Note: Email reporting action shall also be used to support alphanumeric paging services, where email servers support pagers.
   c. File Write: The ASCII File write reporting action shall enable the operator to append operator defined alarm information to any alarm through a text file. The alarm information that is written to the file shall be completely definable by the operator. The operator may enter text or attach other data point information (such as AHU discharge temperature and fan condition upon a high room temperature alarm).
   d. Write Property: The write property reporting action updates a property value in a hardware module.
   e. SNMP: The Simple Network Management Protocol (SNMP) reporting action sends an SNMP trap to a network in response to receiving an alarm.
   f. Run External Program: The Run External Program reporting action launches specified program in response to an event.

K. Trends: Trends shall both be displayed and user configurable through the Web Browser GUI. Trends shall comprise analog, digital or calculated points simultaneously. A trend log's properties shall be editable using the Navigation Tree and Graphic Pane.
1. Viewing Trends: The operator shall have the ability to view trends by using the Navigation Tree and selecting a Trends button in the Graphic Pane. The system shall allow y- and x-axis maximum ranges to be specified and shall be able to simultaneously graphically display multiple trends per graph.
2. Local Trends: Trend data shall be collected locally by Multi-Equipment/Single Equipment general-purpose controllers, and periodically uploaded to the BAS server if historical trending is enabled for the object. Trend data, including run time hours and start time date shall be retained in non-volatile module memory. Systems that rely on a gateway/router to run trends are NOT acceptable.
3. Resolution. Sample intervals shall be as small as one second. Each trended point will have the ability to be trended at a different trend interval. When multiple points are selected for displays that have different trend intervals, the system will automatically scale the axis.
4. Dynamic Update. Trends shall be able to dynamically update at operator-defined intervals.
5. Zoom/Pan. It shall be possible to zoom-in on a particular section of a trend for more detailed examination and 'pan through' historical data by simply scrolling the mouse.
6. Numeric Value Display. It shall be possible to pick any sample on a trend and have the numerical value displayed.
7. Copy/Paste. The operator must have the ability to pan through a historical trend and copy the data viewed to the clipboard using standard keystrokes (i.e. CTRL+C, CTRL+V).

L. Security Access: Systems that Security access from the web browser GUI to BAS server shall require a Login Name and Password. Access to different areas of the BAS system shall be defined in terms of Roles, Privileges and geographic area of responsibility as specified:
1. Roles: Roles shall reflect the actual roles of different types of operators. Each role shall comprise a set of 'easily understood English language' privileges. Roles shall be defined in terms of View, Edit and Function Privileges.

a. View Privileges shall comprise: Navigation, Network, and Configuration Trees, Operators, Roles and Privileges, Alarm/Event Template and Reporting Action.
b. Edit Privileges shall comprise: Setpoint, Tuning and Logic, Manual Override, and Point Assignment Parameters.
c. Function Privileges shall comprise: Alarm/Event Acknowledgement, Control Module Memory Download, Upload, Schedules, Schedule Groups, Manual Commands, Print, and Alarm/Event Maintenance.

2. Geographic Assignment of Roles: Roles shall be geographically assigned using a similar expandable/collapsible navigation tree. For example, it shall be possible to assign two HVAC Technicians with similar competencies (and the same operator defined HVAC Role) to different areas of the system.

4.4 GRAPHICAL PROGRAMMING

A. The system software shall include a Graphic Programming Language (GPL) for all DDC control algorithms resident in all control modules. Any system that does not use a drag and drop method of graphical icon programming shall not be accepted. All systems shall use a GPL is a method used to create a sequence of operations by assembling graphic microblocks that represent each of the commands or functions necessary to complete a control sequence. Microblocks represent common logical control devices used in conventional control systems, such as relays, switches, high signal selectors, etc., in addition to the more complex DDC and energy management strategies such as PID loops and optimum start. Each microblock shall be interactive and contain the programming necessary to execute the function of the device it represents.

B. Graphic programming shall be performed while on screen and using a mouse; each microblock shall be selected from a microblock library and assembled with other microblocks necessary to complete the specified sequence. Microblocks are then interconnected on screen using graphic "wires," each forming a logical connection. Once assembled, each logical grouping of microblocks and their interconnecting wires then forms a graphic function block which may be used to control any piece of equipment with a similar point configuration and sequence of operation.

C. Graphic Sequence: The clarity of the graphic sequence must be such that the operator has the ability to verify that system programming meets the specifications, without having to learn or interpret a manufacturer's unique programming language. The graphic programming must be self-documenting and provide the operator with an understandable and exact representation of each sequence of operation.

D. GPL Capabilities: The following is a minimum definition of the capabilities of the Graphic Programming software:
1. Function Block (FB): Shall be a collection of points, microblocks and wires which have been connected together for the specific purpose of controlling a piece of HVAC equipment or a single mechanical system.
2. Logical I/O: Input/Output points shall interface with the control modules in order to read various signals and/or values or to transmit signal or values to controlled devices.
3. Microblocks: Shall be software devices that are represented graphically and may be connected together to perform a specified sequence. A library of microblocks shall be submitted with the Control Contractors bid.
4. Wires: Shall be Graphical elements used to form logical connections between microblocks and between logical I/O.
5. Reference Labels: Labels shall be similar to wires in that they are used to form logical connections between two points. Labels shall form a connection by reference instead of a visual connection, i.e. two points labeled 'A' on a drawing are logically connected even though there is no wire between them.
6. Parameter: A parameter shall be a value that may be tied to the input of a microblock.
7. Properties: Dialog boxes shall appear after a microblock has been inserted which has editable parameters associated with it. Default parameter dialog boxes shall contain various editable and non-editable fields, and shall contain 'push buttons' for the purpose of selecting default parameter settings.

8. Icon: An icon shall be graphic representation of a software program. Each graphic microblock has an icon associated with it that graphically describes its function.
9. Menu-bar Icon: Shall be an icon that is displayed on the menu bar on the GPL screen, which represents its associated graphic microblock.
10. Live Graphical Programs: The Graphic Programming software must support a 'live' mode, where all input/output data, calculated data, and setpoints shall be displayed in a 'live' real-time mode.

E. Graphical Programming Specifies
1. New point's designations to match Beaverton School District standards.
2. Include office HVAC system on new graphics.

PART 5 - SYSTEM SETUP

5.1 RESPONSIBILITIES OF INSTALLER AND PROGRAMMER

A. This section further defines the responsibilities of the installer and programmer.

B. The following features shall be incorporated into the final delivered product.

C. System shall allow up to five (5) different remote (wet base) viewers to access and modify data (level 1 access) at the same time.

5.2 PASSWORDS

A. Provide four password levels:
1. Level 1: Full access to change programming code and all variables.
2. Level 2: Access limited to changing any adjustable parameter (e.g., fan status). Level 2 access shall allow the operator to perform the following commands including, but not limited to:
   a. Start-up or shutdown selected equipment
   b. Adjust setpoints
   c. Add/Modify/Delete time programming
   d. Enable/Disable process execution
   e. Lock/Unlock alarm reporting for each point
   f. Enable/Disable Totalization for each point
   g. Enable/Disable Trending for each point
   h. Enter temporary override schedules
   i. Define Holiday Schedules
   j. Change time/date
   k. Enter/Modify analog alarm limits
   l. Enter/Modify analog warning limits
3. Level 3: Access limited to changing room temperature setpoints and override operation.
4. Level 4: User is only able to view data on screen.

B. Programmer will not provide Owner level 1 high clearance passwords until job has been accepted.

5.3 POINTS

A. All points (DI, DO, AI, and AO) will have unique alphanumeric names and addresses. Installer and programmer will determine: scanning frequency (rate), units, scaling factors, high and low alarm values, alarm differentials, default values, and ranges in coordination with engineer and Owner staff.

B. Provide the following minimum programming for each analog input:
1. Name
2. Address
3. Scanning frequency

4. Engineering units
5. Offset calibration and scaling factor for engineering units
6. High and low alarm values and alarm differentials for return to normal condition
7. High and low value reporting limits (reasonableness values) which shall prevent control logic from using shorted or open circuit values.
8. Default value to be used when the actual measured value is not reporting. This is required only for points that are transferred across the primary and/or secondary networks and used in control programs residing in control units other than the one in which the point resides. Events causing the default value to be used shall include failure of the control unit in which the point resides, or failure of any network over which the point value is transferred.
9. Selectable averaging function which shall average the measured value over a user selected number of scans for reporting.

C. Provide the following minimum programming for each analog output:
1. Name
2. Address
3. Output updating frequency
4. Engineering units
5. Offset calibration and scaling factor for engineering units
6. Output Range
7. Default value to be used when the normal controlling value is not reporting.

D. Provide the following minimum programming for each digital input:
1. Name
2. Address
3. Scanning frequency
4. Engineering units (on/off, open/closed, freeze/normal, etc.)
5. Debounce time delay
6. Message and alarm reporting as specified.
7. Reporting of each change of state and memory storage of the time of the last change of state.
8. Totalization of on time (for all motorized equipment status points), and accumulated number of off-to-on transitions.

E. Provide the following minimum programming for each digital output:
1. Name
2. Address
3. Output updating frequency
4. Engineering units (on/off, open/closed, freeze/normal, etc.)
5. Direct or Reverse action selection
6. Minimum on time
7. Minimum off time
8. Status association with a DI and failure alarming (as applicable)
9. Reporting of each change of state and
10. Reporting of memory storage of the time of the last change of state.
11. Totalization of on time (for all motorized equipment status points), and accumulated number of off-to-on transitions.
12. Default value to be used when the normal controlling value is not reporting.

5.4 ALARM MANAGEMENT

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

B. Point Change Report Description
1. All alarm or point change reports shall include the point's English language description, and the time and date of occurrence.

C. Prioritization
1. The installer shall set up all system analog points with high and low alarm limits. All digital system points shall be associated with a status feedback point and all exceptions shall be reported as alarms. The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized and filtered to minimize nuisance reporting and to speed operator response to critical alarms.
2. The user shall also be able to define under which conditions point changes need to be acknowledged by an operator, and/or sent to follow-up files for retrieval and analysis at a later date.

D. Critical and Non-Critical Alarm Routing
1. Critical alarms shall be defined as major equipment failure such as chiller, boiler, large air-handler, critical space temperature or others requested by the Owner. Critical alarms shall be displayed at the workstation.
2. All other alarms shall be considered non-critical and shall be auto acknowledged and then sent to the alarm log.

E. Report Routing
1. Alarm reports, messages, and files will be directed to a user-defined list of operator devices, or PCs used for archiving alarm information. Alarms shall also be automatically directed to a default device in the event a primary device is found to be off-line.

F. Alarm Messages
1. In addition to the point's descriptor and the time and date, the user shall be able to print, display, or store a 65-character alarm message to more fully describe the alarm condition or direct operator response.
2. Each standalone DDC panel shall be capable of storing a library of at least 250 Alarm Messages. Each message may be assignable to any number of points in the panel.
3. Alarm state for individual points shall be displayed on operator workstations as "NORMAL" or "ALARM".

5.5 DATA TRENDING

A. Data trending will be set for the start-up period and after system acceptance.

B. Date trended during system start-up and before system acceptance shall include all real and virtual data points. Data will be collected and stored every one minute unless otherwise noted on blueprints or in appendices.

C. Establish data trended (every 15 minutes) of the following points after system acceptance:
1. Outside Air Temperature
2. Outside Air Enthalpy
3. Occupancy schedule
4. For each air handler
    a. On/Off status
    b. Damper position (as determined by BAS)
    c. Damper Output Signal
    d. Damper position (as determined from actuator output)
    e. Cooling Setpoint
    f. Heating Setpoint
    g. Discharge Air Temperature for each zone
    h. Discharge Air Temperature setpoint for each zone
    i. Mixed Air Temperature

j. Mixed Air Temperature setpoint
k. Return Air Temperature
l. Return Air Enthalpy
m. Heatering valve
n. DX status or cooling value
o. DX stages if applicable

5. Space Temperatures and temperature setpoints
6. Percent heating and Cooling Load for each zone

D. All data will be saved on the hard drive for at least one year.

5.6 SCHEDULES

A. Schedule will be installed using time parameters provided by Owner or obtained on drawings.

5.7 DYNAMIC ANIMATED COLOR GRAPHIC DISPLAYS

A. Color graphic floor plan display's and system schematic's for each piece of mechanical equipment (including air handling units, variable air volume boxes, fan coils, unit ventilators, cabinet heaters, exhaust fans, fin tube radiation, chilled water systems, hot water boiler systems, and so forth) shall be provided as specified in the point list portion of this Specification. The Controls Contractor shall fully configure the color graphics and plot all associated control/monitoring points on the screen. Samples of all color graphics screens shall be provided to the Owner for approval.

B. System Selection/Penetration
1. The operator interface shall allow users to access the various system schematics and floor plans via a graphical penetration scheme, menu selection, or test-based commands. Floor plans shall display room numbers and each zone shall be color-coded. The operator shall be able to point and click on a room or zone of rooms (in the case of an air handler that serves more than one zone). The room or zone will display an animated flow diagram of the mechanical equipment that serves that zone, with all control and monitoring points associated with that piece of equipment, including setpoints. Operator shall be able to override or modify setpoints from this screen.

C. Dynamic Animated Data Displays
1. Dynamic temperature values, humidity values, flow values, and status indication shall be shown in their actual respective locations, and shall automatically update to represent current conditions without operator intervention. Damper and valve positions, air and water flow shall be animated and shall represent actual, current conditions.

D. System Performance Analysis Screens
1. System performance analysis screens shall be provided for the major mechanical systems (such as air handlers, chillers, boilers, and so forth.). For each of these systems, the screen shall be split into quadrants, simultaneously displaying the following data:
a. Quadrant 1. – Dynamic animated flow diagrams.
b. Quadrant 2. – All analog values associated with the mechanical system shall be graphed on an X-Y axis graph. Five-minute samples for the last twenty-four hour period shall plotted. Scaling shall be automatic.
c. Quadrant 3. – Text sequence of operations from engineering as-built submittals.
d. Quadrant 4. – Space temperature summaries from each zone being served by mechanical system.

E. Windowing
1. The windowing environment of the PC Operator Workstation shall allow the user to simultaneously view several graphics at the same time to analyze total building operation, or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.

F. Alarm Annunciation
1. Any point in a state of alarm shall change the color of its symbol to red until it is no longer in alarm. This alarm shall be carried up each level of graphics to the main screen you see after log in.

G. On each system graphic provide a button to open the associated sequence as a PDF file.

5.8 ON-SCREEN SENSOR RESOLUTION

Sensor Type	Resolution (displayed on screen)
Temperature	0.1°F
Pressure	0.01 inches w.c.
Actuators (damper and valve)	1% of full range
Humidity	0.5% RH
Air Flow	10 CFM
CO_2 sensors	20 PPM
Current Sensor	0.1 kW

5.9 OVERRIDES

A. The DDC system should recognize the override and report to the screen and the printer.

B. The manual overrides for all system shall be in one location as specified by the Engineer.

C. Software shall have adjustable time limits for each override.

D. Provide override switches (see drawings for location of panel for each unit). Each momentary switch with lockout and light (green for “on,” red for “off”) to activate an override of unit(s) as programmed through software. Each override to have adjustable time setting and revert to previous mode of operation at time’s end.

E. Retain existing override switches in boiler room. Each momentary switch with lockout and light (green for “on”, red for “off”) to activate an override of existing unit(s) as programmed through software currently. Each override to have adjustable time setting and revert to previous mode of operation at time’s end. Program overrides to operate new systems placed on the new network. Those on the existing network not being updated to new shall operate per existing sequence.

5.10 SAFETY CIRCUITS

A. All safety circuits shall be hard wired circuits with independent manual reset type switches.

5.11 LABELING AND IDENTIFICATION

A. All devices relating to the work or systems included herein, including controllers, valves, motors, relays, etc., shall be identified with a unique identification number or name on the submitted engineering drawings. This identification number or name, along with the service of the device (discharge air controller, mixed air controller, etc.), shall be permanently affixed to the respective device.

B. All field devices will be supplied with a nameplate indicating its name, number, address, and all other pertinent information.

C. If the field device is too small for the nameplate to be "adhered" to or on another piece of equipment near it (e.g., nameplate on air handling unit at wire penetration for mixed air temperature sensor), then attach the nameplate via nylon ties.

D. Tagging shall be computer generated. For input/output wiring, cabling, or tubing, the panel side of the terminals shall be labeled with the automation panel circuit board and terminal numbers associated with the point. The field side shall be labeled with the point number. Cable, wiring and tubing not specifically associated with an input or output shall be labeled with a number and function.

E. All wiring, tubing, and cabling both inside and outside of control panels shall be labeled at both ends using Thomas and Betts EDP printable wire and cable markers using style WSL self-laminating vinyl. Input and output cables and wiring shall be labeled with the point number and the point description, such as:

CPDPS005
Primary Heating Water
Pump #1 On/Off Status

F. Cable and wiring not specifically associated with an input or output shall be labeled with a number and a function description such as:

120 VAC
Panel #

G. Raceway Identification. All the covers to junction and pull boxes of the control system raceways shall be painted blue, or have identification labels stating "Control System Wiring" affixed to the covers. Labels shall be typed, not hand written.

H. Wire Identification. All low and line voltage control wiring shall be identified by a number, as referenced to the associated control diagram, at each end of the conductor or cable. Identification number shall be typed and permanently secured to the conductor or cable. Wiring to all control devices shall be labeled at each end of the conductor with the point name and description.

I. Beaverton School District - Standard Naming Conventions: HVAC standard system Owner reference is **BSD** (Beaverton School District). Due to the size and complexity of the mechanical systems, controls network definitions may be expanded to represent the educational levels of the facilities. **BSD-ES** will be used for any elementary level facilities. **BSD-MS** will be used for facilities housing 6th, 7th, and 8th grade level facilities that do not serve the lower grades. **BSD-HS** will be the reference used for all facilities serving 9th grade students and beyond. This group will also include any additional ancillary facilities (e.g., Transportation.).

1. Equipment Labels
   a. Control systems or groups shall be named with industry standard labels. Acronyms will be consistent and must match the current BSD control system naming conventions. All control system components will reference the building, equipment association, and unit ID in their descriptor. For example, an air handler labeled "BY-ACU-3" represents Bethany air-conditioning unit number 3. A list of currently used, eight-character building descriptors is available from BSD.
   b. The following is a sample of currently used acronyms in BSD control systems. All new construction must follow a similar industry standard format. The intention of this standard format is that all systems and related equipment are easily identifiable in order to aid in efficient operation and service of the building. All controls systems on retrofit or capital growth and improvement projects must be formatted to match the existing facility systems as reflected on the prints. Numbering of equipment shall logically and sequentially follow the numbering used on existing equipment. The naming conventions used for each Project shall be consistent throughout all documentation, including prints, schedules, and controls.
   c. System groups/Systems:
      1) Air Handling Equipment
         a) AC: Air conditioning unit
         b) ACU: Air conditioning unit

c) AHU: Air handling unit, typically indoor penthouse unit
d) FC: Fan coil unit, split systems
e) HVU (HV): Heating/ventilating unit, without cooling, with return air
f) RTU: Rooftop unit
g) MAU (MU): Make-up air unit, 100% outside air with no return
h) MZU: Multi-zone air handlers

2) VAV System Components
a) NORTH (SOUTH): Building area designator
b) MAIN (LOWER): Building area designator
c) VAV: Variable air volume boxes
d) VT: VVT/variable volume by temperature boxes

3) UNITVENT (U-VENT, UV): Classroom or individual zone unit ventilators

4) ZONE: Zone or channel on time-clock replacements.

5) BOILER: Boiler room equipment, central plant
a) BLR (BR): Boilers, pumps

6) PT: Portables

7) MISC: Miscellaneous group for small systems
a) EDH: Electric duct heaters
b) OVPNL: Override panel
c) OST: Optimal start group/program
d) MISC: Exhaust fans, domestic water pumps, demand meters, Em. Shutdown, lighting relays, security input, (portables), global points, fire input points
e) (ZONE: (Time-clock retrofit zones)

5.12 REPORTS

A. At a minimum, the system shall allow the user to easily print the following types of reports.
1. General listing of all points in the network
2. List of user accounts and access levels
3. List of all points currently in alarm
4. List of all off-line points
5. List of all points currently in override status
6. List of all disabled points
7. List of all points currently locked out
8. List of all Weekly Schedules
9. List of all Holiday Programming
10. List of Limits and Deadbands, throttling ranges, gains, etc.
11. List of all adjustable and virtual points.

5.13 INSTALLATION DETAILS

A. Low Differential Air Pressure Applications (Under 5” w.c.) Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the Balancing Contractor and Owner permanent easy-to-use connection. Provide a minimum of a NEMA 1 housing for the transmitter. Locate transmitters in accessible local control panels wherever possible. Except on VAV box applications.

B. Medium to High Differential Water Pressure Applications (5” to Over 21” w.c.): Mount stand-alone pressure transmitters in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with hi and low connections piped and valved. Air bleed units, bypass valves and compression fittings shall be provided.

C. Building Differential Air Pressure Applications (-1” to +1” w.c.): Mount pressure transmitter in

the local control panel. Transmitters exterior sensing tip shall be installed with a shielded static air probe to reduce pressure fluctuations caused by wind. The interior tip shall be inconspicuous and located within a central corridor shown on the drawings.

D. Outside Air Sensors: Outside air sensors shall be mounted on the North wall to minimize solar radiant heat impact or located in a continuous intake flow adequate to monitor outside air temperatures accurately. Sensors exposed to solar radiation must be installed with solar shields. Sensor's which are exposed to wind velocity pressures shall be shielded by a perforated plate surrounding the sensor element.

E. Duct Temperature Sensors: Duct mount sensors shall mount in an electrical box through a hole in the duct and be positioned to be easily accessible for repair or replacement. The sensors shall be insertion type and constructed as a complete assembly including lock nut and mounting plate. For ductwork greater in any dimension that 48 inches and/or air temperature stratification exists such as a mixed air plenum, utilize an averaging sensor with multiple sensing points. The sensor shall be mounted to suitable supports using factory approved element holders. For large plenum applications such as mixed air temperature measurements, utilize a string of sensors mounted across the plenum to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12 feet long segment.

F. Low Temperature Limit Switches: Mount element horizontally across duct in a serpentine pattern insuring each square foot of coil is protected by 1 foot of sensor. For large duct areas where the sensing element does not provide full coverage of the air stream, provide additional switches as required to provide full protection of the air stream.

PART 6 - SYSTEM COMMISSIONING AND TRAINING

Air and water balancing shall be completed (and discrepancies resolved) before Control Contractor's final system check and before the acceptance test to be conducted in the presence of the Engineer/Commissioning Agent.

6.1 CONTROL TECHNICIAN MEETING REQUIREMENTS

A. During all pre-installation meetings with Owner/Engineers and separate meetings pertaining to the commissioning process, the control technician attending the meetings must be the same technicians that are/will install and program the DDC system.

B. The Control Contractor's installer and programmer must attend all the commissioning meetings. These meetings occur throughout the design and construction process.

C. First Meeting - discuss point naming and sequence of operation with Engineer and Owner

1. Prior to software and database installation and checkout but subsequent to software and database development, the Control Contractor shall meet with the Owner and the Engineer and review the database and program code in detail on a point by point, sequence by sequence basis. The Control Contractor (using blueprints and this specification) shall provide the project point list and sequence of operation to initiate discussion.
2. Any necessary modifications required to make the database and sequence match the intent and requirements of the contract documents shall be identified at this meeting including point names, descriptors, alarm setpoint, numeric setpoint requirements, access requirements, sequence adjustments, etc.
3. Successful completion of this review process will result in software and database approval for installation and start-up. Any software or database that is installed prior to this approval process shall be corrected to match the results of the approval process at no additional cost to the Owner.
4. The results of this meeting shall be documented in meeting minutes taken and issued by the Control Contractor. Documentation can be in the form of marked up data base forms and sequences of operation.

D. Second Meeting - graphic screen development shall be coordinated with the Owner through a series of meetings that will allow the functions described above (sequence of operation, alarms, etc.) and any other Owner's requirements to be incorporated into the graphic screens.

6.2 PRE-COMMISSIONING TESTING, ADJUSTING, AND CALIBRATION REQUIREMENTS

A. Prior to acceptance, the following steps will be used by the Control Contractor to produce a testing and pre-commissioning report by system to be submitted for approval by the Engineer/Commissioning Agent or Owner.

