UNIVERSITY OF COLORADO AT BOULDER

Music Building Delta-P Valve Upgrade Project
MUS-Delta P, CP133892

SPECIFICATIONS

BID DOCUMENTS

January 24, 2011

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SECTION 15050 - BASIC MECHANICAL MATERIALS AND METHODS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: This section covers basic materials and methods that may be common to two or more subsequent sections.

B. Scope: The work covered by this Division of the specifications consists of furnishing all labor, supervision, equipment, materials, incidentals, and appurtenances, and performing all operations as necessary to complete the installation of Division 15 work in strict accordance with this Division of the specifications and as indicated on the contract drawings.

C. Related Sections: The General Conditions of the Contract, Supplementary Conditions, and General Requirements are a part of these specifications and shall be used in conjunction with this Division as a part of the contract documents. Consult them for further instructions pertaining to this work. Contractors shall be responsible for and be governed by all requirements thereunder.

D. Permits and Tap Fees:
   1. Secure and pay for all permits, tap fees, taxes, royalties, licenses, and inspections in connection with the work specified under Division 15 and indicated on the drawings, unless otherwise noted in General and Supplementary Conditions and/or Division 1.
   2. Upon completion of work, furnish to the Architect/Engineer a certificate of inspection and final approval of the state plumbing inspectors, and wastewater authority.

E. Drawings and Specifications:
   1. The mechanical drawings are diagrammatic in character and do not necessarily indicate every required offset, valve, fitting, etc.
   2. All drawings relating to this structure, together with these specifications, shall be considered in bidding and construction. The drawings and specifications are complementary, and what is called for in either of these shall be as binding as though called for by both. Should any conflict or omissions arise between the drawings and specifications, such conflict shall be brought to the attention of the Architect/Engineer for resolution.
   3. Unless otherwise indicated, all equipment and performance data listed is for job site conditions (elevation 5,400 ft.).
   4. Drawings are not to be scaled.

1.2 DEFINITIONS

A. It is the intention of these specifications and drawings to call for finished work, tested, and ready for operation. Wherever the word "provide" is used, it shall mean "furnish and install complete and ready for use."

B. "Contractor" shall mean any contractor performing work under this Division of the Specifications.

C. Where this Division of the Specifications states work to be performed by the words "shall" or "secure" or other performance functions, it shall be assumed that such work shall be performed by the Mechanical Contractor unless stated otherwise.

D. The word "Mechanical" applies to all work specified herein wherever applicable.
E. The phrase "Architect/Engineer" implies that either may perform the task at hand.

1.3 SUBMITTALS

A. Substitution Approvals:
1. Equipment and/or materials manufactured by any one of the manufacturers listed in this specification or on the drawings shall be acceptable if the equipment and material is equivalent in performance, capacity, and configuration.
2. Where no specific manufacturer is listed, a first-class item of cataloged manufacture shall be furnished.
3. Prior (to Bid) Approvals: Refer to Division 1, Section 01600, "Substitutions." No prior approvals will be given by the Engineer unless the product is specifically mentioned in these specifications.
4. Substitution Requests after Execution of Contract: None allowed.

B. Submittal Data and Shop Drawings:
1. Refer to Division 1, Section 01300, "Submittals," for general requirements.
2. Contractor agrees that shop drawings and/or submittals processed by the Engineer are not change orders and that the purpose of shop drawings and/or submittals by the Contractor is to inform the Engineer which equipment and materials he intends to furnish and install.
3. Submittals and/or shop drawings shall be edited to show specific data and all options for the mechanical equipment that the Contractor intends to provide.
4. Submittals and/or shop drawings shall be identified with numbers or letters identical to those listed on the drawings and/or specifications.
5. All shop drawings for special systems (fire protection, temperature controls, etc.) that will become permanent record documents shall be prepared as CAD drawings the same size as the project construction documents.
6. See "Electrical Equipment" of this section, for special electrical equipment submittal requirements.
7. Mechanical contractor shall obtain approval in writing from Balancing contractor and submit it to the Engineer for review for type and size of all balancing and flow measuring devices.