B. Work and/or systems installed under this section shall be fully functioning prior to Demonstration, Acceptance Period and Contract Close Out. Control Contractor shall start, test, adjust, and calibrate all work and/or systems under this contract, as described below:

1. Verify proper electrical voltages and amperages, and verify all circuits are free from grounds or faults.
2. Verify integrity/safety of all electrical connections.
3. Verify proper interface with fire alarm system.
4. Coordinate with TAB Subcontractor to obtain control settings that are determined from balancing procedures. Record the following control settings as obtained from TAB Contractor (and note any TAB deficiencies):
   a. Minimum outside air damper settings for air handling units and CFM values.
5. Test, calibrate, and set all digital and analog sensing, and actuating devices.
   a. Calibrate each instrumentation device by making a comparison between the DDC display and the reading at the device, using a standard traceable to the National Bureau of Standards, which shall be at least twice as accurate as the device to be calibrated (e.g., if field device is +/-0.5% accurate, test equipment shall be +/-0.25% accurate over same range). Record the measured value and displayed value for each device in the Pre-Commissioning Report.
   b. All analog input points are to be tested by comparing the reading obtained through the workstation and through an independent reading device (meter).
   c. Check each analogue output by making a comparison between the control command at the DDC controller and the status of the controlled device. Check each output point by making a comparison of the state of the sensing device and the Host computer display. Record the results for each device in the Pre-Commissioning Report.
      1) All analog output points are to be tested using a command from the workstation modulating the output in 10% increments and recording the associated voltage/amps sent to the controlled device.
6. Check each digital input/output point by making a comparison between the control command at the DDC controller and the status of the controlled device. Check each digital point by making a comparison of the state of the sensing/control device and the Host computer display. Record the results for each device in the Pre-Commissioning Report.
   a. ON/OFF commands from the workstation should be performed in order to verify its true operation.
7. Check and set zero and span adjustments for all actuating devices. Manually activate damper and valve operators to verify free travel and fail condition. Check valve or damper to insure that it shuts off tight when the appropriate signal is applied to the operator. Adjust the operator spring compression as required. If positioner or volume booster is installed on the operator, calibrate per manufacturer's procedure to achieve spring range indicated. Check split range positioner to verify proper operation. Record settings for each device in the Pre-Commissioning Report.
8. Verify proper sequences of operation. Record results and submit with Pre-Commissioning Report. Verify proper sequence and operation of all specified functions by adjusting input variable to determine if sequence of operation is operating as specified.
9. Tune all control loops to obtain the fastest stable response without hunting, offset or overshoot. Record tuning parameters and response test results for each control loop in

the Pre-Commissioning Report. Except from a startup, maximum allowable variance from set point for controlled variables shall be as follows:

a. Air temperature: ± 0.5 degrees F
b. Water temperature: ± 1 degrees F
c. Duct pressure: ± 0.05 inches wc

C. Pre-Commissioning Testing, Adjusting, and Calibration shall be completed prior to Substantial Completion.

D. Provide Pre-Commissioning Test Report for approval by the Engineer/Commissioning Agent or Owner before system demonstration.

6.3 DEMONSTRATION

A. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Control Contractor has completed the installation, started up the system, and performed its own tests (outlined in 6.1 and to be submitted in writing).

B. The tests described in this section are to be performed in addition to the tests that the Control Contractor performs as a necessary part of the installation, startup, and debugging process. The Commissioning Agent/ Engineer will be present to observe and review these tests. The Commissioning Agent/Engineer shall be notified at least 10 days in advance of the start of the testing procedures.

C. Demonstration shall not be scheduled until all hardware and software submittals, and the Pre-Commissioning Test Report are approved by the Commissioning Agent/Engineer.

D. Verifying compliance of equipment operation and sequence of operation with this specification through all modes of operation.

1. If more than 10 percent of the demonstrated equipment operation and sequence of operation fails to operate per the submittals, the demonstration test will be rescheduled after the Control Contractor takes corrective action.
2. If the Control Contractor fails to demonstrate proper equipment operation and sequence of operation in the second round of tests, the Commissioning Agent/Engineer's costs for witnessing all further demonstration may be assigned to the Control Contractor by the Owner as a deduct to their contracted price. Note: The Control Contractor will not be responsible for costs related to poor design or to other factors beyond their control, though it is expected to call any design concerns and other factors beyond their control that might cause system failure to the attention of the Commissioning Agent/ Engineer and the Owner.

E. Programming changes for correction of improperly programmed sequences will not be considered legitimate reasons for change orders.

F. Demonstration/Commissioning Software:

1. Provide fully licensed copy of the required BAS workstation graphic software to be used by the Commissioning Agent/Engineer on a remote computer (not included in contract) for accessing the BAS network via modem. This software copy shall be used only for the purpose of commissioning this project. The Owner agrees that the commissioning BAS software license shall become null and void upon termination of the Contract Warranty Period. The software shall be returned to the Control Contractor within one year after system acceptance.
2. Software shall be fully configured to view project specific database and shall include trend logs, specified graphic screens, alarms, and reports.
3. Provide assistance by telephone upon request if required to assist Commissioning Agent/Engineer in setting up software on Commissioning Agent/Engineer's remote computer.

4. Submit one complete set of programming and operating manuals for all graphics software packages concurrently with the commissioning software. This set will be returned to the Control Contractor within one year after system acceptance.

G. The Control Contractor shall provide at least two persons equipped with two-way communication, and shall demonstrate actual field operation of each controlled and sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. The purpose is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the Control Contractor.

H. As each control input and output is checked, a log shall be completed showing the date, technician's and Commissioning Agent/Engineer's initials, and any corrective action taken or needed.

I. The system shall be demonstrated following the same procedures used in Pre-Commissioning (Section 6.1)

J. Demonstrate that all points specified and shown can be interrogated and/or commanded (as applicable) from all workstations.

K. At a minimum, demonstrate correct calibration of input/output devices using the same methods specified for the pre-commissioning tests. A maximum of [10] percent of I/O points shall be selected at random by Commissioning Agent/Engineer for demonstration. Upon failure of any device to meet the specified accuracy, an additional [10] percent of I/O points shall be selected at random by Commissioning Agent/Engineer for demonstration. This process shall be repeated until 100 percent of randomly selected I/O points have been demonstrated to meet specified accuracy.

L. The Contractor shall demonstrate that the panels' response to LAN communication failures meet the requirements of these Specifications.

M. Demonstrate that required trend graphs and trend logs are set up per the requirements. Provide a sample of the data archive. Indicate the file names and locations.

N. Demonstrate successful communication of point values between the BAS and other HVAC equipment (e.g., chiller).

O. Demonstrate complete operation of Operator Interface such as graphic screens, trend logs, alarms, etc.

P. Additionally, the following items shall be demonstrated:

1. DDC Loop Response. The Control Contractor shall supply trend data output in a graphical form showing the step response of each DDC loop. The test shall show the loop's response to a change in set point that represents a change of actuator position of at least 25% of its full range. The sampling rate of the trend shall be from 1 second to 3 minutes, depending on the speed of the loop. The trend data shall show for each sample the set point, actuator position, and controlled variable values (e.g., VFD frequency or Amperage). Any loop that yields unreasonably under-damped or over-damped control shall require further tuning by the Control Contractor.
2. Optimum Start/Stop. The Control Contractor shall supply a trend data output showing the capability of the algorithm. The 5 minute trends shall include the operating status of all optimally started and stopped equipment, as well as temperature sensor inputs of affected areas.
3. Operational logs for each system that indicate all set points, operating points, valve positions, mode, and equipment status shall be submitted to the Commissioning Agent/Engineer. These logs shall cover three 48-hour periods and have a sample frequency of not more than 10 minutes. The logs shall be provided in both printed and

disk formats.

4. The DDC and HVAC systems will be shut down for 15 minutes and then re-started. Within 15 minutes, the DDC system shall start and obtain stable control of the HVAC systems without safety trips, alarms, or excessive deviations in temperature and pressure (as defined by the Engineer).

Q. System acceptance shall occur within 120 days of substantial completion. Any delay beyond this period of time shall initiate liquidated dampers unless waived by Owner. Failure or delays on Engineers / Owners part shall not be included in 120 day count.

6.4 ACCEPTANCE

A. All tests described in this specification shall have been performed to the satisfaction of both the Commissioning Agent/Engineer and Owner prior to the acceptance of the control system as meeting the requirements of this document.

B. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved.

C. The warranty period starts when the Commissioning Agent/Engineer accepts the system and provides this acceptance in written from the Owner and the Control Contractor.

D. Any tests that cannot be performed due to circumstances beyond the control of the Control Contractor may be exempt from the Completion requirements if stated as such in writing by the Commissioning Agent/Engineer. The Owner shall then perform such tests no later than 3 months after the building is occupied. The costs for these additional tests will be incurred by the Control Contractor.

6.5 SPARE PARTS

A. The Control Contractor shall provide two spare fuses of the correct size and capacity for each fuseholder located in all the installed control systems and the Control Contractor's related equipment.

B. The Control Contractor shall provide two spare pilot lights for each control unit that contains one or more pilot lights.

6.6 TRAINING

A. Training must be on fully operational system, or the training must be repeated when the system is fully operational at no additional cost to the Owner. The Controls Contractor shall provide the following training services:

1. One day of on-site orientation by a field engineer who is fully knowledgeable of the specific installation details of the project as part of the system start-up requirements. This orientation shall, at a minimum, consist of a review of the project as-built drawings, the control system software layout and naming conventions, and a walk through of the facility to identify panel and device locations. This training will include Project Managers, Maintenance, and Custodial personnel.
2. Operator Training: Operator training shall include the detailed review of the control installation drawings, points list, and equipment list. The instructor shall then walk through the building identifying the location of the control devices installed. For each type of systems, the instructor shall demonstrate how the system accomplishes the sequence of operation. This training will include Project Managers, and Maintenance staff.
3. From the workstation, the instructor shall demonstrate the software features of the system. As a minimum, the instructor shall demonstrate and explain logging on, setting passwords, setting up a schedule, trend, point history, alarm, and archiving the database.
4. Maintenance Training: The system maintenance course shall be taught at the project site

within one month after the completion of the operators training. The course shall last for one 8-hour training day. The course shall include answering questions from the last training session, trouble shooting and diagnostics, repair instructions, preventive maintenance procedures and schedules, and calibration procedures.

5. Include this section at Owner's discretion. Modify as appropriate to project size.
   a. Formal Institute Training: This project includes all costs associated with training for _2__ students at the manufacturers formal training institute. The training shall extend for a 40-hour work week and be conducted by professional instructors. The instructors shall submit a report to the supervisor of the attendee on the performance at the training institute. The Owner shall have the right to choose the appropriate course for their employees as long as they meet prerequisite qualifications.

END OF SECTION

SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes the sequence of operations for HVAC control systems specified elsewhere in these specifications.

B. Related Work: The requirements of Section 23 05 00, Common HVAC Materials and Methods, also apply to this section.

C. All work under this section is related to Highland Park Middle School.

PART 2 - PRODUCTS

2.1 NO PRODUCTS LISTED FOR THIS SECTION

PART 3 - EXECUTION

3.1 SEQUENCE OF OPERATIONS

A. Provide a complete and operational temperature control and building automation system based on the following points and sequence of operation, complete as to sequences and standard control practices. The determined point list is the minimum amount of points that are to be provided. Provide any additional points required to meet the sequence of operation.

B. Object List:
1. The following points as defined for each piece of equipment are designated as follows:
   a. Binary Out (BO) - Defined as any two-state output (start/stop) (enable/disable), etc.
   b. Binary In (BI) - Defined as any two-state input (alarm, status), etc.
   c. Analog In (AI) - Defined as any variable input (temperature) (position), etc.
   d. Analog Out (AO) - Defined as any electrical variable output. 0–20mA, 4–20mA, 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.

C. Occupancy and Performance Time Periods:
1. Occupied Period is signaled automatically by adjustable settings at DDC server, Building Controller, Application Controller and also, at each zone when zone bypass timer is activated.
2. Warm-up period occurs one hour before occupied start time or as calculated by Building Controller based on system performance history and outside air temperature.
3. Unoccupied period occurs whenever Occupied, Warm-up, and Cool-down are not in effect.

PART 4 - SEQUENCE OF OPERATION

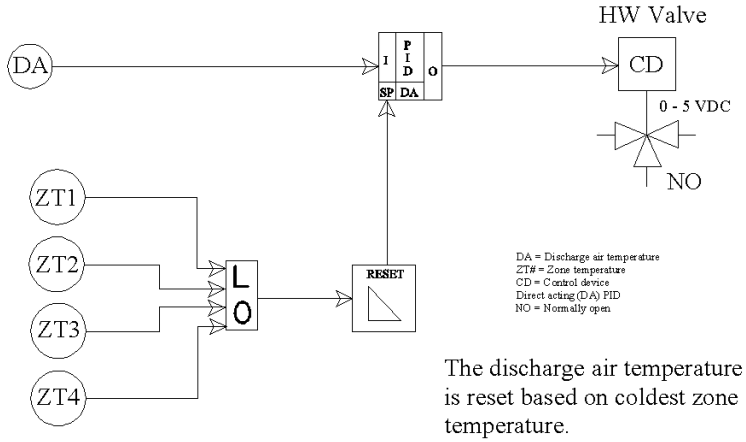
4.1 LEVEL OF DETAIL

A. Major changes in provided sequence of operation must be approved of in writing by the Owner and the Engineer.

B. The Control Contractor shall provide two types of documentation for each system (e.g., boiler plant, VAV system, etc.). The two types of documentation include:
1. Control Logic

a. Control logic shall be a series of statements providing, for each system, the following items:
   1) Identification of control process.
   2) Narrative of control loop or logic algorithm.
   3) Control parameters such as setpoints and differentials (e.g., throttling range, gains) reset schedules, and adjustable parameters for all points.
   4) Identification of all constraints, limits, or interlocks that apply to control loop.
   5) Identification of all DO, DI, AO, AI points that apply to system.
   6) Identification of all communication needs (data points from outside control unit).

2. Logic Diagrams
   a. For each control logic system, a logic diagram shall show the actual interaction of the points (real and virtual) and the logic algorithm.
   b. The diagram should identify
      1) System being controlled (attach abbreviated control logic text).
      2) All DO, DI, AO, AI points.
      3) Virtual points.
      4) All functions (logic, math, and control) within control loop.
      5) Legend for graphical icons or symbols.



4.2 STANDARDIZATION

A. All control loops will be standardized throughout the programming code.

4.3 PROGRAMMING GUIDELINES

A. All adjustable setpoints shall be developed as software points stored at memory locations so that setpoints can be changed by recommending the data stored at the memory location rather than by entering the program and changing parameters and lines in program code.

B. Where reset schedules are specified or required the schedules shall be set up so that the operator enters the following points into memory locations.
   1. Two points for the independent variable on the reset schedule.
   2. Two points for the dependent variable on the reset schedule.

   The computer system shall then use these values as input parameters to the appropriate program or programs and calculate the reset schedule based on these values.

C. Where several analog outputs are to be controlled in sequence by one control loop, software shall be arranged so that the sequence is guaranteed regardless of the spring range of the actuators and

to prevent simultaneous heating and cooling.

D. Programs controlling several pieces of equipment as one system shall reside in one control unit. Where programs use data points that reside in other control units the programs shall employ logic (either in software, firmware, hardware, or a combination of all three) to detect loss of communications with the remote control units containing the required data. When such a failure is detected, the program logic shall revert to a safe operating mode that will allow the controlled systems to remain in operation until normal system communication resumes. A pilot light on the control unit shall be illuminated when such a failure mode exists. In addition, an alarm shall be sent to the HOST computers (alarm level 4). The software shall track this type of alarm and report if communication failure is higher than expected (this condition shall generate an alarm level 3, with descriptive text, at the HOST computer). All safe operating modes shall be approved by the Engineer prior to implementation.

E. Control sequences that use outdoor air conditions to trigger certain specific operating modes shall use data generated by one outdoor air temperature sensor and one outdoor humidity sensor. In other words, the data from one pair of sensors shall be shared by the entire system.

F. All safety circuits shall be hard wired circuits using standard snap acting electric or pneumatic switches as required by the function, and shall be totally independent of the DDC system controllers. This includes interlocks that return dampers and valves to some normal, fail-safe position when the system they are associated with shuts down. It is the intent of this paragraph that the systems have the capability to be operated manually complete with safeties and fail safe interlocks even if the DDC system is off line.

G. Provide hours of operation accumulation and lead/lag sequencing of equipment based on hours of operation for all equipment with proof of operation inputs.

H. Global point name changing:
1. The system shall provide an easy means to allow the operator to change a point name such that the point will automatically be referenced everywhere in the system by the new name.
2. If a point name is removed from the database, any program code where the name appears must show an appropriate error signal for undefined point when the program is viewed, edited, or printed.

I. Synchronization of real-time clocks between all control panels shall be provided.

4.4 GENERAL SEQUENCE OF OPERATION GUIDELINES

A. Control of all central fan systems, boilers, DX units, heaters, and pumping stations shall be based on run requests, heating requests or cooling requests from zone controls.

B. Reset of supply air temperature and hot water temperature shall be based on zone temperature conditions via the zone's percentage of heating or cooling load.

C. Unless otherwise indicated, all control loops will use PID loops. The coefficient for the derivative component is zero (0) unless otherwise indicated.

D. All HVAC system controls shall be designed such that simultaneous heating and cooling, reheating, and re-cooling are minimized. This applies as well to non-mechanical treatment of mixed air (e.g. outside air, heat recovery, etc.) which must then be mechanically reheated or re-cooled.

E. Alarms: Except as directed otherwise by the Owner, all alarms will be registered at the building operator's terminal as well as at the Maintenance Building remote operator's station. Alarms are to be registered with a message explaining the nature of the alarm and which building/location the alarm is in.

F. 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 Maintenance Building remote operator's station, and is not to require any code modification. This may require assigning virtual points to all adjustable setpoints. Frequently adjusted points, including space temperature setpoints, shall be adjustable from the graphics screen (e.g., floor plan screen).

G. There are many interlocks and limits within each control loop or algorithm that may not be obvious or stated in this specification. The Control Contractor is responsible for identifying and programming these interlocks and limits into the software. The CO_2 Demand Ventilation Control algorithm is a good example of the complexity of the control loop with interlocks and limits.

H. The Control Contractor will replace any and all equipment (actuators, chillers, etc) that fail due to programming errors. Such errors include, but are not limited to: moving actuators a couple fractions of a degree every second or so in response to some infinitesimal change in a measured variable or repeatedly turning equipment on/off within a short time period. The Control Contractor will avoid these problems by incorporating time delays, dead bands, and other programming techniques into the sequence of operation.

I. Programmable time-of-day (start/stop) control shall be implemented for all HVAC equipment, except for:
   1. Equipment that is interlocked with other equipment under direct start/stop control (e.g. exhaust fans interlocked with an air handling unit).
   2. Equipment that must run continuously for reasons of safety.
   3. As otherwise noted in these standards.

J. Auto-tuning algorithms will not be used to initially tune control loops.

4.5 SEQUENCE OF OPERATION GUIDELINES

A. This specification is intended to refine or elaborate on the sequence of operations provided by the Engineer. Note: there are many issues that may make any of these standard sequences inapplicable to a specific situation: thus, the Control Contractor should obtain written approval by the Engineer to implement the sequence of operations contained in this specification.

B. The Control Contractor shall adhere to all applicable specifications, unless they submit written exceptions to the Owner and Engineer and such exceptions are approved in writing. Written exceptions shall state the specification's sequence of operations, the Control Contractor's proposed sequence of operations, and the reasons why the proposed sequence specifications are preferable to the sequences in this specification or those provided by the Engineer.

C. It is the Control Contractor's responsibility to improve upon these specified sequences of operations if necessary. All improvements will be provided in writing to the Engineer for his/her written approval.

D. The Control Contractor is responsible for accurately controlling and communicating with all packaged fan units or air handling units.

4.6 SEQUENCE OF OPERATION – SCHEDULING

A. The system will have the three (3) schedules that will be utilized based on the type of event selected by the building operator. The operator will be able to select the desired schedule to be actively used and select the equipment group to be associated with each schedule (equipment selection is user adjustable).

B. Occupancy Override: The building operator shall be able to initiate occupancy (occupied operation) from the building operator's workstation (overriding any non-occupied sequences) for each individual air handling system. Override will last for eight (8) hours (adjustable) and then

revert back to the current operating mode. Operator will be able to release override at any time during the override period.

4.7 SEQUENCE OF OPERATION FOR VAV AIR HANDLERS (ACU-1A, ACU-1B & ACU-3A)

A. Supply Fan Control:
1. This section applies to supply fans that are modulated by variable frequency drives (VFDs).
2. Static Pressure Control:
   a. Supply fan volume is controlled to maintain the duct static pressure at setpoint as sensed at remote static pressure sensor.
   b. Ensure that the static pressure signal is communicated quickly to the control loop (and not delayed due to network timing) and that a default value is set in the event of a network failure.
   c. Control duct pressure at AHU:
      1) Initiate start fan command before signal sent to VFD
      2) Run timer should limit initial start up to 50% full power (ramp up without overshooting)
      3) Ramp-up and ramp-down incremental changes shall be equal.
      4) Use P or PI loop to control fans speed based on static pressure setpoint.
   d. Pressure Reset Control: On any (2) (adjustable) VAV box dampers at 100% (adj.) open reset discharge static pressure up by 0.010" (adj.) WC every 5 minutes. On all VAV dampers at 95% (adj.) open or less reset discharge pressure down by 0.05" (adj.) WC every 5 minutes.
3. Variable speed drive acceleration settings, deceleration settings, minimum speeds, etc. shall be adjusted at start up in coordination with the drive supplier and installer to achieve stable control system performance.
4. Fan speed is reset to 0 (zero) Hz when the AHU is off.
5. Coordinate signal from fire alarm panel to duct mounted smoke detector. One signal to detector disables fan (Hz = 0), waits 15 seconds (adjustable), and starts smoke damper closing.
6. Duct High Pressure Shutdown: When the duct pressure exceeds the high limit set point (4" in H2O, adjustable at the device) the fan will shut down for three (3) minutes (adjustable) and then attempt to restart. If three (3) restart attempts occur over a period of 15 minutes (adjustable), the system shall be disabled (software). Lockout reset will occur at the operator's workstation.

B. Return Fan Control:
1. This section applies to return fans with variable frequency drives (VFDs).
2. Fan will start/stop when supply fan starts.
3. Space pressure Control, Return Fan Speed Endpoints: The return fan shall modulate based on supply fan speed and outside air damper position. The air balancing Contractor will attain the return fan speed based on the following values for the given operating mode.

Return Fan Speed Endpoint Values				
Mode	**Supply Fan Speed Hi/Lo Reset Limits**	**Desired Space Pressure (InH2O)**	**Economizer Position**	**Return Fan Speed**
Full Heating (All terminal units are operating at heating flow setpoints)	TBD – Noted during the full heating condition	**Ideal - 0.02** Acceptable Test Range: 0.01 – 0.03	Min-Min (25% of the minimum ventilation requirement)	Minimum Return Fan Speed-TBD
Full Cooling (All terminal units are operating at cooling flow setpoints)	TBD – Noted during the full cooling condition	**Ideal - 0.02** Acceptable Test Range: 0.01 – 0.03	Min-Max (100% of the minimum ventilation requirement)	Maximum Return Fan Speed-TBD

4. Space Pressure Return Fan Speed Reset: During Occupied mode the return fan speed shall reset based on the following schedule.

Return Fan Speed Reset Schedule	
Supply Fan Speed	**Return Fan Speed**
Supply Fan Speed Lo Reset Limit-TBD	Minimum Return Fan Speed-TBD
Supply Fan Speed Hi Reset Limit-TBD	Maximum Return Fan Speed-TBD

5. During warm-up and night low limit, operate the unit in 100% recirculation mode.
6. Fan speed is reset to zero (0) Hz when the AHU is off.
7. Variable speed drive acceleration settings, deceleration settings, minimum speeds, etc. shall be adjusted at start up in coordination with the drive supplier and installer to achieve stable control system performance.
8. Provide separate sequences to be enable if directed by Engineer to control fan based on a set difference in fan speed between supply air and return air, using this method rather than space pressure control.