C. Provide submittal data for:
1. Pipe joining materials
2. Welder's Operator's Performance Qualification tests and records
3. Welding Procedures Specifications

D. Close-out Submittals:
1. Operating and Maintenance Manual:
   a. Provide Operating and Maintenance Manuals in accordance with Division 1, Section 01730 "Operating and Maintenance” and Section 01700 "Contract Close-out.”
   b. The Contractor shall prepare an operating and maintenance manual that shall cover all systems and equipment installed under this Division. Incorporate the standard technical literature into system-specific formats for this facility as designed and actually installed. The resulting manual shall also serve as the training manual and shall be specific, concise, to the point, and tailored specifically for this facility.
   c. The maintenance manual shall be submitted to the Engineer in draft form for approval prior to preparation of five copies for final submission to the Architect for delivery to the Owner.
   d. The maintenance manual shall be 8-1/2" x 11" size and assembled in loose-leaf three-ring or post binder. The manual shall be adequately indexed and contain the following information:
      1) Contractors' names, addresses, and telephone numbers
2) Alphabetical list of all equipment items with the name and address and 24-hour phone number of the company responsible for servicing each item during the first year of operation.

3) Guarantees and warranties of all equipment whenever applicable.

4) All manufacturers' data that is applicable to the installed equipment, with appropriate highlighting, such as the following:
   a) Final approved shop drawings (latest copy)
   b) Installation instructions
   c) Lubrication instructions
   d) Wiring diagrams

5) Temperature control diagrams (Contractor), including an explanation of the control sequence of each system along with the following instruction wherever applicable.
   a) Emergency procedures for fire or failure of major equipment
   b) Normal starting, operating, and shutdown
   c) Summer or winter shutdown
   d) Drawings shall be the same size as the construction documents.

6) Valve tag list.

7) An outline of a preventative maintenance program for each system which shall include a schedule of inspection and maintenance. It shall suggest the maintenance and inspection that should be performed by the Owner and that which should be done with outside service.

8) System balancing report.

2. Record of Changes: Refer to Division 1, Section 01720 "Project Record Documents," for requirements.

E. Non-Responsive Submittals: Submittals are intended to be reviewed as an initial submittal with comments corrected, and then re-submitted. Non-responsiveness to the initial submittal comments in the resubmittal will result in return of the documents for correction and additional resubmittals. Any time charged by the Engineer in review of additional resubmittals due to non-responsiveness shall be deducted from the Contractor's billings.

1.4 QUALITY ASSURANCE

A. Regulatory Requirements:

1. Chemical and physical properties of materials, performance characteristics, and methods of construction shall be in accordance with applicable sections of the following references and standards of current editions in effect 90 days prior to receipt of bids:
   a. Air Movement and Control Association, Inc. (AMCA)
   b. American National Standards Institute (ANSI)
   c. Air Conditioning and Refrigeration Institute (ARI)
   d. American Society of Heating, Refrigerating, Air Conditioning Engineers (ASHRAE)
   e. American Society of Mechanical Engineers (ASME)
   f. American Society for Testing and Materials (ASTM)
   g. American Water Works Association (AWWA)
   h. Cast Iron Soil Pipe Institute (CISPI)
   i. Environmental Protection Agency (EPA)
   j. Manufacturers Standards Institute (MSI)
   k. National Electrical Manufacturer's Association (NEMA)
   l. National Fire Protection Association (NFPA)
   m. Plumbing and Drainage Institute (PDI)
   n. Sheet Metal and Air Conditioning Contractors National Association (SMACNA)
   o. Underwriters' Laboratories, Inc. (UL)
2. All work, materials, and equipment shall comply with the rules and regulations of the following codes and the state electrical and plumbing authorities. Such codes, where applicable, shall take precedence over these plans and specifications. As a minimum, the installation shall comply with the following codes:
   a. International Building Code (UBC), 2009
   b. International Fire Code (UFC), 2009
   c. Americans with Disabilities Act (ADA)
   d. National Fire Codes (NFC)
   e. Occupational Safety and Health Act (OSHA)
   f. National Electrical Code (NEC), 2008
   g. International Mechanical Code (UMC), 2009
   h. International Plumbing Code (UPC), 2009
   i. International Energy Conservation Code (IECC), 2009
   j. International Fuel Gas Code (IFGC), 2009
   k. Applicable state and local codes