C. Discharge Air Temperature Reset:
1. Occupied Mode: The discharge air setpoint will reset based on the maximum cooling demand from the spaces. When the maximum cooling demand of any two (2) (adjustable) terminal units is greater than 95%, the discharge air setpoint shall reset down by 0.5 °F (adjustable) every five (5) minutes (adjustable). When the maximum cooling demand is less than 90%, reset discharge air setpoint up by 0.5 °F (adjustable) every five (5) minutes (adjustable). Minimum and maximum discharge air set points are 55 °F (adjustable) and 65 °F (adjustable) respectively. Initial discharge air temperature setpoint when transitioning into an occupied mode is based on the following schedule.

Initial Discharge Air Setpoint	
Maximum Terminal Unit Cooling Demand	**Discharge Air Temperature Setpoint**
0	65
100	55

2. The following discharge air setpoints are applicable for all other modes:

Discharge Air Setpoints, Non-Occupied Modes	
Mode	**Discharge Air Temperature Setpoint (Adjustable)**
Night High Limit	50
Nigh Low Limit	85
Cooling Optimal Start	50
Heating Optimal Start	85
Night Purge	50

D. Fan Enable / Optimal Start Control or Warm-Up Mode:
   1. All fan systems with heating capability (in AHU and/or at terminal units) shall have this sequence.
   2. The intent of this sequence is that the air handling system be started early enough so that the maximum negative deviation of space temperature from the occupied heating set point (for all within the system) is less than 0.5 °F no more than 20 minutes prior to or 10 minutes after scheduled occupancy. Spaces should not be heated up above occupied heating space temperature set points.
   3. Air handling systems may be started under the optimal start mode no more than 3 hours (adjustable) prior to scheduled occupancy.
   4. This optimal start sequence will be locked out when the 3 hour rolling average outdoor air temperature is greater than setpoint (initial setpoint, 55°F, adjustable). If locked out, the AHU will start 10 minutes (adjustable, maximum of 30 minutes) before occupied time period.
   5. Air handling systems will be started as a function of:
      a. Outdoor air temperature
      b. Space temperature
      c. Time until start of scheduled occupancy
      d. Historical time period required to reach setpoint as a function of a, b, and c above.
   6. Discharge air temperature setpoint will be set to the maximum optimal start temperature setpoint (85°F, adjustable) during this mode.
   7. When the system is in heating optimal start mode, the mixed air dampers will be in full recirculation mode (i.e., outside air dampers are fully closed and the supply air volume will be limited to the return volume).
   8. Unit is operating at full cooling air flow rate.
   9. Exhaust fans are off and exhaust dampers are closed.
   10. Mechanical cooling is disabled.
   11. The building operator will be able to command start of occupancy at the operator's terminal and at the Maintenance Building remote operator's station (overriding the optimal start sequence) for each individual air handling system and globally for all air handling systems in the building.

E. Fan Enable / Optimal Start Control (Cooling Mode) – Cool Down:
   1. All air handling systems with cooling capability shall have this sequence.
   2. The intent of this sequence is that the air handling system be started early enough so that the maximum positive deviation from the space temperature to the occupied cooling set point (for all zones in the system) is less than 0.5 °F no more than 20 minutes prior to or 10 minutes after scheduled occupancy. Spaces should not be cooled down below occupied cooling space temperature set points.
   3. Air handling systems may be started under the optimal start mode no more than 3 hours (adjustable) prior to scheduled occupancy.
   4. This optimal start sequence should be locked out when the 3 hour rolling average outdoor air temperature during the scheduled unoccupied mode is less than setpoint (initial setpoint, 50°F, adjustable). If locked out, the AHU will start 10 minutes (adjustable, maximum of 30 minutes) before the occupied time period.
   5. Air handling systems will be started as a function of:
      a. Outdoor air temperature
      b. Space temperature
      c. Time until start of scheduled occupancy
      d. Historical time period required to reach setpoint as a function of a, b, and c above.
   6. Discharge air temperature setpoint will be set to the minimum temperature setpoint during this mode.
   7. Mechanical cooling is disabled unless spaces have not achieved cool down setpoint (adjustable) 30 minutes (adjustable) before the occupancy period. Mechanical cooling will utilize economizer mode if outside air temperature is less than return air temperature.
   8. Exhaust fans are on and exhaust dampers are open (unless limited by mixed air setpoint

control due to outside air damper interlock).

9. Heating is disabled.
10. The building operator will be able to command start of occupancy for each individual air handling system and globally for all air handling systems in the building.

F. Cooling Operation:
1. Cooling coil shall modulate in sequence with economizer dampers to maintain discharge air temperature setpoint. Discharge air control is applicable whenever mechanical cooling is required.
2. Mechanical cooling shall remain off during warm-up and night low limit.

G. Heating Mode:
1. Discharge air control is applicable whenever mechanical heating is required. During occupied mode, mechanical heating is permitted when the economizer has maintained the minimum outside air position for a minimum of 5 minutes (adjustable) when ventilation demand sequences are inactive or when ventilation demand sequences are active and the discharge air temperature is more than 3°F below the setpoint for more than 5 minutes (adjustable).
2. Mechanical heating permitted only during occupied, night low limit and heating optimal start modes.
3. When mechanical heating is enabled hot water heating valve shall modulate to maintain discharge air temperature setpoint.

H. Night Low Limit Mode:
1. Night low limit mode is initiated during unoccupied times (mode), when any two (2, adjustable) terminal unit space temperature(s) falls below the unoccupied heating setpoint.
2. When all spaces served by the system are above the unoccupied heating setpoint plus the dead band setpoint (initial 5°F, adjustable), the system will revert to the unoccupied mode.
3. If the minimum hourly outside air temperature is less than 20°F (adjustable) in Western Oregon for the previous 12 (adjustable) consecutive hours, then the AHU will remain in operation during the unoccupied period. The system will maintain a setpoint temperature 10°F (adjustable) less than occupied setpoint. All outside air dampers will remain closed during the unoccupied period.

I. Night High Limit Mode:
1. Night high limit mode is initiated during unoccupied times (mode), when any two (2, adjustable) terminal unit space temperature(s) rises above the unoccupied cooling setpoint and the outside air temperature is 10°F (adjustable) less than the average space temperature.
2. When all spaces served by the system are below the unoccupied heating setpoint minus the dead band setpoint (initial 5°F, adjustable), the system will revert to the unoccupied mode.

J. Night Purge Mode:
1. This sequence is initiated before occupancy during the cooling season.
2. Night purge will be enabled when the following conditions are true:
   a. The average space temperature is above 80º F (adjustable).
   b. Outside air temperature is greater than setpoint (initial setpoint, 45°F, adjustable).
   c. Outside air relative humidity is less than 50%.
   d. Outside air temperature is at least 10°F (adjustable) less than the average space temperature
   e. Occupancy period occurs within 3 hours (adjustable).
3. Night purge will be disabled when average space temperature is within 3°F (adjustable) of the outside air temperature or the average space temperature has reach the occupied heating set point.

K. Economizer Damper Control:
1. Occupied Mode: Economizer dampers (Outside Air, Return Air and Relief Air) modulate to maintain supply air temperature set point and air quality setpoint.
2. Economizer shall operate as first stage of cooling. If discharge set-point is not satisfied for 5 minutes (above set-point) enable cooling.
3. Unoccupied, Night Low Limit, Optimal Start and Low Limit Freeze Conditions: Dampers to modulate to full recirculation (0% Outside Air).
4. Night High Limit and Night Purge: Dampers to modulate to full ventilation (100% Outside Air).
5. The outside air economizer is enabled when the outside air enthalpy is less than the return air enthalpy.
6. The outside air economizer is disabled when the outside air enthalpy is greater than the return enthalpy for greater than 2 minutes. When the economizer is disabled, the outside air damper modulates to the minimum position setpoint based on the air quality sensor.
7. Demand Ventilation Control (DVC): During occupied mode the outside air dampers shall modulate to maintain return air CO2 levels at or below 900 PPM (adj.). DVC shall occur when levels begin to exceed the CO2 set point plus a dead-band of 100 PPM (adj.).
8. Economizer Minimum Position (Air Quality Control): Economizer minimum-minimum (min-min) position value is based on 25% of the minimum ventilation requirement unless otherwise noted. The economizer minimum-maximum (min-max) position is based on the full minimum ventilation requirement. During DVC sequences, outside air damper position (outside airflow) is limited to the min-max setting. Balancer to determine actual damper positions at the min-min and min-max airflow setpoints. Control system shall use damper position setpoints for control purposes. Based on 900 PPM with dead-band of 100 the OSA damper will modulate up to min-max position on CO2 levels above 1000 PPM and will modulate to min-min once CO2 level is below 800 PPM.
9. CO2 sensor fail:
    a. lf the CO2 goes below 200 PPM or above 1600 PPM and remains at that level for 30 min (adj), the sensor is assumed to have failed and the CO2 control will be disabled and an alarm generated.
        1) A faulted sensor will revert to a fixed min OAD setpoint adjustable from the graphics.
    b. There will be a manual reset on graphics after CO2 controls are repaired.
10. The airside economizer control shall include fault detection and diagnostics as required by ASHRAE 90.1-2016. See ASHRAE requirements for full description of sensor, monitoring and alarm requirements which are available normally due to the DDC system. Specific requirements not normally provided are listed below and required.
    a. The system shall display the status of:
        1) Free cooling available
        2) Economizer enabled
        3) Cooling enabled
        4) Heating Enabled
        5) Mixed air low limit cycle active
    b. The system shall be capable of detecting and reporting the following faults
        1) Air temperature sensor failure or fault
        2) Economizing when unit should not be economizing
        3) Not economizing when the unit should be economizing
        4) Damper not modulating
        5) Excess outside air

4.8 SEQUENCE OF OPERATION – TERMINAL UNIT CONTROL

A. Space Temperature Setpoints:
1. Default Setpoints:
    a. Occupied Heating Setpoint: 70 °F (adjustable)
    b. Occupied Cooling Setpoint: 76 °F (adjustable)
    c. Unoccupied Heating Setpoint: 55 °F (adjustable)

d. Unoccupied Cooling Setpoint: 85 °F (adjustable)

2. Space Setpoint Adjustment:
   a. Adjustment (General): Setpoint adjustments may be accomplished either at the operator workstation or locally at the thermostat.
   b. Adjustment Range: Setpoint adjustments are limited to (+/-) 2°F (adjustable). Space temperature dead band (4 °F, adjustable) is maintained during setpoint adjustments.
3. Damper Operation:
   a. Occupied Mode: Air flow setpoint will linearly reset based on terminal unit cooling demand as shown in the schedule below.

Air Flow Setpoint-Occupied Mode	
Terminal Unit Cooling Demand (%)	**Air Flow Setpoint (CFM)**
0-100 (space temperature is within standby setpoints)	Cooling Flow Setpoint X 0.20
0 (space temperatures are outside of the standby range)	Heating Flow Setpoint
100 (space temperatures are outside of the standby range)	Cooling Flow Setpoint

   b. Optimal Start Mode: Air flow setpoint will reset based on the schedule below. Implement dead band to prevent oscillation between cooling and heating flow setpoints.

Air Flow Setpoint – Heating Optimal Start	
Space Temperature > Occupied Heating Set Point	**Air Flow Set Point**
No	Cooling Flow Setpoint X 1.25, (Multiplier is adjustable from GUI)
Yes	Heating Flow Setpoint X 0.1, (Multiplier is adjustable from GUI)

Air Flow Setpoint – Cooling Optimal Start	
Space Temperature < Occupied Cooling Set Point	**Air Flow Set Point**
No	Cooling Flow Setpoint X 1.25, (Multiplier is adjustable from GUI)
Yes	Heating Flow Setpoint X 0.1, (Multiplier is adjustable from GUI)

   c. Night High Limit, Night Purge Mode: Cooling flow setpoint shall be used during this mode. Units that did not initiate the control mode and have space temperatures above the occupied cooling setpoint shall also control to their respective cooling flow set point until the mode is canceled or the space temperature has reached the occupied cooling setpoint. Implement 1°F space temperature dead band to prevent damper oscillations.
   d. Night Low Limit Mode: Cooling flow setpoint shall be used during this mode. Units that did not initiate the control mode and have space temperatures below

the occupied heating setpoint shall also control to their respective cooling flow set point until the mode is canceled or the space temperature has reached the occupied heating setpoint. Implement 1°F space temperature dead band shall be used to prevent damper oscillations.

e. Unoccupied Mode: Damper modulates fully closed. Flow setpoint is 0 CFM.

4. Heating Valve Operation:

a. Occupied Mode: Valve will modulate based on heating demand to maintain occupied heating setpoint.

b. Optimal Start Mode: Heating Valve will modulate based on the schedule below. Implement 1°F space dead band to prevent valve oscillation.

Valve Position - Optimal Start	
Space Temperature > Occupied Heating Set Point	**Valve Position**
No	100% (Subject to discharge air temperature limiting)
Yes	0%

c. Unoccupied Mode, Night High Limit, Night Purge Mode: Valve is closed.

d. Night Low Limit Mode: Valve modulates fully open (Subject to discharge air temperature limiting). Units that did not initiate the control mode and have space temperatures below the occupied heating setpoint shall also modulate valves fully open until the mode is canceled or the space temperature has reached the occupied heating setpoint. Implement 1°F space temperature dead band to prevent valve oscillations.

B. Discharge Air Temperature Limiting (All Modes):

1. Discharge temperature maximum is 110º F.

C. Space CO_2 Sensor:

1. On Signal that space CO_2 values exceed set-point (1000 ppm adj.) modulate air flow damper from heating air flow to cooling air flow regardless of space demand. Disable dead band operation. Once space is below lower level set-point (800 ppm) return to normal mode. If after 30 min. (adj.) CO_2 level is not below lower level send signal to air handler.

4.9 SEQUENCE OF OPERATION – SINGLE ZONE VARIABLE AIR VOLUME (ACU-2, & HVU-1)

A. Supply Fan Control:

1. This section applies to supply fans that are modulated by variable frequency drives (VFDs) or EC motors.

2. Demand Based Control: Supply fan volume is controlled based on the space temperature deviation from the occupied heating and cooling space temperature set points as indicated in the schedule below. Fan speed shall linearly reset between setpoints.

Supply Fan Speed – Demand Based Control		
Cooling Deviation Temperature (Space Temperature – Occupied Cooling Setpoint)	**Heating Deviation Temperature** (Space Temperature – Occupied Heating Setpoint)	**Fan Speed**
<= (-0.5) °F (adjustable)	NA	Minimum Speed (50%, adjustable)

>= 2 °F (adjustable)	NA	Maximum Speed (100%, adjustable)
NA	>= 0.5 °F (adjustable)	Minimum Speed (50%, adjustable)
NA	<= (-2) °F (adjustable)	Maximum Speed (100%, adjustable)
Operating Non-Occupied Modes		Maximum Speed (100%, adjustable)

3. Variable speed drive acceleration settings, deceleration settings, minimum speeds, etc. shall be adjusted at start up in coordination with the drive supplier and installer to achieve stable control system performance.
4. Fan speed is reset to 0 (zero) when the AHU is off.
5. Coordinate signal from fire alarm panel to duct mounted smoke detector. One signal to detector disables fan (speed = 0), waits 15 seconds (adjustable), and starts smoke damper closing.

B. HVU-1, Return fan does not exist. Operate space mounted relief dampers based on a percentage of the OSA damper. Provide an offset to allow space pressurization of approximately 0.02" WC positive.

C. Fan Enable / Optimal Start Control or Warm-Up Mode:
1. All fan systems with heating capability (in AHU and/or at terminal units) shall have this sequence.
2. The intent of this sequence is that the air handling system be started early enough so that the maximum negative deviation of space temperature from the occupied heating set point (for all within the system) is less than 0.5 °F no more than 20 minutes prior to or 10 minutes after scheduled occupancy. Spaces should not be heated up above occupied heating space temperature set points.
3. Air handling systems may be started under the optimal start mode no more than 3 hours (adjustable) prior to scheduled occupancy.
4. This optimal start sequence will be locked out when the 3 hour rolling average outdoor air temperature is greater than setpoint (initial setpoint, 55°F, adjustable). If locked out, the AHU will start 10 minutes (adjustable, maximum of 30 minutes) before occupied time period.
5. Air handling systems will be started as a function of:
   a. Outdoor air temperature
   b. Space temperature
   c. Time until start of scheduled occupancy
   d. Historical time period required to reach setpoint as a function of a, b, and c above.
6. Discharge air temperature setpoint will be set to the maximum optimal start temperature setpoint (110°F, adjustable) during this mode.
7. When the system is in heating optimal start mode, the mixed air dampers will be in full recirculation mode (i.e., outside air dampers are fully closed and the supply air volume will be limited to the return volume).
8. Exhaust fans are off and exhaust dampers are closed.
9. Mechanical cooling is disabled.
10. The building operator will be able to command start of occupancy at the operator's terminal and at the Maintenance Building remote operator's station (overriding the optimal start sequence) for each individual air handling system and globally for all air handling systems in the building.

D. Heating Valve Control:
1. Occupied, Occupied Purge Mode: Heating valve to modulate to maintain space temperature heating setpoint subject to discharge air temperature limiting.
2. Night Low Limit, Optimal Start and Low Limit Freeze Conditions: Heating valve shall

modulate fully open.

3. Unoccupied and Night High Limit Mode: Heating valve to modulate fully closed.
4. Night Purge Mode: When night purge mode has been imitated, the heating valve shall not be enabled to operate for a minimum of 4 hours (adjustable) from the occupied time. If the space temperature is 2ºF less than the occupied heating set point during the lockout time, heating valve modulated is allowed.
5. Heating Valve Lockout: Heating valve shall not modulate when the outside air temperature is above 65ºF (Adjustable).
6. Considerations: Modulating the heating valve simultaneously with cooling valve and economizer operation is not permitted except during demand ventilation control. Oscillation between heating valve, cooling valve and economizer operation is also not permitted.

E. Cooling Operation: ACU-2 DX Cooling
1. Cooling section shall modulate in sequence with economizer dampers to maintain space temperature setpoint.
2. Mechanical cooling shall remain off during warm-up and night low limit.

F. Night Low Limit Mode:
1. Night low limit mode is initiated during unoccupied times (mode), when any terminal unit space temperature(s) falls below the unoccupied heating setpoint.
2. The night low flag will start boiler sequence.
3. The fan will delay starting until there is sufficient heat to run the unit without tripping a safety to lockout.
4. The NLL valve position will be 100 percent.
5. The unit will operate until the Unoccupied heating SP is reached plus a 3˚deadband is reached. The fan will have a 10 minute (Adj) off delay.
6. Sufficient heat for hot water systems: Sufficient heat will be met when HWST is 10 deg less than the active HWST set point reset.

G. Night High Limit Mode:
1. Night high limit mode is initiated during unoccupied times (mode), when the space temperature(s) rises above the unoccupied cooling setpoint and the outside air temperature is 10°F (adjustable) less than the average space temperature.
2. When all spaces served by the system are below the unoccupied heating setpoint minus the dead band setpoint (initial 5°F, adjustable), the system will revert to the unoccupied mode.

H. Night Purge Mode:
1. This sequence is initiated before occupancy during the cooling season.
2. Night purge will be enabled when the following conditions are true:
   a. The space temperature is above 80º F (adjustable).
   b. Outside air temperature is greater than setpoint (initial setpoint, 45°F, adjustable).
   c. Outside air relative humidity is less than 50%.
   d. Outside air temperature is at least 10°F (adjustable) less than the average space temperature.
   e. Occupancy period occurs within 3 hours (adjustable).
3. Night purge will be disabled when average space temperature is within 3°F (adjustable) of the outside air temperature or the average space temperature has reach the occupied heating set point.

I. Economizer Damper Control:
1. Occupied Mode: Economizer dampers (Outside Air, Return Air and Relief Air) modulate to maintain supply air temperature set point and air quality setpoint.
2. Unoccupied, Night Low Limit, Optimal Start and Low Limit Freeze Conditions: Dampers to modulate to full recirculation (0% Outside Air).

3. Night High Limit and Night Purge: Dampers to modulate to full ventilation (100% Outside Air).
4. The outside air damper will be at minimum position during occupied mode unless another sequence (economizer cooling, CO2 control, or any safeties) require a different position.
5. The economizer cooling function will be enabled when the OSA is 3˚F (adj) less than return air temp and disabled when OSA equals RAT. lf there is no return air temperature sensor available, space temp will be used for comparison.
6. CO2 Control:
   a. The CO2 control will keep dampers at min-max position unless there is a call for economizer cooling. Dampers will remain in that position until the CO2 concentration reaches and remains above 900 PPM (adj) for 10 minutes. Then the damper will go to min-max set point. This setpoint is determined by balancer.
   b. The CO2 control will enable at 900 PPM (adj.) plus a deadband of 100 PPM (adj). When CO2 levels return to 900 PPM minus the dead-band the control will disable and release damper to min-min position.
   c. lf the CO2 goes below 200 PPM or above 1600 PPM and remains at that level for 30 min (adj), the sensor is assumed to have failed and the CO2 control will be disabled and an alarm generated. A faulted sensor will revert to a fixed min OAD setpoint adjustable from the graphics.
   d. There will be a manual reset on graphics after CO2 controls are repaired.
7. The airside economizer control shall include fault detection and diagnostics as required by ASHRAE 90.1-2016. See ASHRAE requirements for full description of sensor, monitoring and alarm requirements which are available normally due to the DDC system. Specific requirements not normally provided are listed below and required.
   a. The system shall display the status of:
      1) Free cooling available
      2) Economizer enabled
      3) Cooling enabled
      4) Heating Enabled
      5) Mixed air low limit cycle active
   b. The system shall be capable of detecting and reporting the following faults
      1) Air temperature sensor failure or fault
      2) Economizing when unit should not be economizing
      3) Not economizing when the unit should be economizing
      4) Damper not modulating
      5) Excess outside air

4.10 SEQUENCE OF OPERATION FOR SINGLE ZONE CONSTANT VOLUME AIR HANDLERS (HVU-2, HVU-3)

A. Supply Fan Control:
   1. Operation is subject to schedule and fire smoke detector (if applicable).

B. Temperature Control:
   1. Modulate heating or cooling coil valve based on space temperature. Economizer is the first stage of cooling.

C. Fan Enable / Optimal Start Control or Warm-Up Mode:
   1. All fan systems with heating capability (in AHU and/or at terminal units) shall have this sequence.
   2. The intent of this sequence is that the air handling system be started early enough so that the maximum negative deviation of space temperature from the occupied heating set point (for all within the system) is less than 0.5 °F no more than 20 minutes prior to or 10 minutes after scheduled occupancy. Spaces should not be heated up above occupied heating space temperature set points.
   3. Air handling systems may be started under the optimal start mode no more than 3 hours

(adjustable) prior to scheduled occupancy.

4. This optimal start sequence will be locked out when the 3 hour rolling average outdoor air temperature is greater than setpoint (initial setpoint, 55°F, adjustable). If locked out, the AHU will start 10 minutes (adjustable, maximum of 30 minutes) before occupied time period.
5. Air handling systems will be started as a function of:
   a. Outdoor air temperature
   b. Space temperature
   c. Time until start of scheduled occupancy
   d. Historical time period required to reach setpoint as a function of a, b, and c above.
6. Discharge air temperature setpoint will be set to the maximum optimal start temperature setpoint (85°F, adjustable) during this mode.
7. When the system is in heating optimal start mode, the mixed air dampers will be in full recirculation mode (i.e., outside air dampers are fully closed and the supply air volume will be limited to the return volume).
8. Unit is operating at full cooling air flow rate.
9. Exhaust fans are off and exhaust dampers are closed.
10. Mechanical cooling is disabled.
11. The building operator will be able to command start of occupancy at the operator's terminal and at the Maintenance Building remote operator's station (overriding the optimal start sequence) for each individual air handling system and globally for all air handling systems in the building.

D. Fan Enable / Optimal Start Control (Cooling Mode) – Cool Down:

1. All air handling systems with cooling capability shall have this sequence.
2. The intent of this sequence is that the air handling system be started early enough so that the maximum positive deviation from the space temperature to the occupied cooling set point (for all zones in the system) is less than 0.5 °F no more than 20 minutes prior to or 10 minutes after scheduled occupancy. Spaces should not be cooled down below occupied cooling space temperature set points.
3. Air handling systems may be started under the optimal start mode no more than 3 hours (adjustable) prior to scheduled occupancy.
4. This optimal start sequence should be locked out when the 3 hour rolling average outdoor air temperature during the scheduled unoccupied mode is less than setpoint (initial setpoint, 50°F, adjustable). If locked out, the AHU will start 10 minutes (adjustable, maximum of 30 minutes) before the occupied time period.
5. Air handling systems will be started as a function of:
   a. Outdoor air temperature
   b. Space temperature
   c. Time until start of scheduled occupancy
   d. Historical time period required to reach setpoint as a function of a, b, and c above.
6. Discharge air temperature setpoint will be set to the minimum temperature setpoint during this mode.
7. Mechanical cooling is disabled unless spaces have not achieved cool down setpoint (adjustable) 30 minutes (adjustable) before the occupancy period. Mechanical cooling will utilize economizer mode if outside air temperature is less than return air temperature.
8. Exhaust fans are on and exhaust dampers are open (unless limited by mixed air setpoint control due to outside air damper interlock).
9. Heating is disabled.
10. The building operator will be able to command start of occupancy for each individual air handling system and globally for all air handling systems in the building.

E. Heating Mode:

1. During occupied mode, mechanical heating is permitted when the economizer has maintained the minimum outside air position for a minimum of 5 minutes (adjustable) when ventilation demand sequences are inactive or when ventilation demand sequences

are active and the discharge air temperature is more than 3°F below the setpoint for more than 5 minutes (adjustable).

2. Mechanical heating permitted only during occupied, night low limit and heating optimal start modes.
3. When mechanical heating is enabled hot water heating valve shall modulate to maintain space temperature setpoint.

F. Night Low Limit Mode:
1. Night low limit mode is initiated during unoccupied times (mode), when space temperature falls below the unoccupied heating setpoint.
2. When space served by the system is above the unoccupied heating setpoint plus the dead band setpoint (initial 5°F, adjustable), the system will revert to the unoccupied mode.

G. Night High Limit Mode:
1. Night high limit mode is initiated during unoccupied times (mode), when space temperature rises above the unoccupied cooling setpoint and the outside air temperature is 10°F (adjustable) less than the average space temperature.
2. When space served by the system is below the unoccupied heating setpoint minus the dead band setpoint (initial 5°F, adjustable), the system will revert to the unoccupied mode.

H. Night Purge Mode:
1. This sequence is initiated before occupancy during the cooling season.
2. Night purge will be enabled when the following conditions are true:
   a. The space temperature is above 80º F (adjustable).
   b. Outside air temperature is greater than setpoint (initial setpoint, 45°F, adjustable).
   c. Outside air relative humidity is less than 50%.
   d. Outside air temperature is at least 10°F (adjustable) less than the average space temperature
   e. Occupancy period occurs within 3 hours (adjustable).
3. Night purge will be disabled when average space temperature is within 3°F (adjustable) of the outside air temperature or the average space temperature has reach the occupied heating set point.

I. Economizer Damper Control(HVU-3):
1. Occupied Mode: Economizer dampers (Outside Air, Return Air and Relief Air) modulate to maintain supply air temperature set point and air quality setpoint.
2. Economizer shall operate as first stage of cooling. If discharge set-point is not satisfied for 5 minutes (above set-point) enable cooling.
3. Unoccupied, Night Low Limit, Optimal Start and Low Limit Freeze Conditions: Dampers to modulate to full recirculation (0% Outside Air).
4. Night High Limit and Night Purge: Dampers to modulate to full ventilation (100% Outside Air).
5. The outside air economizer is enabled when the outside air enthalpy is less than the return air enthalpy.
6. The outside air economizer is disabled when the outside air enthalpy is greater than the return enthalpy for greater than 2 minutes. When the economizer is disabled, the outside air damper modulates to the minimum position setpoint based on the air quality sensor.
7. Demand Ventilation Control (DVC): During occupied mode the outside air dampers shall modulate to maintain return air CO2 levels at or below 900 PPM (adj.). DVC shall occur when levels begin to exceed the CO2 set point plus a dead-band of 100 PPM (adj.).
8. Economizer Minimum Position (Air Quality Control): Economizer minimum-minimum (min-min) position value is based on 25% of the minimum ventilation requirement unless otherwise noted. The economizer minimum-maximum (min-max) position is based on the full minimum ventilation requirement. During DVC sequences, outside air damper position (outside airflow) is limited to the min-max setting. Balancer to determine actual damper positions at the min-min and min-max airflow setpoints. Control system shall

use damper position setpoints for control purposes. Based on 900 PPM with dead-band of 100 the OSA damper will modulate up to min-max position on CO2 levels above 1000 PPM and will modulate to min-min once CO2 level is below 800 PPM.

9. CO2 sensor fail: lf the CO2 goes below 200 PPM or above 1600 PPM and remains at that level for 30 min (adj), the sensor is assumed to have failed and the CO2 control will be disabled and an alarm generated.
   a. A faulted sensor will revert to a fixed min OAD setpoint adjustable from the graphics.
   b. There will be a manual reset on graphics after CO2 controls are repaired.
10. The airside economizer control shall include fault detection and diagnostics as required by ASHRAE 90.1-2016. See ASHRAE requirements for full description of sensor, monitoring and alarm requirements which are available normally due to the DDC system. Specific requirements not normally provided are listed below and required.
    a. The system shall display the status of:
       1) Free cooling available
       2) Economizer enabled
       3) Cooling enabled
       4) Heating Enabled
       5) Mixed air low limit cycle active
    b. The system shall be capable of detecting and reporting the following faults
       1) Air temperature sensor failure or fault
       2) Economizing when unit should not be economizing
       3) Not economizing when the unit should be economizing
       4) Damper not modulating
       5) Excess outside air
11. (HVU-3)On status that the kitchen hood fan is on modulate the RA damper more closed and the OSA damper more open to a condition where OSA flow rate is XXXX CFM to provide make-up to the kitchen for hood operation.

4.11 MISCELLANEOUS

A. Freeze Stat: Set at 38ºF. When freeze stat is tripped turn off fan, ensure coil valve is 100% open, outside air damper is 100% closed, and boiler system is operational. Turn fan back on in 5 minutes (Adj.) once status confirmed. If freeze stat trips again, signal alarm and return to fan off, coil valve 100% open and outside air damper 100% closed.

B. Cabinet unit heaters or unit heaters: Modulate heating valve to maintain space temperature setpoint. Operate fan only when heating valve is open more than 5% and there is a call for heating.

C. Booster Coils: Modulate heating valve to maintain space temperature setpoint.

4.12 SEQUENCE OF OPERATION FOR FAN COIL UNITS WITH COMMON RETURN AIR

A. Supply Fan Control:
   1. Operate together on demand of any zone.

B. Return Fan Control:
   1. Fan will start/stop when any supply fan starts.
   2. During warm-up and night low limit, operate the unit in 100% recirculation mode.
   3. Fan speed is reset to zero (0) Hz when the AHU is off.
   4. Provide soft start. Operation of VFD for variable fan speed other than soft start is not required.

C. Fan Enable / Optimal Start Control or Warm-Up Mode:
   1. The intent of this sequence is that the air handling system be started early enough so that the maximum negative deviation of space temperature from the occupied heating set point (for all within the system) is less than 0.5 °F no more than 20 minutes prior to or 10

minutes after scheduled occupancy. Spaces should not be heated up above occupied heating space temperature set points.

2. Air handling systems may be started under the optimal start mode no more than 3 hours (adjustable) prior to scheduled occupancy.
3. This optimal start sequence will be locked out when the 3 hour rolling average outdoor air temperature is greater than setpoint (initial setpoint, 55°F, adjustable). If locked out, the AHU will start 10 minutes (adjustable, maximum of 30 minutes) before occupied time period.
4. Air handling systems will be started as a function of:
   a. Outdoor air temperature
   b. Space temperature
   c. Time until start of scheduled occupancy
   d. Historical time period required to reach setpoint as a function of a, b, and c above.
5. Discharge air temperature setpoint will be set to the maximum optimal start temperature setpoint (85°F, adjustable) during this mode.
6. When the system is in heating optimal start mode, the mixed air dampers will be in full recirculation mode (i.e., outside air dampers are fully closed and the supply air volume will be limited to the return volume).
7. Exhaust fans are off and exhaust dampers are closed.
8. Mechanical cooling is disabled.
9. The building operator will be able to command start of occupancy at the operator's terminal and at the Maintenance Building remote operator's station (overriding the optimal start sequence) for each individual air handling system and globally for all air handling systems in the building.

D. Fan Enable / Optimal Start Control (Cooling Mode) – Cool Down:

1. The intent of this sequence is that the air handling system be started early enough so that the maximum positive deviation from the space temperature to the occupied cooling set point (for all zones in the system) is less than 0.5 °F no more than 20 minutes prior to or 10 minutes after scheduled occupancy. Spaces should not be cooled down below occupied cooling space temperature set points.
2. Air handling systems may be started under the optimal start mode no more than 3 hours (adjustable) prior to scheduled occupancy.
3. This optimal start sequence should be locked out when the 3 hour rolling average outdoor air temperature during the scheduled unoccupied mode is less than setpoint (initial setpoint, 50°F, adjustable). If locked out, the AHU will start 10 minutes (adjustable, maximum of 30 minutes) before the occupied time period.
4. Air handling systems will be started as a function of:
   a. Outdoor air temperature
   b. Space temperature
   c. Time until start of scheduled occupancy
   d. Historical time period required to reach setpoint as a function of a, b, and c above.
5. Discharge air temperature setpoint will be set to the minimum temperature setpoint during this mode.
6. Mechanical cooling is disabled unless spaces have not achieved cool down setpoint (adjustable) 30 minutes (adjustable) before the occupancy period. Mechanical cooling will utilize economizer mode if outside air temperature is less than return air temperature.
7. Exhaust fans are on and exhaust dampers are open (unless limited by mixed air setpoint control due to outside air damper interlock).
8. Heating is disabled.
9. The building operator will be able to command start of occupancy for each individual air handling system and globally for all air handling systems in the building.

E. Cooling Operation:

1. Condensing unit shall stage on / up / down / off as required to maintain space temperature in the zone served by the specific fan coil system.

2. Mechanical cooling shall remain off during warm-up and night low limit.

F. Heating Mode:
1. Mechanical heating permitted only during occupied, night low limit and heating optimal start modes.
3. When mechanical heating is enabled hot water heating valve shall modulate to maintain space temperature in the zone served by the specific fan coil system.

G. Night Low Limit Mode:
1. Night low limit mode is initiated during unoccupied times (mode), when any two (2, adjustable) fan coil unit space temperature(s) falls below the unoccupied heating setpoint.
2. When all spaces served by the system are above the unoccupied heating setpoint plus the dead band setpoint (initial 5°F, adjustable), the system will revert to the unoccupied mode.
3. If the minimum hourly outside air temperature is less than 20°F (adjustable) in Western Oregon for the previous 12 (adjustable) consecutive hours, then the AHU will remain in operation during the unoccupied period. The system will maintain a setpoint temperature 10°F (adjustable) less than occupied setpoint. All outside air dampers will remain closed during the unoccupied period.

H. Night High Limit Mode:
1. Night high limit mode is initiated during unoccupied times (mode), when any two (2, adjustable) fan coil unit space temperature(s) rises above the unoccupied cooling setpoint and the outside air temperature is 10°F (adjustable) less than the average space temperature.
2. When all spaces served by the system are below the unoccupied heating setpoint minus the dead band setpoint (initial 5°F, adjustable), the system will revert to the unoccupied mode.

I. Night Purge Mode:
1. This sequence is initiated before occupancy during the cooling season.
2. Night purge will be enabled when the following conditions are true:
   a. The average space temperature is above 80º F (adjustable).
   b. Outside air temperature is greater than setpoint (initial setpoint, 45°F, adjustable).
   c. Outside air relative humidity is less than 50%.
   d. Outside air temperature is at least 10°F (adjustable) less than the average space temperature
   e. Occupancy period occurs within 3 hours (adjustable).
3. Night purge will be disabled when average space temperature is within 3°F (adjustable) of the outside air temperature or the average space temperature has reach the occupied heating set point.

J. Economizer Damper Control:
1. Occupied Mode: Economizer dampers (Outside Air, Return Air and Relief Air) modulate to maintain mixed air temperature set point and air quality setpoint.
2. Economizer shall operate as first stage of cooling. If discharge set-point is not satisfied for 5 minutes (above set-point) enable cooling.
3. Unoccupied, Night Low Limit, Optimal Start and Low Limit Freeze Conditions: Dampers to modulate to full recirculation (0% Outside Air).
4. Night High Limit and Night Purge: Dampers to modulate to full ventilation (100% Outside Air).
5. The outside air economizer is enabled when the outside air enthalpy is less than the return air enthalpy.
6. The outside air economizer is disabled when the outside air enthalpy is greater than the return enthalpy for greater than 2 minutes. When the economizer is disabled, the outside air damper modulates to the minimum position setpoint based on the air quality sensor.
7. Demand Ventilation Control (DVC): During occupied mode the outside air dampers shall

modulate to maintain return air CO2 levels at or below 900 PPM (adj.). DVC shall occur when levels begin to exceed the CO2 set point plus a dead-band of 100 PPM (adj.).

8. Economizer Minimum Position (Air Quality Control): Economizer minimum-minimum (min-min) position value is based on 25% of the minimum ventilation requirement unless otherwise noted. The economizer minimum-maximum (min-max) position is based on the full minimum ventilation requirement. During DVC sequences, outside air damper position (outside airflow) is limited to the min-max setting. Balancer to determine actual damper positions at the min-min and min-max airflow setpoints. Control system shall use damper position setpoints for control purposes. Based on 900 PPM with dead-band of 100 the OSA damper will modulate up to min-max position on CO2 levels above 1000 PPM and will modulate to min-min once CO2 level is below 800 PPM.
9. CO2 sensor fail:
    a. lf the CO2 goes below 200 PPM or above 1600 PPM and remains at that level for 30 min (adj), the sensor is assumed to have failed and the CO2 control will be disabled and an alarm generated.
        1) A faulted sensor will revert to a fixed min OAD setpoint adjustable from the graphics.
    b. There will be a manual reset on graphics after CO2 controls are repaired.
10. The airside economizer control shall include fault detection and diagnostics as required by ASHRAE 90.1-2016. See ASHRAE requirements for full description of sensor, monitoring and alarm requirements which are available normally due to the DDC system. Specific requirements not normally provided are listed below and required.
    a. The system shall display the status of:
        1) Free cooling available
        2) Economizer enabled
        3) Cooling enabled
        4) Heating Enabled
        5) Mixed air low limit cycle active
    b. The system shall be capable of detecting and reporting the following faults
        1) Air temperature sensor failure or fault
        2) Economizing when unit should not be economizing
        3) Not economizing when the unit should be economizing
        4) Damper not modulating
        5) Excess outside air

4.13 SEQUENCE OF OPERATION – EXHAUST FAN

A. General exhaust fans: Operate based on associated air handler.

4.14 SEQUENCE OF OPERATION – ROOF TOP UNITS

A. Sequences are subject to the limitation of the unit and package economizer controller.

B. Supply Fan Control: Operate during all sequences unless commanded off.

C. Exhaust Fan Control: None, units have barometric damper for pressure control.

D. Fan Enable /or Warm-Up Mode:
1. All fan systems with heating capability (in AHU and/or at terminal units) shall have this sequence.
2. The intent of this sequence is that the air handling system be started early enough so that the maximum negative deviation of space temperature from the occupied heating set point (for all within the system) is less than 0.5 °F no more than 20 minutes prior to or 10 minutes after scheduled occupancy. Spaces should not be heated up above occupied heating space temperature set points.
3. Air handling systems may be started under the optimal start mode no more than 1 hour (adjustable) prior to scheduled occupancy.
4. Air handling systems will be started as a function of:

a. Time until start of scheduled occupancy.

5. When the system is in heating optimal start mode, the mixed air dampers will be in full recirculation mode (i.e., outside air dampers are fully closed).
6. Mechanical cooling is disabled.

E. Compressor Operation (Cooling Mode):
1. Cooling section shall stage in sequence with economizer dampers to maintain space temperature set-point.
2. Mechanical cooling shall remain off during warm-up and night low limit.
3. Mechanical Cooling shall not operate when outside air temperature is below 60 °F (adjustable).
4. Cycle time of any compressor to be a minimum of 10 minutes (adjustable).

F. Gas Heat Heating Section: Stage single gas heating section to maintain space temperature set-point.

G. Night Low Limit Mode:
1. Night low limit mode is initiated during unoccupied times (mode), when the space temperature(s) falls below the unoccupied heating setpoint.
2. When space served by the system is above the unoccupied heating setpoint plus the dead band setpoint (initial 5°F, adjustable), the system will revert to the unoccupied mode.
3. If the minimum hourly outside air temperature is less than 20°F (adjustable) the previous 12 (adjustable) consecutive hours, then the AHU will remain in operation during the unoccupied period. The system will maintain a setpoint temperature 10°F (adjustable) less than occupied setpoint. All outside air dampers will remain closed during the unoccupied period.

H. Night High Limit Mode:
1. Night high limit mode is initiated during unoccupied times (mode), when the space temperature(s) rises above the unoccupied cooling setpoint and the outside air temperature is 10°F (adjustable) less than the average space temperature.
2. When space served by the system is below the unoccupied cooling setpoint minus the dead band setpoint (initial 5°F, adjustable), the system will revert to the unoccupied mode.

I. Economizer Damper Control:
1. Operate in conjunction with mechanical cooling to maintain space temperature set-point.
2. Unoccupied, Night Low Limit, Optimal Start: Dampers to modulate to full recirculation (0% Outside Air).
3. Night High Limit and Night Purge: Dampers to modulate to full ventilation (100% Outside Air).
4. Outside Air Damper Lockout: If the outside air temperature is greater than the return air temperature or unit is in heating mode, then modulate dampers to the minimum position. Otherwise, economizer operates as first stage of cooling.
5. Damper Position Limiting: Damper position shall be limited to prevent the mixed air temperature from falling below 45°F (adjustable).
6. Demand Ventilation Control (DVC): During occupied mode the outside air dampers shall modulate to maintain return air CO2 levels at or below 1000 ppm (Adjustable). DVC shall occur when levels begin to exceed the CO2 set point.
7. Economizer Minimum Position (Air Quality Control): Economizer minimum-minimum (min-min) position value is based on 25% of the minimum ventilation requirement (vent limit factor). The economizer minimum-maximum (min-max) position is based on the full minimum ventilation requirement. During DVC sequences, outside air damper position (outside airflow) is limited to the min-max setting. Balancer to calibrate outside air flow station and determine actual damper positions at the min-min and min-max airflow setpoints. Control system shall use damper position setpoints for control purposes and use airflow rate as feedback to verify proper economizer damper operation.

END OF SECTION

HYDRONIC PIPING

PART 1 - GENERAL

1.1 DESCRIPTION

A. The requirements of this section apply to the HVAC heating and cooling water systems. Provide pipe, pipe fittings, pumps, and related items required for complete piping system.

B. Related Work: The requirements of Section 23 05 00, Common HVAC Materials and Methods, also apply to this section.

1.2 QUALITY ASSURANCE

A. General: ASTM and ANSI Standards are indicated. In addition, special standards are referenced where neither ASTM nor ANSI Standards are applicable.

B. Labeling: All piping shall be continuously and legibly labeled on each length as required by codes and standards and including as a minimum, country of origin, manufacturers identification marking, wall thickness designation, and applicable standards and approvals. Fittings shall be labeled as required by the referenced standard.

C. Concealed Plastic Piping: No concealed plastic piping inside the building unless approved by Code or Governing Authorities.

D. Definitions: Where piping fluid is not indicated in the following paragraphs, provide similar piping materials for similar fluids.

E. To assure uniformity and compatibility of piping components in grooved piping systems, all grooved products utilized shall be supplied by a single manufacturer. Grooving tools shall be supplied from the same manufacturer as the grooved components.
   1. All castings used for coupling housings, fittings, and valve bodies shall be date stamped for quality assurance and traceability.

F. See Commissioning specification for additional requirements.

1.3 STORAGE AND HANDLING

A. Provide factory-applied end caps on each length of pipe and tube. Maintain end caps through shipping, storage and handling as required to prevent pipe-end damage and eliminate dirt and moisture from inside of pipe and tube. Protect flanges and fittings from moisture and dirt by inside storage and enclosure, or by packaging with durable, waterproof wrapping.

1.4 SUBMITTALS

A. Submit catalog data, construction details, and performance characteristics for all equipment.

B. Submit operating and maintenance data.

PART 2 - PRODUCTS

2.1 PIPING MATERIALS

A. Black Steel Pipe:
   1. Applications:
      a. Heating water
   2. Pipe: Schedule 40, standard black steel pipe ASTM A-106 or A-53.

3. Threaded Fittings: For above ground installations only.
   a. Banded class 120 cast iron fittings, ANSI B16.4 to 125 psi.
4. Flanged Fittings: For above ground installations only.
   a. Class 125 cast iron fittings, ANSI B16.2 including bolting to 125 psi.
   b. Facing and Gasketing: Selected for service pressures and temperatures. Full-faced for cast iron and raised face for steel flanges.

B. Black Steel Pipe:
1. Applications:
   a. Heating water
2. Pipe: Schedule 40, standard black steel pipe ASTM A-106 or A-53.
3. Fittings: Cold Press Mechanical Joint Fitting shall conform to material requirements of ASTM A420 or ASME B16.3 and performance criteria of IAPMO PS117. Sealing elements for press fittings shall be EPDM. Sealing elements shall be factory installed or an alternative supplied by fitting manufacturer. Press ends shall have Smart Connect® feature design (leakage path). MegaPress fittings with the Smart Connect feature assure leakage of liquids and/or gases from inside the system past the sealing element of an unpressed connection. The function of this feature is to provide the installer quick and easy identification of connections which have not been pressed prior to putting the system into operation.
4. Pipe Thread: Pipe Threads shall conform to ASTM B16.3.
5. Hangers and supports: Hangers and supports shall conform to MSS SP 58.
6. Hanger spacing: In accordance with ASME B 31.1, NFPA54, UPC, IMC other National or local codes.
7. Source Quality Control:
   a. Fittings shall be listed and approved for their intended application.
   b. Manufacture shall be Viega MegaPress or approved.

2.2 MISCELLANEOUS PIPING MATERIALS/PRODUCTS

A. Insulating (Dielectric) Fittings: Not allowed. See Section 3.

B. Soldering and Brazing Materials: Provide soldering materials as determined by the installer to comply with installation requirements.
1. Tin-Antimony Solder: ASTM B32, Grade 95TA.
2. Lead-Free Solder: ASTM B32, Grade HB. Harris “Bridgit" approved.
3. Silver Solder: ASTM B32, Grade 96.5TS.”

C. Gaskets for Flanged Joints: ANSI B16.21; full-faced for cast-iron flanges; raised-face for steel flanges. Pressure and temperature rating required for the service indicated.

D. Strainers: “Y-pattern,” ductile iron or bronze body (depending on pipe system) rated for pressures indicated with blow-off connection and 20 mesh stainless steel scree. Provide with drain valve and hose connection. Basis of Design: Victaulic Style 732.

E. Valves up to 12": Model #’s listed are Nibco unless noted otherwise. Approved equal are Watts, Hammond, Apollo, and Victualic.
1. Ball (to 2"):
   a. Two-piece, cast bronze body, full port, 600 psi WOG, T/S 585-70.
2. Check: Bronze or ductile iron body, spring-assisted swing check, 300 psi WOG, T/S-413B and F-918B, Grooved body – Victaulic Series 716.

2.3 HEATING WATER SPECIALTIES

A. Air Vents: Install at all system high points whether shown or not;
1. At all locations not in mechanical rooms use manual air vents.
2. At mechanical rooms fabricate of 2" diameter or larger pipe at least 12" long. At the high point of each main install an Armstrong No. 1AV autovent, or equivalent
Bell & Gossett, Dunham-Bush approved substitute. Route discharge line to over floor

sink.

3. As an option to 2 above install a Spirotop VTP dry design vent at the high point of each main.

B. Circuit Setter and Balancing Valves: Globe style with calibrated handle style balancing fitting with differential pressure taps, brass or bronze body and trim. TA Hydronics STAD Series, or equal Nexus, Wheatley or approved substitute. Valves shall only be used where specifically called out for balance valve, otherwise use flow control valve.

C. Flow Control Valve:
1. Install where shown on plans, flow metering or flow limiting fittings complete with P/T test flow meter valves and with size and series identification tags. Install as recommended by manufacturer.
2. Valves shall be dynamic flow limiting devices sized to the nearest 0.5 gpm. Stainless steel cartridge and spring with ductile iron or steel body and ends to match piping system.
3. Unless noted otherwise all flow control valves are flow limiting not balancing valves.
4. Griswold Uniflange, for size 3" and smaller or steel flange for sizes larger than 3". Other approved manufactures are Nexus UltraMatic or approved equal.