B. Job Site Personnel:
   1. Furnish the services of an experienced superintendent who shall be constantly in charge of the installation of the work together with all skilled workmen, plumbers, fitters, metal workers, welders, helpers, and labor required to unload, transfer, erect, connect-up, adjust, start, operate, and test each system.
   2. The University requires all plumbing and pipefitting work be performed under the direct supervision of licensed plumbers and pipefitters (4-year), with a ratio of not more than two apprentices per journeymen.

C. Workmanship: The appearance of the finished work shall be of equal importance with its mechanical efficiency. All work shall be done in accordance with acceptable commercial practices.

D. Materials and Manufacturers:
   1. All materials and equipment shall be new, free of defects, installed in accordance with manufacturer's current published recommendations in a neat manner and in accordance with standard practice of the Industry. All materials used above the roof or exposed to weather shall be non-corrosive, hot dipped galvanized, or otherwise adequately protected.
   2. Certain materials and/or equipment in this specification are specified by manufacturer and catalog numbers. The design was based on the specified equipment and establishes a degree of quality, performance, physical configuration, etc. If the Contractor should elect to use equipment other than the equipment used as a basis for design but listed as "acceptable" in the specifications, he shall be responsible for space requirements, configuration, performance and changes in bases, supports, vibration isolators, structural members, structural framing, structural supports, changes in ductwork and piping connections, sound power levels, maintenance clearances, electrical characteristics, openings in structure, electrical requirements, control requirements, and other apparatus that may be affected by its use. Contractor shall be responsible for redesign of piping, ductwork, and electrical service to accommodate equipment configuration. Contractor shall be responsible for redesign and engineering required to modify structural framing support systems and enclosures to accommodate equipment. Contractor shall submit stamped structural, mechanical, and electrical shop drawings for review by the engineer, showing structural, mechanical and electrical revisions required to accommodate equipment. A stamped shop drawing submittal does not release the Contractor from these responsibilities.
   3. Contractor further agrees that if deviations, discrepancies, or conflicts between reviewed submittals and/or shop drawings and the contract documents in the form of design drawings and specifications are discovered after submittals and/or shop drawings are processed by the Engineer, the design drawings and specifications shall control and shall be followed.
E. Welding and Joining:
   1. All welding performed on the mechanical systems shall be done following acceptable procedures by operators qualified for the type of welding and materials being welded. Each manufacturer or contractor shall be responsible for the quality of welding done by his organization, whether performed at the job site or in the fabrication shop, and shall repair or replace any work not in accordance with these specifications.
   2. Before any welding is performed on the mechanical systems, the Contractor shall submit to the Architect/Engineer a copy of the qualified Welding Procedures Specification to be used, along with each welders' Operator Performance Qualification tests and records. The welding procedures and performance of welders shall comply with Section IX of the ASME Boiler and Pressure Vessel Code. The qualification tests shall be no more than two years old at the time of submittal.
   3. Welding of pressure vessels shall comply with the applicable sections of the latest published version of the ASME Boiler and Pressure Vessel Code.
   4. Unless otherwise noted, all welding of piping and acceptance criteria for welds shall comply with Section B31. of the latest published version of the ASME Code for Building Systems Piping.
   5. Soldering and brazing materials and procedures shall conform to applicable sections of the CDA Copper Tube Handbook and the applicable sections of the latest published version of the ASME Code for Pressure Piping B31.
   6. Fabrication, assembly, and erection of piping shall comply with the latest published version of the following applicable codes except where the welding requirements contained herein are more stringent.
      a. ASME Code for Pressure Piping B31
      b. National Fuel Gas Code ANSI Z223.1
      c. Fuel Oil Piping NFPA 30
      d. Exterior Water Service Piping AWWA C206 and Plumbing Code
      e. Pipe Supports and Structural Steel AWS D1.0

1.5 SAFETY AND HEALTH REQUIREMENTS

A. These construction documents and the joint and several phases of construction hereby contemplated are to be governed at all times by applicable provisions of the "Williams-Steiger Occupational Safety and Health Act of 1970, Public Law 91-596" and the latest amendments thereto.