D. Coil Connection Hoses: Not allowed. Use Union. Dielectric Unions not allowed.

PART 3 - EXECUTION

3.1 PIPE INSTALLATION

A. General: Install pipe, tube and fittings in accordance with recognized industry practices. Install each run accurately aligned with a minimum of joints and couplings, but with adequate and accessible unions and flanges for disassembly, maintenance and/or replacement of valves and equipment. Reduce sizes (where indicated) by use of reducing fittings.
1. Unions and flanges for disassembly, maintenance and/or replacement of valves and equipment are not required in installations using grooved joint couplings. (The couplings shall serve as disconnect points.)

B. Piping Runs: Route piping close to and parallel with walls, overhead construction, columns and other structural and permanent-enclosure elements of the building (pitched for drainage). If not otherwise indicated, run piping in the shortest route which does not obstruct usable space or block access for servicing the building or equipment and avoid diagonal runs. Wherever possible in finished and occupied spaces, conceal piping from view. Do not encase horizontal runs in solid partitions.

3.2 PIPING JOINTS

A. General: Provide joints of the type indicated in each piping system, and where piping and joint as manufactured form a system, utilize only that manufacturer's material.

B. Ferrous Threaded Piping: Thread pipe in accordance with ANSI 82.l; cut threads full and clean using sharp dies. Ream threaded ends to remove burrs and restore full inside diameter. Apply pipe joint compound or pipe joint tape (Teflon) where recommended by pipe/fitting manufacturer, on male threads at each joint and tighten joint to leave no more than 3 threads exposed.

C. Solder Copper Tube and Fitting Joints for 2" and Smaller: In accordance with recognized industry practice. Cut tube ends squarely, ream to full inside diameter, and clean outside of tube ends and inside of fittings. Apply solder flux to joint areas of both tubes and fittings. Insert tube full depth into fitting, and solder in a manner which will draw solder full depth and circumference of joint. Wipe excess solder from joint before it hardens. “T-Drill” field formed tees may be utilized where the main is at least two pipe sizes larger than the branch.

D. Braze Copper Tube and Fitting Joints: Where indicated, in accordance with ANSI/ASME B31.5.

Pass a slow stream of dry nitrogen gas through the tubing at all times while brazing to eliminate formation of copper oxide.

E. Flanged Joints: Match flanges within piping system, and at connections with valves and equipment. Clean flange faces and install gaskets. Tighten bolts to provide uniform compression of gasket.

F. Insulating (Dielectric) Fittings: Where the "joining of ferrous and non-ferrous piping". Use brass valve or brass nipple with length/nominal dramatic ratio of 8 or greater rather than dielectric fitting.

G. Changes in Direction: Use fittings for all changes in direction. Run lines parallel with building surfaces.

H. Unions and Flanges: At all equipment to permit dismantling and elsewhere as consistent with good installation practice.

I. Press Fittings: MegaPress Cold Press Mechanical Joint Fittings shall be installed in accordance with the manufacturer's installation instructions. The protective corrosion coating shall be removed from the outside of the pipe end. The pipe shall be fully inserted into the fitting and the pipe marked at the shoulder of the fitting. The fitting alignment shall be checked against the mark on the pipe to assure the pipe is fully engaged (inserted) in the fitting. The joints shall be pressed using the tool(s) approved by the manufacturer.

3.3 MISCELLANEOUS PIPING EQUIPMENT

A. Strainers: Install in a manner to permit access for cleaning and screen removal and with blow-off valve.

B. Valves: Install valves in accordance with Section 23 05 00. Install control valves specified in other Division 23 sections.

3.4 EQUIPMENT INSTALLATION

A. Installation and Arrangement: Install and arrange as shown on the Drawings. Comply with manufacturer's recommendations for installation connections and start-up.

B. Air Vents: Conduct 1/4" copper tubing from high end of air chambers to accessible locations and terminate with screwdriver cock. Conduct 1/4" copper tubing from outlets of automatic air vents to floor drains indicated or to the outside when approved by Governing Authorities.

C. Mechanical Contractor and Balancing Contractor shall be trained on installation, connection, and balancing procedures by certified representative of differential pressure control valves.

3.5 CLEANING

A. General: Clean all dirt and construction dust and debris from all mechanical piping systems and equipment and leave in a new condition. Touch up paint where necessary.

B. Heating Water Piping Systems: Clean manufacturing and cutting oils from the inside and outside of all new piping installed.

3.6 TEST

A. General:

1. Minimum duration of two hours or longer, as directed for all tests. Furnish report of test observation signed by qualified inspector. Make all tests before applying insulation, backfilling, or otherwise concealing piping or connecting fixtures or equipment. Where

part of the system must be tested to avoid concealment before the entire system is complete, test that portion separately, same as for entire system.

2. Remove control devices before testing and do not use piping system valves to isolate sections where test pressure exceeds valve pressure rating. Fill each section with water and pressurize for the indicated pressure and time.
3. Observe each test section for leakage at end of test period. Test fails if leakage is observed or if pressure drop exceeds 5% of test pressure.

B. Repair:
1. Repair piping system sections which fail the required piping test by disassembly and re-installation, using new materials to the extent required to overcome leakage. Do not use chemical stop-leak compounds, solder, mastics, or other temporary repair methods.
2. Drain test water from piping systems after testing and repair work has been completed.

C. Heating Water Piping: Prior to insulation operate systems at make-up water pressures of 30 psig for 8 hours. Observe all new connection points for leaks. If no leaks the system is to be returned to normal make-up water pressures and may be insulated.

END OF SECTION

REFRIGERANT PIPING SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

A. The requirements of this section apply to the refrigerant piping system connecting refrigeration and HVAC equipment specified in other sections of these specifications. Provide pipe, pipe fittings and related items required for complete piping system.

B. Related Work: The requirements of Section 23 05 00, Common HVAC Materials and Methods, also apply to this section.

1.2 QUALITY ASSURANCE

A. General: ASTM, and ANSI Standards are indicated. In addition, special standards are referenced where neither ASTM nor ANSI Standards are applicable. Comply with federal and local regulations regarding the handling of refrigerant.

B. Labeling: All piping shall be continuously and legibly labeled on each length as required by codes and standards and including as a minimum, country of origin, manufacturer's identification marking, wall thickness designation, and applicable standards and approvals. Fittings shall be labeled as required by the referenced standard. Tubular fixture traps shall be stamped with manufacturer's mark and material thickness.

C. Air Conditioning and Refrigeration Equipment Rating: Rated in accordance with ARI certified rating procedures and bear the ARI label.

D. Installation Contractor: Manufacturer's authorized installation and start-up agency normally engaged and experienced in air conditioning/refrigeration work and certified in the handling of refrigerant.

1.3 SUBMITTALS

A. Submit catalog data, construction details, and performance characteristics for each type and size of refrigeration equipment.

B. Submit operating and maintenance data.

C. Provide design Drawings showing routing, pipe size, traps, and devices necessary for a complete installation between coil and condensing unit or heat pump.

1.4 STORAGE AND HANDLING

A. Provide factory-applied end caps on each length of pipe and tube. Maintain end caps through shipping, storage and handling as required to prevent pipe-end damage and eliminate dirt and moisture from inside of pipe and tube. Protect flanges and fittings from moisture and dirt by inside storage and enclosure, or by packaging with durable, waterproof wrapping.

PART 2 - PRODUCTS

2.1 PIPING MATERIALS

A. Copper Pipe and Tube:
   1. Application:
      a. Refrigerant.
   2. Pipe: ASTM B88. Type ACR hard temper copper with soldered joints. Cleaned and sealed at the factory.

3. Refrigerant Fittings: ANSI/ASME B31.5 or SAE J 513-F, "Refrigeration Tube Fittings." Where conflicts occur, B31.5 shall govern.

B. Copper Pipe and Tube:
1. Application: Refrigerant.
2. Pipe: U.L. recognized for 700 psi working pressure with insulation consisting of polyethylene outer layer, 1/2" thick (for lines less than 1" diameter), ASTM E84 25/50 rated. Assembly shall be made in the U.S.A.. Cleaned and sealed at the factory.
3. See restrictions for use in installation.

C. Copper Pipe and Tube:
1. Application:
a. Cooling coil condensate drain
2. Pipe: Type L hard temper copper with brazed or soldered joints, ASTM B88. Brazing required for 2" and larger lines.
3. Fittings: Wrought copper solder-joint fittings, ANSI B16.22.

2.2 MISCELLANEOUS PIPING MATERIALS/PRODUCTS

A. Brazing Materials: Provide brazing filler rod and flux materials as determined by the installer to comply with installation requirements.

B. Gaskets for Flanged Joints: ANSI B16.21 with pressure and temperature rating required for the service indicated.

2.3 REFRIGERATION SPECIALTIES

A. General: Provide the following equipment where they are not a part of the factory installed equipment accessories**.** Select equipment for operation with the refrigerant being utilized and for the pressure and temperature conditions indicated. Sporlan, Alco, Henry, Detroit, or as listed for each equipment.

B. Thermostatic Expansion Valve: Capacity matched for the system, angle or straight through pattern external equalizer, brass body complete with capillary and remote sensing bulb.

C. Liquid and Moisture Indicators: Moisture and liquid indicator installed after the liquid line filter dryer.

D. Liquid Line Filter Dryer: Sealed container up to approximately 10 tons of capacity and replaceable desiccant dryer core and strainer on larger capacity systems.

E. Charging Valves: Quick coupling type connection with removable valve core.

F. Service Valves: Install liquid, suction and discharge line valves, all suitable for refrigerant used and location in the system, designed so as to be easily packed with pressure on the line and with wing caps that completely enclose valve stem. Install all purge valves, relief valves or other valves required for safe and proper operation of the system and as may be required by State or local codes. Detroit, Alco, Sporlan or Automatic Products approved substitute.

PART 3 - EXECUTION

3.1 PIPE INSTALLATION

A. Air Conditioning Refrigeration Subcontractor: Submit 5 copies of piping diagram for approval. Install all refrigerant piping, major components and all minor components, such as dehydrator, service valves, etc., and arrange piping for hot gas bypass for low load operation. Test system, evacuate, charge, start-up and adjust. Refer to applicable sections of these Specifications for test, evacuation, etc.

B. Piping Runs: Route piping close to and parallel with walls, overhead construction, columns and other structural and permanent-enclosure elements of the building. If not otherwise indicated, run piping in the shortest route which does not obstruct usable space or block access for servicing the building or equipment and avoid diagonal runs. Wherever possible in finished and occupied spaces, conceal piping from view. Do not encase horizontal runs in solid partitions.

C. Refrigerant Piping:
1. Use hard drawn copper tubing and make all changes in direction with specified fittings.
2. Lay out the refrigerant piping system in a manner to prevent liquid refrigerant from entering the compressor and so that oil will return to the compressor. Slope all horizontal suction lines toward the compressor. Take special care to keep all tubing clean and dry.
3. Install all refrigerant piping straight and free from kinks and restrictions, properly supported to minimize vibration. Provide hangers at 5' spacing for 1/2" lines, 6' spacing for 1" lines and 8' spacing for 1-1/2" and larger lines. Submit complete diagram for approval.
4. Comply with the refrigerant piping installation instructions of the refrigeration equipment manufacturer.
5. If line sets per 2.1, B are used they shall be installed plumb and supported per specifications or per manufacture recommendations (whichever is more restrictive) and follow building lines. Turns shall be made using appropriate bending tools. The installation shall have a workmanship like quality similar to the ACR type installation or it shall be modified or replaced per directions of Engineer.

3.2 PIPING JOINTS

A. General: Provide joints of the type indicated in each piping system, and where piping and joint as manufactured form a system, utilize only that manufacturer's material.

B. Braze Copper Tube and Fitting Joints: Where indicated, in accordance with ANSI/ASME B31.5. Pass a slow stream of dry nitrogen gas through the tubing at all times while brazing to eliminate formation of copper oxide.

C. Changes in Direction: Use fittings for all changes in direction. Run lines parallel with building surfaces.

D. Unions and Flanges: At all equipment to permit dismantling and elsewhere as consistent with good installation practice.

E. Expansion: Provide loops, swing joints, anchors, runouts and spring pieces to prevent damage to piping or equipment.

3.3 MISCELLANEOUS PIPING EQUIPMENT

A. Floor, Wall and Ceiling Plates: Chrome-plated pressed steel or brass screw locked split plates on all pipe penetrations in finished spaces.

B. Filters: Install in a manner to permit access for removal and replacement of filter cartridge.

3.4 CLEANING

A. General: Clean all dirt and construction dust and debris from all mechanical piping systems and leave in a new condition. Touch-up paint where necessary.

B. Refrigeration System Piping: If, for any reason, sanitized and sealed-at-the-mill tubing is not used, clean the tubing as follows:
1. Wipe each tube internally with a dry, lintless cloth followed with a clean lintless cloth saturated with recommended refrigerant.

2. Repeat until the saturated cloth is not discolored by dirt.
3. Wipe with a clean cloth saturated with compressor oil and squeezed dry.
4. Wipe with a dry, lintless cloth.

3.5 TEST

A. Comply with manufactures IOM directions.

END OF SECTION

AIR DISTRIBUTION

PART 1 - GENERAL

1.1 DESCRIPTION

A. Provide Air Distribution Materials as specified herein and as shown on the Drawings.

B. Material characteristics and size shall be as indicated on the Drawings.

C. Related Work: The requirements of Section 23 05 00, Common HVAC Materials and Methods, also apply to this section.

1.2 QUALITY ASSURANCE

A. Air Distribution Equipment Rating: In accordance with AMCA certified rating procedures and bearing the AMCA label.

B. See Section 23 08 00 for commissioning requirements.

1.3 SUBMITTALS

A. Submit catalog data, construction details and performance characteristics for all manufactured materials.

B. Submit operating and maintenance data.

PART 2 - PRODUCTS

2.1 SHEET METAL

A. Quality Assurance: Galvanized steel sheet metal except where otherwise indicated. Metal gauges, joints and reinforcement in accordance with Mechanical Code, ASHRAE and SMACNA standards. Ductwork shall be fabricated to the following pressure classifications:
1. Return and exhaust ducts: 1" negative.
2. Supply ducts from fan discharge: 3" positive.

B. Acoustical Duct Lining: Line ducts with 1" thick lining (unless noted otherwise) for installation inside the building insulation envelope, and 1-1/2" for installation outside the building insulation envelope. Schuller “Linacoustic,” Owens Corning “Aeroflex” Type 150, and Certainteed “ToughGard” Type 150 approved, meeting NFPA 90A and B requirements for maximum flame spread and smoke developed. Duct liner adhesive shall conform to ASTM C916.Mechanically attach lining to sheet metal duct with fasteners conforming to SMACNA Standard MF-1-1971, Schuller Grip Nails or Gramweld welding pins. Apply fire-retardant type adhesive similar to Schuller No. 44 adhesive, Benjamin Foster 81-99, Insul-Coustic 22 or 3M equivalent on all leading edges, joints and seams.

C. Duct Sealing Tapes: Provide one of the following UL listed ductwork sealing tape systems.
1. Two-part sealing system with woven fiber, mineral gypsum impregnated tape and non-flammable adhesive. Hardcast “DT” tape and “FTA-20” adhesive, United “Uni-Cast” system, or accepted substitute.
2. For joints and seams exposed to the weather in lieu of soldering, United “Uni-Cast” system or approved.

D. Optional Duct Joints for Sheet Metal Ducts: “Ductmate System” by Ductmate Industries, Inc., Ward Duct Connectors, Inc., Mez Industries, or acceptable substitute. Spiramir self-sealing round duct connector system meeting Class 3 leakage standards with EPDM o-ring seal.

E. Concealed Round Duct: Round and flat oval spiral seam duct shall be manufactured of galvanized sheet metal with spiral lock seam. Construction, gauges, and reinforcement in accordance with SMACNA standards. Fittings shall be manufactured of galvanized steel with spot welded or riveted and sealed seams or continuously welded seams. Snap lock longitudinal seam duct shall fully comply with SMACNA standards for duct gauge and seam type for appropriate pressure class. Adjustable elbows are prohibited.

F. Flexible Ductwork-Low Pressure: Insulated low pressure flexible duct, factory fabricated assembly consisting of a zinc-coated spring steel helix seamless inner liner, wrapped with a nominal 1" thick insulation for installation inside the building insulation envelope, and 1-1/2" for installation outside the building insulation envelope, 1 pound/cubic foot density fiberglass insulation. The assembly shall be sheathed in a vapor barrier jacket, factory vapor resistance sealed at both ends of each section. The composite assembly, including insulation and vapor barrier, shall meet the Class 1 requirements of NFPA Bulletin No. 90-A and be labeled by Underwriters Laboratories, Inc., with a flame spread rating of 25 or less and a smoke developed rating of 50 or under. The duct shall have factory sealed double air seal (interior and exterior) to assure an airtight installation. Genflex, ATCO, Wiremold, Thermaflex, Glassflex, Clevepak, Schuller, or accepted substitute.

2.2 ACCESSORIES

A. Manual Volume Dampers: Construct of material two gauges heavier than duct in which installed; single plate up to 12" wide; multiple over 12" wide. Hem both edges 1/2" and flange sides 1/2". Use Young, Duro-Dyne, MAT, or accepted substitute damper accessories. Young numbers are shown.
1. No. 605 bearing set with No. 403 regulator for dampers up to 24" long.
2. For dampers over 24" long use No. 660 3/8" rod, No. 656 end bearing and No. 403 regulator.
3. Where damper regulators are not readily accessible, use No. 660 or No. 661 rod extensions and No. 301 and No. 315 concealed damper regulators or MAT cable operated dampers as required.

Location of all volume dampers is not necessarily shown on Drawings; minimum required is one in each supply, return or exhaust main, and one in each branch.

B. Locking Connection Straps: 1/2" wide positive locking steel straps or nylon self-locking straps. Panduit or accepted substitute.

C. Access Doors In Sheet Metal Work:
1. Hollow core double construction of same or heavier gauge material as duct in which installed. Use no door smaller than 12" by 12" for simple manual access or smaller than 18" by 24" where personnel must pass through infrequently. Use 24" by 60" minimum for filters and more frequent maintenance. Use Ventlok or accepted substitute hinges and latches on all doors.
   a. 100 Series hinges and latches on low pressure system doors up to 18" maximum dimension.
   b. 200 Series on larger low pressure system doors and 333 series on high pressure systems.
2. Construct doors up to 18" maximum dimension with 1" overlap, furr and gasket with 3/4" by 1/8" sponge rubber. Fit larger doors against 1-1/2" by 1/8" or angle frame and gasket with 3/4" by 1/8" sponge rubber or felt.

D. Flexible Connections: Neoprene impregnated fiberglass connection. Ventglass, Duro-Dyne, or accepted substitute.

2.3 AIR TERMINALS

A. Variable Air Volume Terminal Box: Construct unit casings of 22 gauge galvanized steel fully

lined with 1/2", 2 lb. density, neoprene coated fiberglass complying with the UL Standard 181 for erosion, and NFPA 90A for fire resistivity.

1. Unit Inlets: Round, obround, or rectangular with double thickness gasketed damper blade mounted in self-lubricating bearings.
2. Attenuation Section: Integral to the basic unit. Not required if acoustic performance is below specified allowances. Lined ductwork on the discharge is required regardless.
3. ARI Certified: Test in accordance with ARI Standard 885-98 appendix E.
4. Unit Sound Power Levels (second through seventh octave band): At minimum pressure drop, sound power level at any octave band shall note exceed 70.
5. Pressure Independent VAV Terminals: Equip with velocity controls to control cfm independent of duct static pressure.
6. Factory Furnished Accessories: All actuators, controls, and circuitry contained in a sheet metal enclosure.
7. Manufacturers: Titus, Price, Carnes, Nailor, Krueger, Envirotech, Trane, Metalaire, or approved substitute.

PART 3 - EXECUTION

3.1 EQUIPMENT INSTALLATION

A. Air Handling Equipment Installation and Arrangement: Install and arrange as shown on Drawings. Comply with the manufacturer's recommendations for installation, connection, and start-up.

B. Equipment Access Panels: Locate free of all obstructions such as ceiling bars, electrical conduit, lights, ductwork, etc.

C. Filters: Install specified filters or accepted substitute temporary construction filters in supply units and systems prior to start-up or use for drying and/or temporary heat. Replace prior to acceptance of project.

3.2 DUCTWORK INSTALLATION

A. Support: Install ductwork with 1" wide strap cradle hangers not more than 8' on centers or as required by code. Support terminal units independent of adjacent ductwork. Attach to available building construction according to good practices for materials involved. Manufactured hanger system acceptable in lieu of fabricated hangers at Contractor’s option. Ductmate “Clutcher” system or approved.

B. Fan and Air Handling Unit Flexible Connections: Install neoprene impregnated fiberglass connections in ductwork at all rotating equipment. Ventglass, Duro-Dyne or accepted substitute.

C. Elbows and Fittings: Construct elbows with throat radius equal to 1.5 times duct width in plane of turn or make them square and provide double wall, air foil turning vanes.

D. Fittings: Make transitions and take-offs as shown on Drawings. Provide volume dampers and splitter dampers as indicated on Drawings and as specified. Saddle tees are not allowed.

E. Acoustical Duct Lining:

1. Acoustically line all fan unit intake and discharge plenums, all ductwork indicated as lined on the Drawings, all sheet metal ductwork specified per Section 23 07 00 as insulated, where exposed to view or subject to damage in areas such as mechanical rooms, and, at the Contractor's option, all insulated ductwork specified in Section 23 07 00 except outside air intake ducts. The duct size noted on the Drawings is the clear opening of the duct with insulation. Insulation shall not reduce duct size listed.
2. All duct designated to receive duct liner shall be completely covered with a fire-resistant, fiber-bonding coating, or covering (composite, polymer, vinyl or neoprene) that reduces airflow resistance and controls fiber release. The duct lining shall be adhered to the sheet

metal with 100% coverage of a fire retardant adhesive. The coated surface of the duct liner shall face the airstream. When width of duct exceeds 12" and also when height exceeds 24", use corrosion resistant mechanical fasteners 12" on center maximum lateral spacing and 18" on center maximum longitudinal spacing. Start fastening within 3" of upstream transverse edge of the liner and within 3" of the longitudinal joint. Mechanical fasteners shall be either impact-driven or weld-secured and shall not pierce the duct walls. Fasteners and washers of the specified type and length shall be used assuring no greater than 10% compression of the liner thickness. Installation shall be made so that no fastener pins protrude into the airstream. No gaps or loose edges shall occur in the insulation. Top pieces shall be supported by the side pieces. Provide insulated build out frames for attaching dampers at running vanes where required.

3. All transverse and longitudinal abutting edges of duct lining shall be sealed and lapped 3" with a heavy coat of approved adhesive, in accordance with the manufacturer's recommendations. All upstream transverse edges shall be installed with sheet metal nosings. All raw exposed edges of lining shall be 'buttered' with approved adhesive.

F. Manual Volume Dampers: Location of all volume dampers are not necessarily shown on the Drawings. Provide a minimum of one volume damper in each supply, return or exhaust branch. Install dampers in fiberglass ductwork (where fiberglass ductwork is allowed) with galvanized sheet metal sleeves of sheet metal gauges required for metal duct systems of the same dimensions.

G. Duct Insulation: Specified in Section 23 07 00.

H. Sleeves: Provide galvanized sheet metal plaster ring around ductwork penetrating exposed finished walls. Sleeve and flash all duct penetrations through exterior walls in an air tight and weatherproof manner.

I. Plenums: Construct sheet metal plenums and partitions of not lighter than 18 gauge galvanized steel and reinforce with 1-1/2" by 1/2" by 1/8" angles as required to prevent drumming or breathing.

J. Access: Install necessary access opening and covers for cleaning, wiring or servicing motors, filters, fans, both entering and leaving air sides of coils, fire and/or smoke dampers and to other equipment located within or blocked by sheet metal work.

K. Sealing: Caulk, seal, grout and/or tape ductwork and plenums to make airtight at seams, joints, edges, corners and at penetrations. Solder all seams, joints, etc., on all ductwork exposed to the weather. Install specified tape in accordance with manufacturer's requirements using degreaser on surfaces to be taped and wiped to eliminate moisture.

END OF SECTION

HVAC AIR CLEANING DEVICES

PART 1 - GENERAL

1.1 DESCRIPTION

A. Provide Air Cleaning Devices as specified herein and as shown on the Drawings.

B. Materials characteristics and size shall be as indicated on the Drawings.

C. Related Work: The requirements of Section 23 05 00, Common HVAC Materials and Methods, also apply to this section.

1.2 QUALITY ASSURANCE

A. Air Equipment Rating: In accordance with ASHRAE 52.2-2007.

1.3 SUBMITTALS

A. Submit catalog data, construction details and performance characteristics for all manufactured materials.

B. Submit operating and maintenance data.

PART 2 - PRODUCTS

2.1 AIR FILTERS

A. Disposable Media, MERV 13 Rated:
1. Disposable, preformed 100% synthetic non-woven media, pleated 2” thick cartridge type with carrier board frames with diagonal and horizontal supports. Average ASHRAE test efficiency of MERV 13 per ASHRAE 52.2 with initial pressure drop across the clean filter bank not exceeding 0.4" W.C. when operating at 500 FPM. The filter media shall have an Underwriters Laboratories UL 900 listing.
2. Camfil AP-13 or equal AFF Flanders.

PART 3 - EXECUTION

3.1 EQUIPMENT INSTALLATION

A. Air Handling Equipment Installation and Arrangement: Install and arrange as shown on Drawings. Comply with the manufacturer's recommendations for installation, connection, and start-up.

B. Equipment Access Panels: Locate free of all obstructions such as ceiling bars, electrical conduit, lights, ductwork, etc.

C. Filters: Install specified filters or accepted substitute temporary construction filters in supply units and systems prior to start-up or use for drying and/or temporary heat. Provide 1 additional set of filters and replace those installed during Balancing and Commissioning process.

D. Install and arrange equipment as shown on the Drawings and as recommended by the equipment manufacturer.

END OF SECTION

HVAC DEVICES

PART 1 - GENERAL

1.1 DESCRIPTION

A. Provide systems as specified herein and shown on the Drawings.

B. Equipment capacity and size as indicated in the equipment lists on the Drawings.

C. Related Work: The requirements of Section 23 05 00, Common HVAC Materials and Methods, also apply to this section.

1.2 QUALITY ASSURANCE

A. Air Handling Equipment: Rated in accordance with AMCA certified rating procedures and AMCA labeled.

B. See Section 23 08 00 for Commissioning Requirements.

1.3 SUBMITTALS

A. Submit catalog data, construction details and performance characteristics for each fan.

B. Submit operating and maintenance data.

PART 2 - PRODUCTS

2.1 AIR HANDLERS

A. Unit Construction
1. Configuration: Fabricate as detailed on drawings.
2. Performance: Conform to AHRI 430. See schedules on prints.
3. Acoustics: Sound power levels (dB) for the unit shall not exceed the specified levels shown on the unit schedule. The manufacturer shall provide the necessary sound treatment to meet these levels if required.
4. Fabricate unit with heavy gauge channel posts and panels secured with mechanical fasteners. All panels, access doors, and ship sections shall be sealed with permanently applied bulb-type gasket. Shipped loose gasketing is not allowed.
5. Panels and access doors shall be constructed as a 1-inch nominal thick, injected with foam insulation with an R-value of not less than R-6 or equal fiberglass.
   a. The inner liner shall be constructed of G90 galvanized steel.
   b. The outer panel shall be constructed of G90 galvanized steel.
   c. The floor plate shall be constructed as specified for the inner liner.
   d. Unit will be furnished with solid inner liners at coil panels.
6. The casing leakage rate shall not exceed .5 cfm per square foot of cabinet area at 5 inches of positive static pressure or 6 inches of negative static pressure.
7. Access doors shall be flush mounted to cabinetry, with minimum of two six inch long stainless steel piano-type hinges, latch and full size handle assembly. Access doors shall swing outward for unit sections under negative pressure. Access doors on positive pressure sections, shall have a secondary latch to relieve pressure and prevent injury upon access.

B. Fan Assemblies: Where housed fans are noted, acceptable fan assembly shall be a double width, double inlet, class II, direct-drive type housed forward curved fan dynamically balanced as an assembly, as shown in schedule. Maximum fan RPM shall be below first critical fan speed. Fan assemblies shall be dynamically balanced by the manufacturer on all three planes and at all bearing supports.

C. Heating Water Coils
1. Certification: Acceptable water coils shall be certified in accordance with AHRI Standard 410 and bear the AHRI label. Coils exceeding the scope of the manufacturer's certification and/or the range of AHRI's standard rating conditions will be considered provided the manufacturer is a current member of the AHRI Forced Circulation Air-Cooling and Air-Heating Coils certification programs and that the coils have been rated in accordance with AHRI Standard 410. Manufacturer must be ISO 9002 certified.
2. Provide access to coil(s) for service and cleaning. Enclose coil headers and return bends fully within unit casing. Unit shall be provided with coil connections that extend a minimum of 5" beyond unit casing for ease of installation. Drain and vent connections shall be provided exterior to unit casing. Coil connections must be factory sealed with grommets on interior and exterior panel liners to minimize air leakage and condensation inside panel assembly. If not factory packaged, Contractor must supply all coil connection grommets and sleeves. Coils shall be removable through side and/or top panels of unit without the need to remove and disassemble the entire section from the unit.
   a. Headers shall consist of seamless copper tubing to assure compatibility with primary surface. Headers to have intruded tube holes to provide maximum brazing surface for tube to header joint, strength, and inherent flexibility. Header diameter should vary with fluid flow requirements.
   b. Fins shall have a minimum thickness of 0.0075 inch aluminum plate construction. Fins shall have full drawn collars to provide a continuous surface cover over the entire tube for maximum heat transfer. Tubes shall be mechanically expanded into the fins to provide a continuous primary to secondary compression bond over the entire finned length for maximum heat transfer rates. Bare copper tubes shall not be visible between fins.
   c. Coil tubes shall be 5/8 inch OD seamless copper, 0.020 inch nominal tube wall thickness, expanded into fins, brazed at joints.
   d. Coil connections shall be carbon steel, threaded connection. Vent and drain fittings shall be furnished on the connections, exterior to the air handler. Vent connections provided at the highest point to assure proper venting. Drain connections shall be provided at the lowest point to insure complete drainage and prevent freeze-up.

D. Direct Expansion Cooling Coil: Non-ferrous extended surface, counterflow serpentine type with heavy gauge galvanized steel casing with double sloped, non-ferrous drain pan suitable for mounting required. Assembled with 5/8" OD x 0.020" thick copper tubes brazed to copper headers with one complete circuit distributor for each capacity step of the compressor. Aluminum fins mechanically bonded to tube and spaced a maximum of 12 fins per inch. Construction shall allow for expansion and contraction without developing leaks. Permanently label each coil in accessible location with all operating parameters. Provide Drain pan for cooling coil. Construct drain pans from stainless steel with cross break and double sloping pitch to drain connection. Provide drain pans under cooling coil section.

E. Filters
1. Furnish angled or flat filter section as shown on drawings with 2-inch MERV 13 filter.

F. Approved manufactures: Trane, Carrier, Daikin, or Johnson Controls only.

2.2 CONDENSING UNIT 5 TONS OR LESS

A. General:
1. Units shall be operable down to at least 40º F outdoor temperature.
2. Use R-410a refrigerant.
3. Only one liquid line, one suction line, and one power connection shall be made to each compressor. Provide charging valves with brass caps. Plastic will not be allowed.

B. Condenser Coils:
1. Aluminum plate fins mechanically bonded to seamless copper tubes or 'Spine Fin' trade mark system which has aluminum fins epoxy bonded to aluminum tubes or micro-channel.
2. Provide stamped louver coil guard for unit.

C. Fans:
1. Direct driven propeller type.
2. Fan motor shall be single or two speed, thermostatically controlled, permanently lubricated, and designed with permanent protection.
3. Motors shall be resiliently mounted.
4. Each fan shall have a safety guard.

D. Compressor:
1. Each condenser unit shall have only one compressor.
2. Design with following features:
   a. Externally mounted brass service valves with charging connections.
   b. Crankcase heater.
   c. Resilient rubber mounts.
   d. Compressor motor-overload protection.

E. Controls:
1. Factory wired and located in separate enclosure.
2. Provide field installed safety devices:
   a. High and low pressure cutout.
   b. Condenser fan motor-overload devices.
   c. Anti-cycle timers to prevent units from starting up again for five minutes after any power interruption.
   d. Head pressure type low ambient kit.

F. Casing:
1. Fully weatherproof for outdoor installation. Finish shall be weather resistant.
2. Panels shall be removable for servicing.
3. Openings shall be provided for power and refrigerant connections.

G. Unit shall have rated efficiency of no less than SEER=13.0.

H. Approved manufactures: Match manufacture of unit ventilators.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install and arrange equipment as shown on the Drawings and as recommended by the equipment manufacturer.

3.2 AIR HANDLING INSTALLATION

A. Installation and Arrangement: Air handling equipment shall be installed and arranged as shown on the Drawings. Comply with the manufacturer's recommendations for installation connection and start-up.

B. Lubrication: All moving and rotating parts shall be lubricated in accordance with the manufacturer's recommendations prior to start-up.

C. Filters: Specified filters shall be installed in supply units prior to start-up. Replace filters after commissioning is complete.

3.3 CONTROLS

A. Wiring: All wiring shall be in accordance with the National Electrical Code and local electrical codes.

3.4 RESTORATION OF EXISTING HVAC EQUIPMENT

A. General: Where restoration, refurbish, or rebuild type of work is indicated, include the following as minimum required work.

1. Replace motors as noted, belts (matched set on multiple belt systems), sheaves, and bearings. Motors shall be per 23 05 00 with shaft grounding at VFD driven motors. Belts and sheaves per 23 05 00. Replace backdraft dampers not integral to exhaust fans.
2. Bearings shall be manufactured by SKF, Fafnir or Dodge. Provide submittal. Bearings shall have zone harden path for bearing surface and 120º set screws. Do not use eccentric collar bearings. Provide with new housing (pillow block, side casing flange) etc. Match bearing housing style currently installed. Prior to any replacement work at air handlers complete a vibration analysis of fan, drive, bearing and shaft. Firm completing the analysis shall specialize in this service. (OTS Precision Balancing or approved). Technician completing the bearing replacement shall specialize in this service. If after the bearing replacement is complete fan operation is noisy, or vibrates to a level determined by Engineer to be unacceptable, replacement of all rotating devices shall be at the Contractors expense.
3. Replace flex connectors at all supply**,** return, OSA, and relief duct connections.
4. See Section 23 05 00 for VFD or starter. See drawings for where VFD's are required.
5. Replace filters media. See Section 23 40 00. Filters to be replace after commissioning is complete.
6. Where missing, provide filter close off panels to bridge the gap between air handler wall and nominal filter sizes. Close off panels shall be no wider than 2".
7. Clean unit casing(s), plenum(s), fan scroll(s) and damper blades.
8. Vacuum clean entire air handler enclosure.
9. At air handlers clean fan wheels from low pressure and high pressure side with same method as coil above. Ensure fans are installed correctly if removed for cleaning.
10. Clean damper surfaces and adjust linkage to ensure dampers close/open properly.
11. Clean existing return air and outside air ductwork re-used, see Section 23 30 00 for more information.

END OF SECTION

Errol Hassell ES HVAC Upgrade

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PERMIT / BID SET

September 22, 2021

DIVISION 26 ELECTRICAL

COMMON WORK RESULTS FOR ELECTRICAL

PART 1 - GENERAL

1.1 DESCRIPTION

A. The provisions of the General Requirements, Supplementary Requirements, and Division 1 apply to the electrical work specified in this Section.

B. The requirements of this Section apply to the electrical systems specified in these Specifications and in other Division 26 sections.

C. Provide all items, articles, materials, equipment, operations and/or methods listed, mentioned, shown and/or scheduled on the Drawings and/or in these Specifications, including all labor, supervision, services, permits, fees, and incidentals necessary and required to provide a complete and operable facility with complete systems as shown, specified, and required by applicable codes.

D. The work shall include, but not be limited to, the following systems:
1. Electrical service complete per serving utility company requirements.
2. Electric service and distribution equipment.
3. Complete lighting and power systems, including panelboards, branch circuits, devices, lighting fixtures, etc.
4. Fire alarm central control panel, initiating and annunciating devices, raceway and cabling system, etc.
5. Connection of electrical equipment furnished under other Divisions of this Specification.
6. Wiring to and connection of electrical equipment or appliances furnished outside of these Specifications and Contract but described on the Electrical Drawings.
7. Special systems as specified herein.
8. Grounding.

E. Advise subcontractor, suppliers, and vendors involved in the work specified in this Section of the applicable requirements.

F. Temporary electrical service, Division 1.

1.2 QUALITY ASSURANCE

A. All work and materials shall conform to all applicable local and state codes and all federal, state and other applicable laws and regulations. All clarifications and modifications which have been cleared with appropriate authorities are listed under the applicable sections. All electrical products shall bear the UL label.

B. Whenever the requirements of the Specifications or Drawings exceed those of the applicable code or standard, the requirements of the Specifications and Drawings shall govern.

C. Codes and Standards: Comply with the provisions of the following referenced codes, standards and specifications:
1. Institute of Electrical and Electronic Engineers (IEEE)
2. Federal Specifications (FS)
3. American National Standards Institute (ANSI)
4. National Electrical Manufacturer's Association (NEMA)
5. National Fire Protection Association (NFPA)
6. Underwriters Laboratories, Inc. (UL)
7. Factory Mutual (FM)
8. International Building Code (IBC) with State and Local Amendments
9. National Electrical Code (NEC) with State and Local Amendments
10. American Society for Testing and Materials (ASTM)
11. Americans with Disabilities Act (ADA)

12. International Fire Code (IFC) with State and Local Amendments
13. National Electrical Contractors Association (NECA)

D. Each piece of equipment furnished shall meet all detailed requirements of the Drawings and Specifications and shall be suitable for the installation shown. Equipment not meeting all requirements will not be acceptable, even though specified by name. Where two or more units of the same class of equipment are furnished, use product of the same manufacturer; component parts of the entire system need not be products of same manufacturer. Furnish all materials and equipment, new and free from defect and of size, make, type and quality herein specified or approved by the Architect. All materials shall be installed in a neat and professional manner.

E. All apparatus shall be built and installed to deliver its full rated capacity at the efficiency for which it was designed.

F. All disconnect switches, panelboards, switchboards, motor control centers, and equipment of like nature shall be of the same manufacturer.

G. The Drawings and Specifications are complementary. What is called for by one shall be as though called for by both. If Drawings and Specifications contradict each other, the Contractor shall obtain written clarification prior to the bid. If time constraints are such that this is not possible, then the more stringent of the conflicting requirements shall be included in the bid. The Specifications are not automatically more authoritative than the drawings.

1.3 WORK OF OTHER CONTRACTS

A. Work under this contract shall be conducted in a manner to allow for the future installations of such equipment or items, and include the wiring and/or devices shown on the Drawings or listed in other sections of this Specification. Also see "Equipment Connections."

1.4 WORK OF OTHER DIVISIONS

A. Work under this Division shall be conducted in a manner to cooperate with the installation of such equipment or items as specified in other Divisions.

B. Control devices and control wiring relating to the heating and air conditioning systems are specified under other Sections of these Specifications except for provisions or items specifically noted on the Drawings or specified herein.

C. Consult all Drawings and Specifications in this project and become familiar with all equipment to be installed. Coordinate all aspects of the construction with the other trades on the job to ensure that all work and materials required to provide a complete and operational facility are included in the bid.

D. All sections of Division 26 are interrelated and shall be considered in their entirety when interpreting any material, method, or direction listed in any section of Division 26. Individual sections are not written for specific subcontractors or suppliers but for the general contractor.

1.5 SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES

A. Submit in accordance with Division 1 full technical and descriptive shop drawing data on proposed materials and equipment as detailed in each section.

B. The Contractor shall verify that all equipment submitted can be delivered and installed within the time constraints of the construction period.

C. Include the manufacturer, type, style, catalog number, complete specification, certified dimensions, and description of physical appearance for each item and option submitted. Reproduction of catalog data sheets shall be clean and legible to show all details, including gauge

of metal used.

D. Include only information on exact equipment to be installed, not general catalogs of the manufacturer. Where sheets show proposed equipment as well as other equipment, identify proposed equipment with rubber stamp arrow or similar concise method.

E. Submit with each copy a transmittal letter verifying that all included equipment submittals have been carefully considered for quality, dimensions, function, and have been coordinated with the Drawings and Specifications. Guarantee that proposed materials will meet or exceed the quality and function of those specified.

F. Include wire run and connection diagrams for all signal and/or low voltage systems, including floor plans.

G. Submittal Review: The submittal review process is a means to determine quality control. The action noted to be taken (or where conflicts with the contract documents are not noted) shall not be interpreted by the Contractor as automatic "change orders." Approval of the data for substitution and shop drawings shall not eliminate the contractor's responsibility for compliance with Drawings or Specifications, nor shall it eliminate the responsibility for freedom from errors of any sort in the data discovered prior to or after the review process. Deviations, discrepancies, and conflicts between the submittals and the Contract Documents shall be called to the Architect's attention in writing at the time of transmittal of the data.

H. Unless otherwise directed by Division 1, submittal data shall be in a 3-ring plastic binder with a clear plastic sleeve and a project identification sheet inserted. Arrange submittals numerically with specification sections identified on divider tabs. All required sections shall be submitted at one time. If approved by owner and architect all submittals maybe transmitted electronically in PDF format.

1.6 PRODUCT SUBSTITUTION

A. Material other than those specified may be approved for this project providing a written request is submitted to the Architect prior to bid in accordance with Instructions to Bidders. Requests shall include complete specifications, dimensions, manufacturer and catalog number for each item for which approval is desired. If, in the opinion of the Architect, the material is not complete or if it is not an acceptable substitute, he may reject it. The Architect's evaluation will be based solely on the material submitted.

1.7 CHANGE ORDERS

A. All supplemental cost proposals by the Contractor shall be accompanied by a complete itemized breakdown of labor and materials without exception. At the Architect's request, the contractor's estimating sheets for the supplemental cost proposals shall be made available to the Architect. Labor must be separated and allocated for each item of work.

1.8 RECORD DOCUMENTS

A. Maintain a set of record drawings as directed in Division 1.

B. Keep Drawings clean, undamaged, and up to date.

C. Record and accurately indicate the following:
   1. Depths, sizes, and locations of all buried and concealed conduits/cables.
   2. Changes, additions, and revisions due to change orders, addenda, obstructions, etc. Eradicate extraneous information.

D. Make Drawings available when requested by Architect for review.

E. Submit as part of the required Project Closeout documents as indicated in Division 1.

F. Use standards set in contract documents. Computer-aided design drafting (CADD) shall be used to complete project record drawings. Note field modifications, all addenda and change order items on project record drawings. If deficiencies are found in either the quality or the accuracy of the drawings, they will be returned unapproved. Additional review of subsequent submissions shall be at the contractor's expense.

1.9 OPERATING AND MAINTENANCE DATA

A. Upon completion of Contract and after no further action is noted as being required on catalog data submitted for review, submit multiple sets of Operating and Maintenance Manuals for inclusion in Owner's Maintenance Brochure as specified in Division 1. Operation and maintenance manuals shall include descriptive and technical data, maintenance and operation procedures, wiring diagrams, spare parts lists, service representatives, supplier for replacement parts, etc. Bind each set of Operating and Maintenance Manuals in 3-ring, vinyl or canvas covered, loose leaf binders organized with index and thumb-tab marker for each classification of equipment or data.

1.10 OPERATING AND MAINTENANCE INSTRUCTIONS

A. At the completion of the project, at a time scheduled by the Owner, assemble key mechanics, subcontractors, vendors, factory representatives and similar personnel required to explain all facets of maintenance and operation of the installed system to the Owner's personnel. Instructions shall include actual operation of systems and methods of maintenance.

1.11 ALTERNATE BIDS

A. Refer to Division 1 for possible effect upon Work of this Division.

1.12 WARRANTY

A. Furnish, prior to application for final payment, three copies of written and signed guarantee effective a period of one year from date of completion and acceptance of entire project; agree to correct, repair and/or replace defective materials and/or equipment or the results of defective workmanship without additional expense to the Owner. Where no response satisfactory to the Owner has occurred within three working days from the written report of a warranty covered defect, the contractor shall agree to pay for the cost of repair of the reported defect by a contractor of the Owner's choice.

B. Where the manufacturer's guarantee exceeds one year, the longer guarantee shall govern and include the Contractor's labor.

PART 2 - PRODUCTS

2.1 MATERIALS

A. All electrical products installed in this project shall be listed by Underwriters Laboratories, Inc., or be approved in writing by the local inspection authority as required by governing codes and ordinances.

B. All material shall be new and bear manufacturer's name, model number, electrical characteristics and other identification, and shall be the standard product of manufacturer regularly engaged in production of similar material.

C. All materials shall be of manufacturer's latest design, and of the best quality. The materials shall be manufactured in accordance with applicable standards listed under Quality Assurance.

2.2 ACCESS PANELS

A. Provide panels of adequate size for equipment requiring service and installed above plaster or gypsum board ceilings, behind walls or in furring. Furnish complete with correct frame for type of building construction involved. Size, number and location of access panels is not necessarily shown on Drawings. Use no panel smaller than 12" x 12" for simple manual access, nor smaller than 16" x 20" where personnel must pass through. Milcor Style A, K, L, or M panels or equivalent Bilco or Potter-Roemer as required by construction. Access panels shall maintain ceiling fire rating.

2.3 PAINTING

A. The work of this Division includes painting of the electrical items. All exposed conduits, boxes, surface raceways, etc. shall be painted per the Architect's direction. See Division 9 for additional painting requirements.

2.4 FIRE RATINGS

A. Electrical items recessed into fire rated walls or ceilings shall be alcoved in gypboard enclosures or be UL listed to maintain the fire rating.

PART 3 - EXECUTION

3.1 LAYOUT AND COORDINATION

A. The Contractor shall inspect the job site prior to bidding and become familiar with existing conditions which will affect his work. The Drawings are diagrammatic indicating approximate location of outlets, , electrical equipment, etc. Consult the Architectural, Structural and Mechanical Drawings to avoid conflicts with equipment, structural members, etc. When required, make all deviations from Drawings to make the work conform to the building as constructed, and to related work of others. Minor relocations ordered prior to installation may be made without added cost to the Owner.

B. Obvious omissions from Drawings or Specifications or differences between Drawings and Specifications shall be called to the Architect's attention at least ten (10) days prior to the bid date for clarification. Failure to do so will be construed as the willingness of this Contractor to supply all necessary materials and labor required for the proper completion of this work in a manner approved by the Architect.

C. Call to the attention of the Architect any error, conflict or discrepancy in Drawings and/or Specifications. Do not proceed with any questionable items of work until clarification of same has been made.

D. Supplementary details and plans may be supplied as required and they will become a part of the Contract Documents.

E. Work under this Division shall be conducted in a manner to cooperate with all other trades for proper installation of all items of equipment.

F. Coordination of work with other crafts employed on the project is mandatory. Arrange work to reduce interruption of existing services to minimum. When interruptions are unavoidable, consult Architect and utilities involved and agree in writing, with copy to the Architect, upon a mutually satisfactory time and duration.

G. Verify the physical dimensions of each item of electrical equipment to fit the available space and promptly notify the Architect prior to roughing-in if conflicts appear. Coordination of equipment to fit the available space and the access routes through the construction shall be the Contractor's liability.

H. Locations of items shown on the Drawings as existing are partially based on record and other

drawings which may contain errors. The Contractor shall verify the correctness of the information shown prior to rough-in or demolition and notify the Architect of any discrepancies.

I. Coordinate all work and trim with carpet installers. Provide carpet plates on all carpet surfaces, complete as required.

J. Install equipment such that code-required working clearances are maintained, and allow clearances for future maintenance.

K. Coordinate installation of electrical conduit, boxes, fittings, anchors, and miscellaneous items to be concealed in precast concrete assemblies.

3.2 PROTECTION OF WORK

A. Protect electrical work, wire and cable, materials and equipment installed under this Division against damage by other trades, weather conditions or any other causes. Equipment found damaged or in other than new condition will be rejected as defective.

B. Switchgear, panels, and electrical equipment shall be kept covered or closed to exclude moisture, dust, dirt, plaster, cement, or paint and shall be free of all contamination before acceptance. Enclosures and trims shall be in new condition, free of rust, scratches or other finish defects. Properly refinish in a manner acceptable to the Architect if damaged.

C. Including products of other Sections, clean, repair and touch-up or replace when directed, products which have been soiled, discolored or damaged.

D. Provide for dehumidification of equipment during construction when directed by Architect.

E. Remove debris from project site upon completion or sooner if directed.

3.3 GENERAL INSTALLATION METHODS

A. Provide raceways and conduits for all electrical system wiring as specified herein. Class II or III systems wiring installed per Article 725 of NEC will be required to be installed in raceway unless otherwise indicated. When open wiring is permitted, raceways will be required in insulated walls and in other inaccessible areas. Low voltage wiring installed in return air plenums shall utilize plenum rated cable.

B. The extent of the branch circuiting and control wiring shown shall not be changed.

C. Cross or hash marks on power conduit runs indicate quantity of No. 12 minimum copper branch circuit conductors unless otherwise noted. Where such marks do not appear, provide conductors as required to provide an operable system, sized per local codes.

D. Repair surfaces damaged during installation to match adjacent undisturbed areas. Surface preparation, including cleaning and priming, shall be in accordance with the paint manufacturer's requirements.

E. Adjacent panelboards, component cabinets, terminal cabinets, trench duct, and wire gutter exposed in finished areas shall have matching trim and finish.

F. In general, the mounting heights shall be as noted on the Drawings or as listed below. Where no heights are indicated, request clarification from the Architect. Consult the Architectural, Structural, and Mechanical Drawings to avoid conflicts prior to roughing in. All dimensions are to the center of the device above finished floor unless specified otherwise.

G. All raceways and wiring shall be concealed where possible. All wiring devices, shall be flush mounted unless otherwise noted.

H. Relays, panels, cabinets and equipment shall be level and plumb and installed parallel with structural building lines. All equipment and enclosures shall be suitable for the environmental conditions in which they will operate.

I. The Drawings do not indicate all items necessary. Provide associated equipment, materials, and labor as required for complete and operable systems.

3.4 CUTTING AND PATCHING

A. Under no conditions are beams, girders, footings or columns to be cut for electrical items unless so shown on Drawings or written approval obtained from the Architect.

B. Cutting, patching and repairing for the proper installation and completion of the work specified, including plastering, gypsum board, masonry work, concrete work, carpentry work and painting shall be performed by workers skilled in their respective trades.

C. Follow requirements specified in Division 1.

3.5 SLEEVES AND CHASES

A. Provide necessary rigid conduit sleeves, openings and chases where conduits or cables are required to pass through floors, ceilings or walls. Seal all openings around conduits against leaks and in a manner to maintain the fire rating of the structure penetrated. Prevent unnecessary cutting in connection with the finished work. Make all repairs and seals in a manner acceptable to the Architect.

3.6 NOISE CONTROL

A. The entire electrical system apparatus shall operate at full capacity without objectionable noise or vibration.

B. Outlet boxes at opposite sides of partitions shall not be placed back-to-back, nor shall straight-through boxes be employed, except where specifically permitted on the Drawings by note, to minimize transmission of noise between occupied spaces.

C. Contactors, transformers, starters, and similar noise-producing devices shall not be placed on walls which are common to occupied spaces unless specifically called for on the Drawings. Where such devices must be mounted on walls common to occupied spaces, they shall be shock mounted or isolated in such a manner as to effectively prevent the transmission of their inherent noise to the occupied space.

D. Ballasts, contactors, starters, transformers, and like equipment which are found to be noticeably noisier than other similar equipment on the project will be deemed defective and shall be replaced.

3.7 EQUIPMENT CONNECTIONS

A. Provide complete electrical connections for all items of equipment requiring such connections, including incidental wiring, materials, devices and labor necessary for a finished working installation.

B. Verify the rough-in and wiring requirements for all equipment provided under other Divisions of the work and requiring electrical connections with equipment supplier and installer prior to rough-in. Check the voltage and phase of each item of equipment before connecting. Motor connections shall be made for the proper direction of rotation. Pump motors shall not be test run until liquid is in the system and proper lubrication to all bearings in unit is checked. Minimum size flex for mechanical equipment shall be 1/2". Exposed motor wiring shall be jacketed metallic flex.

C. Conduit, wire and circuit breaker sizes for mechanical equipment and equipment furnished under other Divisions are based on the equipment ratings of one manufacturer. The equipment actually furnished may be of a different brand with different electrical characteristics. Conduit, wire and circuit breakers shall not be ordered or installed until exact electrical requirements are obtained. Responsibility for this coordination shall rest with the Contractor.

3.8 TESTS

A. Complete each system as shown or specified herein and place in operation except where only roughing-in or partial systems are called for. Each system shall be tested and left in proper operation free of faults, shorts, or unintentional grounds.

B. After the interior wiring system installation is completed, and at such time as the Owner may direct, the Contractor shall conduct an operating test for approval. The equipment shall be demonstrated to operate in accordance with the requirements of the Specification. The test shall be performed in the presence of the Owner or an authorized representative. The Contractor shall furnish all instruments and personnel required for the tests, and the Owner will furnish the necessary electric power. The Contractor shall submit in writing to the Owner upon completion of the project the measured ground resistance of each ground rod, indicating the location of the rod, the resistance, and the soil conditions at the time the measurements were made.

END OF SECTION

ELECTRICAL POWER CONDUCTORS AND CABLES

PART 1 - GENERAL

1.1 DESCRIPTION

A. Provide all conductors, cables, connectors, lugs, cable ties, and terminations for all systems.

1.2 QUALITY ASSURANCE

A. All conductors shall be Underwriters Laboratories, Inc., listed and comply with Fed. Spec. J-C-30B and UL 83. Materials omitted here but necessary to complete the work are to be of comparable quality.

1.3 PRODUCT DELIVERY, STORAGE & HANDLING

A. Deliver conductors and cables in complete coils with UL label and bearing manufacturer's name, wire size, and type of insulation.

B. Store and handle materials so as not to subject them to corrosion or mechanical damage and in a manner to prevent damage from environment and construction operation.

C. Deliver conductors No. 10 and smaller in manufacturer's original unopened and undamaged cartons with labels legible and intact.

1.4 SUBMITTAL AND RECORD DOCUMENTATION

A. None required.

PART 2 - PRODUCTS

2.1 CONDUCTORS

A. Conductors No. 10 AWG and smaller may be soft-drawn, stranded, or solid copper. Conductors larger than No. 10 AWG shall be stranded, soft-drawn copper. No aluminum conductors or MC cable allowed.

B. Insulation for new conductors installed in raceways shall be "THWN" for conductors No. 8 AWG or smaller, and "THWN" or "THHN" for conductors No. 6 AWG or larger, or as noted.

C. Where adverse conductor exposure exists, code-approved insulation suitable for the conditions encountered shall be used unless shown otherwise on the Drawings.

D. All wire and cable for feeder circuits shall conform to the latest requirements of the current edition of the NEC and shall meet all ASTM Specifications. Wire and cable shall be new and have wire size, grade of insulation, voltage, and manufacturer's name permanently marked on outer covering at regular intervals.

E. Sizes shall not be less than indicated. Branch circuit conductors shall not be smaller than No. 12 AWG. Class I remote control and signal circuit conductors shall not be less than No. 14 AWG. Class 2 low energy remote control and signal circuit conductors shall not be less than No. 18 AWG.

F. All insulation shall be rated 600 volts unless noted otherwise.

G. Acceptable Manufacturers: General Electric, Hatfield, Anaconda, Rome Cable, Essex, Belden, West Penn, or approved.

2.2 SPLICES AND TERMINATIONS

A. All connectors shall be solderless pressure type per Fed. Spec. W-S-610, properly taped. All taped joints shall be with plastic tape, "Scotch 33," applied in half-lap layers without stretching to deform.

B. Splices shall utilize Scotch "Hyflex" or "Ideal" wing nut connector installed properly. Splices for No. 8 and larger wires shall be made with tin or silver plated copper compression sleeves.

C. Splices made in handholes and manholes, or underground splices, shall be made water tight with epoxy resin-type splicing kits.

PART 3 - EXECUTION

3.1 CONDUCTORS

A. Insulation shall be removed with a stripping tool designated specifically for that purpose. All conductors shall be left nick-free.

B. UL listed pulling compounds may be used with the residue cleaned from the conductors and raceway entrances after the pull is made.

C. Raceway shall be complete, clean and free of burrs before pulling conductors.

D. Wire shall not be left extending out of exposed conduit stubs or incomplete raceways where subject to mechanical injury.

E. Pulleys or blocks shall be used for alignment of the conductors when pulling. Pulling shall be in accordance with manufacturer's specifications regarding tensions, bending radii of the cable and compounds.

F. Conductors shall be terminated as required.

G. Conductor sizes for special systems shall be as recommended by the equipment manufacturer except as noted.

H. Stranded conductors shall not be terminated with post and screw unless compression spade/ring lug is utilized.

I. 120-volt homeruns over 80 feet in length shall be minimum #10 conductor.

3.2 LABELING

A. Provide color coding of building wiring consistent throughout the work as listed herein, unless required otherwise by local code authority. Band feeder conductors not available in colors where clearly visible at each termination, tape or splice using two full wraps of 3/4" adhesive vinyl tape or equally visible color marking corresponding to the following table.

Less than 250V between phases	251 to 600V between phases
Phase A - Black	Phase A - Brown
Phase B - Red	Phase B - Orange
Phase C - Blue	Phase C - Yellow
Neutral - White	Neutral - Gray
Ground - Green	Ground - Green

B. Switch legs, travelers, etc., to be consistent with the above phases to which they are connected or may be any other color distinctive from those listed above. Complex control circuits may utilize any combination of colors but the identification shall be by labels throughout. Labeling shall be

accomplished by using computer-generated heat shrink labels suitable for the wire size used. In no case will hand lettering or wraparound labels be accepted.

C. Phase color code to be consistent at all feeder terminations, A-B-C left to right or A-B-C top to bottom.

D. Conductor identification shall be provided within each enclosure where a tap, splice, or termination is made.

E. Control circuit terminals of equipment shall be properly identified. Terminal and conductor identification shall match that shown on approved shop drawings. Hand lettering or marking is not acceptable.

3.3 SPLICES AND TERMINATIONS

A. Splices are to be made up completely promptly after wire installation. Single wire pigtails shall be provided for fixture and device connections. Wire nuts may be used for fixture wire connections to single wire circuit conductor pigtails.

3.4 CONNECTORS

A. Control and special systems wires shall be terminated with a tool- applied, spade-flared lug when terminating at a screw connection.

B. All screw and bolt-type connectors shall be made up tight and be retightened after an eight-hour period.

C. All tool-applied compression connectors shall be applied per manufacturer's recommendations and physically checked for tightness.

D. Check terminations in all panelboards, switchgear, motor control centers, etc., six months after completion of installation. Supply a confirming letter to the Owner at completion of test.

3.5 TESTS

A. Perform insulation resistance tests on all feeders and circuits over 100 A, 480 volt and below, with a 1,000 volt megger. The written test report listing the results of the test to be included in the Operating and Maintenance Manuals. Equipment which may be damaged by this test shall be disconnected prior to the test.

END OF SECTION

GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Provide ground system as specified herein, as shown on the Drawings, and as required by NEC and other rules and regulations pertaining to grounding.

1.2 SUBMITTAL AND RECORD DOCUMENTATION

A. None required.

PART 2 - PRODUCTS

2.1 GROUND CONDUCTORS

A. Equipment or grounding conductors shall be soft drawn copper, stranded per ASTM B8 and, if insulated, shall have green insulation.

2.2 GROUNDING BUSHINGS/WEDGES

A. Sufficient ampacity with grounding conductor set screw connection.

2.3 CONNECTOR

A. Cast, set screw or bolted type.

2.4 GROUND RODS

A. Copper-clad steel, not less than 3/4" in diameter, 8' long, driven full length into the earth.

PART 3 - EXECUTION

3.1 INSTALLATION

A. All grounding conductors shall be sized in accordance with Article 250, Tables 250.66 and 250.122 of the NEC.

B. Except where specifically indicated otherwise, all exposed non-current-carrying metallic parts of electrical equipment, metallic raceway systems, and neutral conductor of the wiring system shall be grounded.

C. The ground connection shall be made at the main service equipment and shall be extended to the point of entrance of the metallic water service. Connection to the water pipe shall be made by a suitable ground clamp. If flanged pipes are encountered, connection shall be made with the lug bolted to the street side of the flange connection.

D. Where the metallic water service is used, it shall be grounded as described by Article 250.53 of the NEC.

E. Generally, all supplemental grounding electrodes shall be ground rods.

F. All ground wire connections below finished grade, cast in concrete, or bonding solid wire shall be exothermically welded.

G. Where there is no metallic water service to the building, ground connections shall be made to

driven ground rods on the exterior of the building.

H. The maximum resistance measured in accordance with IEEE Standard 142 of a driven ground shall not exceed 25 ohms under normally dry conditions. If this resistance cannot be obtained with a single rod, additional rods shall be installed not less than 6' on centers, or if sectional-type rods are used, additional sections may be coupled and driven with the first rod. If the resultant resistance exceeds 25 ohms measured not less than 48 hours after rainfall, the Engineer shall be notified immediately.

I. Grounding conductor connectors shall be made up tight and located for future servicing and to ensure low impedance.

J. The Contractor shall submit in writing to the Owner upon completion of the project the measured ground resistance of each ground rod, indicating the location of the rod and the resistance and the soil conditions at the time the measurements were made.

K. Where new circuits are to be served by existing panels with no ground bus, provide supplemental copper ground bus in panel.

END OF SECTION

HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Provide all electrical equipment and wiring with adequate supports of specified type required for a complete installation.

1.2 SUBMITTAL AND RECORD DOCUMENTATION

A. Submit shop drawings indicating details of fabricated products and materials.

PART 2 - PRODUCTS

2.1 FASTENERS

A. Fastenings shall be by wood screws or screw-type nails to wood; by toggle bolts on hollow masonry units; by expansion bolts on concrete or brick; by machine screws, welded threaded studs, heat-treated or spring steel tension clamps on steel work; for new concrete installation use cast-in-concrete inserts. Kindorf D-255 or approved.

B. Hammer-driven and trigger-fired anchors may be used only after obtaining specific written authorization from the Architect.

2.2 OUTLET BOX SUPPORTS

A. Wood Stud Walls: Adjustable bar hangers with "C" channel cross section Steel City 6010 series, or approved, or mounted on solid blocking. 4-inch square boxes adjacent to wood studs may be side nailed and back braced with Steel City No. 50 box brace.

B. Light steel construction, bar hangers with 1-inch long studs between metal studs or metal stud "C" brackets snapped on and tab-locked to metal studs.

C. Concrete or masonry walls boxes shall be flush cast in place.

D. Concrete or masonry walls where boxes are not possible to be cast in place. Flush anchors or concrete inserts.

E. Flush Ceiling Outlets: Steel City 6010 series or equal bar hangers.

2.3 CONDUIT SUPPORTS

A. One Hole Malleable Straps: Steel City, Appleton, T&B, Diamond, Raco, or approved.

B. Conduit Clips: Caddy, Raco, or approved.

C. Nail-Up Straps: 1/2" through 1", Raco 2252, 2253, 2254, or approved.

D. Adjustable Hangers for Conduits 1-1/2" and Larger: Steel City C-149 with threaded steel rod of proper size.

E. Adjustable trapeze hangers to support groups of parallel conduits; Steel City B-905 steel channel, H-119 square washer, C-105 strap, threaded rod. Components of Unistrut, Globe Strut, Harvey Alstrut, Kindorf, Thomas & Betts, or approved.

2.4 HANGER ROD ATTACHMENTS

A. Side Beam Connector, Kindorf E-244; 90 degree fitting, Kindorf B-916; clamp type anchor clips Kindorf Type "C," Unistrut P2675 or approved, spot type concrete insert Kindorf B-255 with "Galv-Krom" finish.

2.5 SUPPORT CHANNELS

A. Conduit: Kindorf B-905 with Galv-Krom finish, and C-105 single bolt channel pipe straps.

B. Lighting: Kindorf B-900 with G-969 closure strip and G-977 swing connector.

C. Recessed in Concrete: Kindorf D-980 with D-982 anchored end caps and D-983 joiner clips.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Every fastening device and support for electrical equipment (includes fixtures, panels, outlets, conduits, and cabinets) shall be capable of sustaining not less than four times the ultimate weight of the object or objects. Fasten support to the building or a building structural member.

B. Provide independent supports to the building or building structural member for electrical fixtures, materials, or equipment installed in or on ceiling, walls, or in void spaces and/or over the furred or suspended ceilings. Chain or additional ceiling wires may be used for light fixture supports.

C. Other crafts' fastening devices shall not be used for the supporting means of electrical, equipment, materials, or fixtures.

D. Supports and/or fastening devices shall not be used to support more than one particular item.

E. Vertical support members for equipment and fixtures shall be straight and parallel to building walls.

F. Examine all equipment locations to determine type of supports required.

G. Raceways or pipe straps shall not be welded to steel structures.

H. Holes cut to a depth of more than 1-1/2" in reinforced concrete beams or to a depth of more than 3/4" in concrete joists shall avoid cutting the main reinforcing bars. Holes not used shall be filled.

3.2 BOXES

A. Boxes and pendants for surface-mounted fixtures on suspended ceilings shall be supported independently of the ceiling supports.

B. In open overhead spaces, cast metal boxes threaded to raceways need not be separately supported except where used for fixture support; cast metal boxes having threadless connectors and sheet metal boxes shall be supported directly from the building structure or by bar hangers.

C. Where bar hangers are used, the bar shall be attached to raceways on opposite sides of the box and the raceway shall be supported with an approved fastener not more than 24" from the box.

3.3 RACEWAYS

A. Support conduits within 18" of outlets, boxes, panels, cabinets, couplings, elbows, and deflections. Maximum distance between supports shall not exceed ten (10) foot spacing.

B. Conduit up to and including 1" EMT may be supported from ceiling fixture wires by conduit clips or other approved devices only with written approval of the installer of the ceiling support system.

All other conduit runs shall be secured to the structure by two-hole straps or supported on Kindorf or Unistrut hangers. Wire will not be permitted for supporting conduit. All visible conduit runs will be parallel to the building structural lines.

C. Anchor conduit installed in poured concrete to the steel reinforcing with No. 14 black iron wire.

D. In partitions of light steel construction, sheet metal screws may be used, and bar hangers may be attached with saddle-suspended ceiling construction only. Lighting system branch circuit raceways shall be fastened to the ceiling supports.

E. Support suspended feeder conduits by metal ring or trapeze hangers with threaded steel rods. Wire ties to prevent displacement, using not less than No. 14 iron wire, may be used only for concealed runs in concrete for conduit up to 1-1/4".

F. At main distribution and surface mounted branch panels and cabinets where conduit exits from the top, provide support channels on wall 24" above panel and at 6'-0" intervals from there on for support of conduits.

END OF SECTION

RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Provide all raceways, fittings, and boxes of specified type required for complete project. Install all systems in raceways unless specifically noted otherwise. Provide all outlet boxes, junction boxes, pull boxes and special boxes required for pulling of wires, making connections, and mounting of devices or fixtures.

1.2 QUALITY ASSURANCE

A. Underwriters Laboratories, Inc., listed and NEC approved

B. All boxes shall be Underwriters Laboratories, Inc., listed. Where special fabrication is required, the work shall be performed by a listed facility in accordance with UL 50, and all products of manufacture shall bear a label. Outlet and junction boxes shall be sized in accordance with NEC requirements for "THHN" wire or as noted on Drawings.

1.3 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Deliver raceways with Underwriters Laboratories, Inc., label and bearing manufacturer's name on each length.

B. Deliver fittings in manufacturer's original unopened and undamaged packages with labels legible and intact.

1.4 APPLICATION

A. Areas of use:

Underground	PVC
Within poured Concrete (except slab-on grade) or CMU	GRC, IMC, PVC
Dry concealed locations	GRC, IMC, EMT
Wet or Dry exposed locations, subject to damage	GRC, IMC
Dry exposed locations, not subject to damage	GRC, IMC, EMT
Hazardous Class I or II	GRC, IMC

B. Underground conduit shall be minimum 3/4" trade size. PVC shall not be used inside building. Unless otherwise approved, all conduits shall be installed under reinforcing steel.

C. Where the contractor elects to utilize PVC in lieu of GRC, the contractor shall provide supplemental ground bus in terminating switch and panelboards, and green ground wire in conduit according to code rules.

D. For the purposes of this section, poured concrete slabs on grade and under-the-building slabs are not classified as dry locations.

E. Flexible metal conduit will be permitted only where flexibility is necessary. Exceptions are connections to recessed light fixtures. Flexible metal conduit shall be used for connection to all equipment subject to movement or vibration such as motors, transformers, etc. Liquid-tight flexible metal conduit shall be used when moisture may be present and for exposed motor and equipment connections.

F. Surface raceway may be used only where specifically called for on the Drawings or in the Specifications.

G. Aluminum conduit and Romex (NM cable) are not permitted.

1.5 SUBMITTAL AND RECORD DOCUMENTATION

A Submit product data for surface raceway and wireway.

B. Submit product data for floor boxes. Submit shop drawings for nonstandard boxes, enclosures, and cabinets. Include layout drawings showing components and wiring.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Allied Tube & Conduit, Western Tube & Conduit, Triangle, Bridgeport, AFC, Carlon, Western Plastics, Alflex, or approved substitute. Wiremold, Walker, or approved substitute. Raco, Thomas & Betts, or approved substitute.

2.2 CONDUITS

A. Galvanized Rigid Conduit (GRC) shall be hot-dip zinc, galvanized inside and out, mild steel pipe manufactured in accordance with UL-6 and ANSI C80.1. All threads shall be galvanized after cutting.

B. Electrical Metallic Tubing (EMT) shall be steel only and shall comply with UL-797 and ANSI C80.3. Exterior shall be hot-dip zinc galvanized and interior protected by a corrosion-resistant lubricating coating.

C. Intermediate Metallic Conduit (IMC) shall comply with UL-1242 and ANSI C80.6. Exterior shall be hot-dip zinc galvanized and interior protected by a corrosion-resistant lubricating coating.

D. Rigid non-metallic conduit (PVC) polyvinyl chloride shall be schedule 40 unless otherwise noted, and shall comply with UL-651 and NEMA TC 2.

E. Surface raceway shall utilize snap-in cover and fittings as recommended by the manufacturer and shall comply with UL 5 standard. Material and size shall be as indicated on the Drawings.

F. Flexible metal conduit shall be steel and comply with UL 1 and ANSI standards. Liquid-tight flexible metal conduit shall comply with UL 360 and ANSI standards.

2.3 WIREWAYS

A. Gutters: Steel, painted, square in cross section, preformed knockouts on standard spacing, screw cover, suitable for environment.

B. Fittings and Accessories: Include couplings, offsets, elbows, expansion joints, adapters, hold-down straps, end caps, and other fittings to match and mate with wireways as required for a complete system.

C. Exterior wireways and fittings/accessories shall be stainless steel.

2.4 FITTINGS

A. GRC and IMC shall be coupled and terminated with threaded fittings. Ends shall be bushed with insulating bushings equal to T&B 1220 or 1230 Series.

B. Connectors and couplings for EMT shall be steel concrete tight compression type or set screw type with insulated throats on connectors. Indent type connectors shall not be used.

C. Conduits piercing a building waterproof membrane shall be provided with O-Z type FSR fittings.

D. Flexible metal conduit shall utilize screw-in type connectors. Couplings and set-screw type connectors are not permitted.

E. Seal-offs with filler fiber, compound, large removable cover. All components shall be of the same manufacturer.

F. Expansion Couplings:
1. Exposed Conduit Runs: Expansion couplings shall be weatherproof with external bonding jumper, providing at least 4" longitudinal movement with bushed conduit ends.
2. Concealed Conduit Runs: Expansion couplings shall be water tight with an internal bonding jumper and neoprene construction. The fitting shall allow 3/4" movement in any direction or deflection of 30 degrees from normal.

G. Locknuts shall be galvanized steel.

2.5 BOXES

A. Boxes for use with raceway systems shall not be less than 4" square and 1-1/2" deep except where shallower boxes required by structural conditions are approved.

B. Flush and Concealed Outlet Boxes: Galvanized stamped steel with screw ears, knock-out plugs, mounting holes, fixture studs if required.

C. Surface Outlet Boxes: Galvanized stamped steel same as above for use on ceilings and walls above 14 feet.

D. Boxes shall be of the cast-metal hub type when located in normally wet locations and when surface mounted on outside of exterior surfaces.

E. Boxes installed for concealed wiring shall be provided with suitable extension rings or plastic covers as required.

F. Cast-metal boxes installed in wet locations and boxes installed flush with the outside of exterior surfaces shall be gasketed.

G. Provide boxes suitable for the intended environment and sized as required to accommodate the equipment within. Exterior boxes shall be stainless steel.

H. Pull boxes of not less than the minimum size required by the National Electrical Code shall be constructed of code-gauge aluminum or galvanized sheet steel except where cast-metal boxes are required in locations specified above. Boxes shall be furnished with screw-fastener covers. Where several feeders pass through a common pull box, the feeders shall be tagged to indicate clearly the electrical characteristics, circuit number, and panel designation.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Ends of metal conduits shall be reamed and left free of burrs.

B. Provide pull boxes or vaults where shown or required to limit the number of bends in any conduit to not more than three 90 degree bends, or to ease pulling tension. Use boxes of code-required

size with removable covers, installed so that covers will be accessible after work is completed.

C. Conceal all wiring in finished spaces so far as practicable. Exposed conduit shall be used only in unfinished spaces.

D. Exposed raceways shall be parallel or at right angles to structural lines, and shall be neatly offset into boxes. Exposed raceways shall follow existing exposed piping/ductwork/conduit paths as far as practicable.

E. Conduit stubbed from a concrete slab or wall to serve an outlet mounted on a table or to supply a machine shall have a rigid conduit coupling flush with the surface of the slab. Provide plug where conduit is to be used in future.

F. Keep conduit and raceway closed with suitable plugs or caps during construction to prevent entrance of dirt, moisture, concrete or foreign objects. Raceways shall be clean and dry before installation of wire and at the time of acceptance.

G. Remove all foreign matter from raceways and pull mandrel through conduits larger than 1-1/2" prior to installing conductors.

H. Where no conduit size is noted on the Drawings, conduit may be the minimum code permitted size for the quantity of type THHN conductors installed, but in no case smaller than 1/2" trade diameter. Conductor quantities indicated in conduits do not include ground wire unless otherwise noted. Adjust conduit sizes accordingly.

I. Where the contractor elects to combine branch circuit runs shown as separate runs on the Drawings, provide a minimum 3/4" conduit or increase raceway size to provide a minimum of 25 percent spare capacity for future conductors. Feeder runs shall not be combined.

J. All conduits installed in concrete construction, underground, or under the building slab shall be minimum 3/4", unless otherwise noted.

K. Assemble, glue and seal PVC conduit in straight lengths prior to installation in trench.

L. Seal-offs shall be installed in all conduits which route from warm areas into refrigerated areas.

M. Install PVC conduit in accordance with manufacturer's instructions. Cut the conduit ends square and apply an approved solvent to clean the joint. Apply an approved cement and allow to set 24 hours before installing conductors.

N. Conduits shall be fastened to all sheet metal boxes and cabinets with two locknuts where required by the National Electrical Code, where insulating bushings are used, and where bushings cannot be brought into firm contact with the box; otherwise, a single locknut and bushing may be used.

O. A pull wire shall be inserted into each empty raceway in which wiring is to be installed by others. The pull wire shall be of No. 15 AWG zinc-coated steel, or of plastic having not less than 200-pound tensile strength. Not less than 10" of slack shall be left at each end of the pull wire.

P. Raceway shall not be installed under the fire pits of boilers and furnaces and shall be kept 6" away from parallel runs of flues, steam pipes and hot water pipes.

Q. Changes in direction of runs shall be made with symmetrical bends or cast-metal fittings. Field-made bends and offsets shall be made with an approved hickey or conduit-bending machine. Crushed or deformed raceways shall not be installed.

R. Expansion fittings complete with grounding jumpers shall be installed where raceways cross expansion joints, construction joints, sawed joints, and where shown.

S. Where conduit is shown stubbed into a telephone, computer or communication terminal area, conduit shall be stubbed up 6" above floor or 12" below ceiling and terminated with insulating bushings.

T. Coordinate layout and installation of raceway and boxes with other construction elements to ensure adequate head room, working clearance, and access to both boxes and other equipment.

U. The end of a conduit stub shall have an insulated bushing.

V. Pack spaces around conduits with polyethylene backing rods and seal with polyurethane caulking to prevent entrance of moisture where conduits are installed in sleeves or block-outs penetrating partitions.

W. Install intumescent material around ducts, conduits, etc., to prevent spread of smoke or fire where installed in sleeves or block-outs penetrating fire-rated barriers. An alternate method utilizing intumescent materials in caulk and/or putty form may be used.

X. Outlet boxes shall be designed for the intended use. Flush outlet boxes shall be installed flush with finished surface lines.

Y. Outlet boxes on flex connected fixtures shall be installed within five feet of conduit knock-out in fixture.

Z. Coordinate layout and installation of raceway and boxes with other construction elements to ensure adequate head room, working clearance, and access to both boxes and other equipment.

3.2 INSTALLING CONDUIT BELOW SLAB-ON-GRADE OR IN THE GROUND

A. All electrical wiring below slab-on-grade shall be protected by a conduit system.

B. No conduit system shall be installed horizontally within concrete slab-on-grade. For slab-on-grade construction, horizontal runs of rigid plastic shall be installed below the floor slab.

C. Conduit passing vertically through slab-on-grades shall be coated rigid steel.

D. Slope conduits away from terminal equipment; drain away from the building interior.

E. Rigid steel or IMC conduits, metal boxes, and couplings installed below slab-on-grade or in the earth shall be field-wrapped with 0.010" pipe-wrapping plastic tape applied with a 50 percent overlay, or shall have a factory applied plastic resin, epoxy, or coal-tar coating system. Zinc coating may be omitted from rigid steel conduit, or IMC which has a factory-applied epoxy system. All joints shall be threaded, sealed and wrapped with tape to prevent entry of water. Use 20 mil pipe wrapping tape to cover wrench marks, field cuts, or abrasions to the outer factory installed anti-corrosion covering.

F. Provide duct seal at ends of all underground and under-slab conduits.

END OF SECTION

IDENTIFICATION FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Clearly and properly label the complete electrical system to indicate the loads served or the function of each item of equipment connected under this work.

1.2 SUBMITTAL AND RECORD DOCUMENTATION

A. None required.

PART 2 - PRODUCTS

2.1 IDENTIFICATION MARKERS

A. Unless otherwise specified, all identification nameplates shall be made of laminated three-ply plastic in accordance with Fed. Spec. L-P-387 equal to "Lamicoid." Nameplates shall be minimum 1/16" thick, with black outer layers and a white core, red outer ply for all emergency applications. Edges shall be chamfered.

B. Provide identification nameplates for starters, switchboards, safety switches, panelboards, motor control centers, transformers, equipment (air handling units, exhaust fans, pumps, etc.), with a minimum of 1/4" high letters.

C. Provide identification nameplates for control power transformers, control devices (relays, contactors, etc.), with a minimum of 1/8" high letters.

D. Where switches control remote lighting, exhaust fans, or power outlets, or where switches in the same gang (two or more) serve different purposes, such as light, power, intercom, etc., or different areas, such as corridor and outlet, furnish engraved cover plates with 1/8" black letters indicating function of each switch or outlet.

PART 3 - EXECUTION

3.1 LABELING

A. Major items of electrical equipment and major components shall be permanently marked with an identification nameplate to identify the equipment by type or function and specific unit number as shown on the Drawings.

B. Provide typewritten branch panel schedules with protective clear, transparent covers accounting for every breaker installed. Use actual room designations assigned by name or number near completion of the work, and not the designation on the construction drawings. Minimum panel schedule width shall be 4" with 1/4" height allowed for each circuit line. Panel schedules shall be the type which install in a metal frame or pocket. Panel schedules shall be of the odd/even sequence (1-3-5-7-9... and 2-4-6-8-10...).

C. Identify service entrance and distribution switchboards with engraved nameplate corresponding with the plans, mounted on the face of the switchboard. Identify each feeder, breaker, and switch with engraved nameplate corresponding with the plans.

D. Identify branch panels with engraved nameplate corresponding with the main or subdistribution panel labeling, mounted on the face of the door. No brand labels or other markings shall be on the outside of the panels.

E. Label all disconnect switches, relays, contactors, starters and time switches indicating voltage,

amperage, power panel source, circuit number and equipment served with laminated plastic label.

F. Nameplates shall be secured with screws or pop rivets. Adhesive-only fasteners shall not be permitted.

END OF SECTION

WIRING DEVICES

PART 1 - GENERAL

1.1 DESCRIPTION

A. Provide all wiring devices and finish plates as required unless specifically indicated otherwise.

1.2 QUALITY ASSURANCE

A. Underwriters Laboratories, Inc., listed and NEC approved.

B. Wiring devices shall be specification grade, with special devices as noted on the Drawings. Should the Drawings indicate a device other than those listed herein, such device shall be of same grade and manufacture as specified below.

C. All lighting switches and duplex receptacles installed shall be from the same manufacturer and have identical appearance characteristics.

1.3 SUBMITTAL AND RECORD DOCUMENTATION

A. Submit product data for wiring devices and cover plates.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Wall Switches: 20 ampere, 120/277 volt AC, quiet type, Hubbell HBL1221 Series, color as selected by Architect. Single pole, double pole, 3-way, locking, or other type as indicated.

B. Receptacles: Single and duplex receptacles shall be rated 20 amperes, 125 volts, two-pole, three-wire, grounded type, Hubbell HBL5362 Series. Receptacles shall have nylon faces, one-piece brass mounting strap with integral ground contacts and bypass power contacts; color as selected by Architect.

C. Receptacles with ground fault interrupters shall be in accordance with UL 943.

D. Special purpose or heavy duty receptacles shall be of the type and of ratings and number of poles indicated or required for the anticipated purpose. Contact surfaces may be either round or rectangular. One appropriate straight or angle-type plug shall be furnished with each receptacle. Locking facilities, where indicated, shall be accomplished by the rotation of the plug.

E. Device plates of the one-piece type shall be provided for all outlets and fittings to suit the devices installed. Plates on unfinished walls and on fittings shall be of zinc-coated sheet steel, cast metal, or impact resistant plastic having rounded or beveled edges. Plates on finished walls shall be impact-resistant plastic, color as selected by the Architect.

F. Receptacles in wet locations shall be in a weatherproof enclosure, the integrity of which is not affected when the receptacle is in use. The enclosure shall be of high-impact polycarbonate construction, with a keyhole hinge without a spring and other metal parts, with a gasketless translucent lid that is lockable and tinted and has large cord openings. The enclosure shall be one or two-gang, and shall be securely secured to the receptacle box with tamper-proof fasteners through factory-drilled or field-drilled through factory-prepared drill points.
Bell "Rayntite II", Intermatic WP1000 series, or equal.

2.2 ACCEPTABLE MANUFACTURERS

A. Hubbell, Bryant, P&S, Leviton, and Cooper.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Devices and finish plates to be installed plumb with building lines.

B. Finish plates and devices not to be installed until final painting is complete. Scratched or splattered finish plates and devices will not be accepted.

C. Wall mounted receptacles shall be installed vertically at centerline height shown on the Drawings unless otherwise specified.

D. Plates shall be installed with all four edges in continuous contact with finished wall surfaces without the use of mats or similar devices. Plaster fillings will not be permitted. Plates shall be installed with an alignment tolerance of 1/16 inch.

E. All outlets shall have a cover plate. Provide blank cover plate to match surrounding area if none other is specified.

3.2 TESTS

A. Test all receptacles for line to line, line to neutral, line to ground, and neutral to ground, opens or shorts, and correct defective wiring.

3.3 LABELING

A. See Section 260553, Identification for Electrical Systems.

END OF SECTION

CIRCUIT PROTECTIVE DEVICES

PART 1 - GENERAL

1.1 DESCRIPTION

A. Provide overcurrent protective devices of a type as specified herein.

B. Provide disconnect switches of a type as specified herein and where required by the National Electrical Code. Provide fused or unfused switches as required by equipment manufacturer or circuit requirements.

1.2 QUALITY ASSURANCE

A. Underwriters Laboratories, Inc., listed.

B. The circuit breaker(s) referenced herein shall be designed and manufactured according to the latest revision of the following standards.
1. NEMA AB 1 - Molded Case Circuit Breakers and Molded Case Switches
2. UL 489 - Molded Case Circuit Breakers and Circuit Breaker Enclosures
3. UL 943 - Standard for Ground Fault Circuit Interrupters
4. CSA C22.2 No. 5.1 - M91 - Molded Case Circuit Breakers
5. NEC

1.3 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Deliver equipment with Underwriters Laboratories, Inc. label and bearing manufacturer's name.

1.4 SUBMITTAL AND RECORD DOCUMENTATION

A. Submit product data for each disconnect switch, circuit breaker, and fuse type, including descriptive data, outline drawings with dimensions, time-current curves, let-through current curves for fuses with current limiting characteristics, and coordination charts and tables and related data.

PART 2 - PRODUCTS

2.1 MOLDED CASE CIRCUIT BREAKERS

A. General Requirements
1. Circuit breakers shall be constructed using glass reinforced insulating material. Current carrying components shall be completely isolated from the handle and the accessory mounting area.
2. Circuit breakers shall have an over center, trip free, toggle operating mechanism which will provide quick-make, quick-break contact action. The circuit breaker shall have common tripping of all poles.
3. The circuit breaker handle shall reside in a tripped position between ON and OFF to provide local trip indication. Circuit breaker escutcheon shall be clearly marked ON and OFF in addition to providing International I/O markings.
4. The maximum ampere rating and UL, IEC, or other certification standards with applicable voltage systems and corresponding interrupting ratings shall be clearly marked on face of circuit breaker.
5. Each circuit breaker larger than 100A shall be equipped with a push-to-trip button, located on the face of the circuit breaker to mechanically operate the circuit breaker tripping mechanism for maintenance and testing purposes.
6. Circuit breakers shall be factory sealed with a hologram quality mark and shall have date code on face of circuit breaker.
7. Branch circuit breakers exposed to fault currents higher than their AIC rating shall be series-rated with upstream feeder breaker, unless noted otherwise on Drawings. Circuit

breaker/circuit breaker and fuse/circuit breaker combinations for series connected interrupting ratings shall be listed by UL as recognized component combinations. Any series rated combination used shall be marked on the end use equipment along with the statement "Caution - Series Rated System. _____A Available. Identical Replacement Component Required".

8. Manufacturer shall provide electronic and hard copy time/current characteristic trip curves (and Ip & I^2t let through curves for current limiting circuit breakers) for each type of circuit breaker.
9. Circuit breakers shall be equipped with UL Listed electrical accessories as noted on the Drawings. Circuit breaker handle accessories shall provide provisions for locking handle in the ON and OFF position.
10. All circuit breakers shall be UL Listed for reverse connection without restrictive line and load markings and be suitable for mounting in any position.
11. Circuit breakers shall have factory installed mechanical lugs. All circuit breakers shall be UL Listed to accept field installable/removable mechanical type lugs. Lug body shall be bolted in place; snap in design not acceptable. All lugs shall be UL Listed to accept solid (not larger than #8 AWG) and/or stranded copper conductors.
12. All circuit breakers shall be capable of accepting bus connections.
13. Circuit breakers used for motor disconnects and not in sight of the motor controller shall be capable of being locked in the open (OFF) position.
14. Acceptable Manufacturers: Siemens, Square D, Cutler-Hammer/Westinghouse, and GE.

B. Thermal-Magnetic Circuit Breakers
1. Circuit breakers shall have a permanent trip unit containing individual thermal and magnetic trip elements in each pole.
2. Thermal trip elements shall be factory preset and sealed. Circuit breakers shall be true rms sensing and thermally responsive to protect circuit conductor(s) in a 40 deg C ambient temperature.
3. Circuit breaker frame sizes above 100 amperes shall have a single magnetic trip adjustment located on the front of the circuit breaker.
4. Standard two- and three-pole circuit breakers up to 250 amperes at 600 VAC shall be UL Listed as HACR type.

C. Equipment Ground Fault Protection (in Thermal Magnetic Circuit Breakers)
1. Where indicated on the Drawings, circuit breakers shall be equipped with a Ground Fault Module.
2. Ground fault sensing system shall be modified zero sequence sensing type.
3. The ground fault system shall require no external power to trip the circuit breaker.
4. Companion circuit breaker shall be equipped with a ground-fault shunt trip.
5. The ground fault sensing system shall be suitable for use on grounded systems. The ground fault sensing system shall be suitable for use on three-phase, three-wire circuits where the system neutral is grounded but not carried through the system or on three-phase, four-wire systems.
6. Ground fault pickup current setting and time delay shall be field adjustable. A switch shall be provided for setting ground fault pickup point. A means to seal the pickup and delay adjustments shall be provided.
7. The ground fault sensing system shall include a ground fault memory circuit to sum the time increments of intermittent arcing ground faults above the pickup point.
8. A means of testing the ground fault system to meet the on-site testing requirements of the NEC shall be provided.
9. Local visual ground fault trip indication shall be provided.
10. Where noted on Drawings, the ground fault sensing system shall be provided with zone selective interlocking communication capabilities compatible with other thermal magnetic circuit breakers equipped with ground fault sensing, electronic trip circuit breakers with integral ground fault sensing and external ground fault sensing systems.
11. The companion circuit breaker shall be capable of being group mounted.
12. The ground fault sensing system shall not affect interrupting rating of the companion circuit breaker.

D. Electronic Trip Circuit Breakers
1. Where indicated on Drawings, provide electronic trip circuit breakers per the following.
2. Breakers shall have a microprocessor-based tripping system which consists of three current sensors, a trip unit, and a flux-transfer shunt trip. The trip unit shall use microprocessor-based technology to provide the adjustable time-current protection functions. True RMS sensing circuit protection shall be achieved by analyzing the secondary current signals received from the circuit breaker current sensors and initiating trip signals to the circuit breaker trip actuators when predetermined trip levels and time delay settings are reached.
3. Interchangeable rating plugs shall establish the continuous trip ratings of each circuit breaker. Rating plugs shall be fixed type as indicated. Rating plugs shall be interlocked so they are not interchangeable between frames, and interlocked such that a breaker cannot be closed and latched with the rating plug removed. Circuit breakers shall be UL listed to carry 80% of their ampere rating continuously.
4. System coordination shall be provided by the following microprocessor-based programmable time-current curve shaping adjustments. The short-time pick-up adjustment shall be dependent on the long-time pick-up setting.
    a. Programmable long-time pick-up.
    b. Programmable long-time delay with selectable I^2t and I^4t curve shaping.
    c. Programmable short-time pick-up.
    d. Programmable short-time delay with selectable flat or I^2t curve shaping and zone selective interlocking.
    e. Programmable instantaneous pick-up.
    f. Programmable ground fault pick-up trip or alarm.
    g. Programmable ground fault delay with selectable flat or I^2t curve shaping and zone selective interlocking.

    The microprocessor-based trip unit shall have a powered/unpowered selectable thermal memory to provide protection against cumulative overheating should a number of overload conditions occur in quick succession.

5. Means to seal the trip unit adjustments in accordance with the NEC shall be provided.
6. Local visual trip indication for overload, short circuit and ground fault trip occurrences shall be provided.
7. An ammeter to individually display all phase currents flowing through the circuit breaker shall be provided. Indication of inherent ground fault current flowing in the system shall be provided on circuit breakers with integral ground fault protection. All current values shall be displayed in true rms with 2% accuracy.
8. Long Time Pickup indication to signal when loading approaches or exceeds the adjusted ampere rating of the circuit breaker shall be provided.
9. The trip system shall include a Long Time memory circuit to sum the time increments of intermittent overcurrent conditions above the pickup point. Means shall be provided to reset Long Time memory circuit during primary injection testing.
10. Circuit breakers shall be equipped with back-up thermal and magnetic trip system.
11. Circuit breaker trip system shall be equipped with an externally accessible test port for use with a Universal Test Set. Disassembly of the circuit breaker shall not be required for testing. Test set shall be capable of verifying the operation of all trip functions with or without tripping the circuit breaker.

2.2 FUSES

A. Fuses 0 through 600 amperes:
1. Circuits protected with fuses 0 through 600 amperes shall be protected by current-limiting Class RK1 or J dual-element time-delay fuses.
2. All fuses shall have separate overload and short-circuit elements.
3. Fuses shall incorporate a spring activated thermal overload element that has a 284 degrees Fahrenheit melting point alloy.

4. The fuses shall hold 500% of rated current for a minimum of 10 seconds with an interrupting rating of 300,000 amperes RMS symmetrical, and be listed by a nationally recognized testing laboratory.
5. Peak let-through currents and i2t let-through energies shall not exceed the values established for Class RK1 or J fuses.

B. Fuses 601 through 6000 amperes.
1. Circuits protected with fuses 601 through 6000 amperes shall be protected by current-limiting Class L time-delay fuses.
2. Fuses shall employ "O" rings as positive seals between the end bells and the glass melamine fuse barrel.
3. Fuse links shall be pure silver (99.9% pure) in order to limit the short-circuit current let-through values to low levels and comply with NEC Sections requiring component protection.
4. Fuses shall be time-delay and shall hold 500% of rated current for a minimum of 4 seconds, clear 20 times rated current in 0.01 seconds or less, with an interrupting rating of 300,000 amperes RMS symmetrical, and be listed by a nationally recognized testing laboratory.
5. Peak let-through currents and i2t let-through energies shall not exceed the values established for Class L fuses.

C. Spares:
1. Upon completion of the project, the contractor shall provide the owner with the following:
   a. 10% (minimum of 3) of each type and rating of installed fuses shall be supplied as spares.
   b. Spare fuse cabinet(s) shall be provided to store the above spares.

D. Acceptable Manufacturers: Bussman, Littelfuse, and Gould-Shawmut.

2.3 DISCONNECTS

A. Enclosed safety switches shall be horsepower rated in conformance with Table III or Fed. Spec. W-S-865. Switches shall disconnect all ungrounded conductors.

B. Safety and disconnect switches shall be NEMA type HD (heavy duty), quick-make, quick-break, dual rated with electrical characteristics as required by the system voltage and the load served. Switches shall be equipped with a defeatable cover interlock. Operating handles shall be located to side of switches.

C. Enclosures shall be NEMA 1 for indoor use, unless specifically noted otherwise, NEMA 3R where installed exposed to the weather or designated by the subscript "WP," and explosionproof where designated with the subscript "EP" or as required by the environment. Exterior enclosures shall be stainless steel.

D. Disconnects shall be fusible or non-fusible as required by function or code. Equip all fusible disconnects with dual element fuses required by the equipment served. Coordinate fuse sizes at the time equipment is connected. Adjust fuse sizes if necessary to accommodate actual equipment installed. In no case shall fuses be sized smaller than the starter heaters on motor circuits.

E. For single-phase motors, a single- or double-pole toggle switch, rated only for alternating current will be acceptable for capacities less than 30 amperes, provided the ampere rating of the switch is at least 125 percent of the motor rating.

F. All disconnects shall be of same manufacturer.

G. Switches identified for use as service equipment are to be labeled for this application.

H. Switches used for motor disconnects and not in sight of the motor controller shall be capable of being locked in the open (OFF) position.

I. Acceptable Manufacturers: Square D, Siemens, Cutler-Hammer/Westinghouse, and GE approved.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install overcurrent protective devices as indicated, in accordance with manufacturer's written instructions and with recognized industry practices to ensure that protective devices comply with requirements. Comply with NEC and NEMA standards for installation of overcurrent protective devices.

B. Coordinate with other work, including electrical wiring work, as necessary to interface installation of overcurrent protective devices with other work.

C. Fasten circuit breakers without causing mechanical stresses, twisting or misalignment being exerted by clamps, supports, or cabling.

D. Inspect circuit breaker operating mechanisms for malfunctioning and, where necessary, adjust units for free mechanical movement.

E. Adjust all adjustable/programmable features of electronic trip circuit breakers in accordance with results of electrical power system studies. Reference Section 26 05 73.

F. Fuses shall not be installed until equipment is ready to be energized. This measure prevents fuse damage during shipment of the equipment from the manufacturer to the job site, or from water that may contact the fuse before the equipment is installed.

G. Install safety and disconnect switches where indicated, in accordance with the manufacturer's written instructions, the applicable requirements of NEC and the National Electrical Contractors Association's "Standard of Installation," and in accordance with recognized industry practices to ensure that products serve the intended function.

H. Install disconnect switches used with motor-driven appliances, motors, and controllers within sight of the controller position and within 25 feet.

3.2 TESTING

A. Prior to energization of overcurrent protective devices, test devices for continuity of circuitry and for short circuits. Correct malfunctioning units, and then demonstrate compliance with requirements.

END OF SECTION