1.6 SCHEDULING

A. Plan the work so that it proceeds with a minimum of interference with other trades. Inform the General Contractor of openings required in the building structure and coordinate mechanical equipment locations with the structural shop drawings.

B. Install pipe and duct sleeves and pipe support inserts before concrete is poured. See Part 3 of this section.

C. Cutting and patching made necessary by failure to plan the Work shall be the responsibility of this Contractor.

1.7 DELIVERY AND STORAGE OF MATERIALS

A. Make provisions for the delivery and safe storage of materials and make the required arrangements with other Contractors for the introduction into the building of equipment too large to pass through finished openings.

1.8 PROJECT/SITE CONDITIONS
A. Examination of Site: The Contractor should visit and examine the premises and/or job site so as to ascertain the existing conditions before bidding. No extras will be allowed due to lack of knowledge of these conditions.

1.9 WARRANTY

A. The Contractor shall warranty all materials, workmanship, and the successful operation of all equipment and apparatus installed for a period of one year from the date of final acceptance of the entire work as identified in Division 1, and shall guarantee to repair or replace at his own expense any part of the apparatus that may show defect during that time, provided such defect is, in the opinion of the Architect/Engineer, due to imperfect material or workmanship and not due to carelessness or improper use.

1.10 OWNER'S ACCEPTANCE

A. At the time of acceptance of the building by the Owner, all Division 15 systems shall be in first-class operating condition in all respects and satisfactory to the Architect/Engineer.

PART 2 - PRODUCTS

2.1 PIPE AND FITTINGS

A. Pipe materials, fittings, valves, and accessories shall be as specified elsewhere in Division 15.

2.2 ACCESS PANELS OTHER THAN SHEET METAL

A. Furnish access panels where required for access to concealed mechanical items such as dampers, valves, strainers, shock absorbers, cleanouts, control devices, and where required for equipment servicing.

B. Panels located in public areas are to have keyed locks.

C. Access panels are to have Underwriters' Laboratories B label fire rating when installed in fire-rated walls or ceiling.

D. Access panels for installation in plaster are to be similar to Milcor style "K;" all other access panels are to be similar to Milcor style "M, unless noted otherwise.

2.3 IDENTIFYING DEVICES AND LABELS

A. Stencils: Standard stencils, prepared for required applications with letter sizes complying with recommendations of ASME A13.1 for piping and similar applications, but not less than 2-inch- (30-mm-) high letters for ductwork and not less than 3/4-inch- (19-mm-) high letters for access door signs and similar operational instructions.
1. Material: Fiberboard
2. Material: Brass
3. Stencil Paint: Standard exterior-type stenciling enamel; black, unless otherwise indicated; either brushing grade or pressurized spray can form and grade.
4. Identification Paint: Standard identification enamel of colors indicated or, if not otherwise indicated for piping systems, comply with ASME A13.1 for colors.

C. Pressure-Sensitive Pipe Markers: Manufacturer's standard preprinted, permanent adhesive, color-coded, pressure-sensitive vinyl, complying with ASME A13.1, Seton "Code" or "Roll Form," or equivalent.

D. Plastic Duct Markers: Manufacturer's standard color-coded, laminated plastic.

E. Equipment Duct and Pipe Label Sizes:
   1. Ductwork: 2-inch-high letters with 6-inch flow arrow
   2. Piping:
      a. 2 inches and smaller: 1/2 inch or 3/4 inch
      b. 6 inches and smaller: 1-1/4 inch
      c. 8 inches and above: 2 inches
      d. Flow arrows shall be at least 2 inches long.
   3. Equipment: 2-inch letters

F. Nameplates: Engraved plastic laminate with letters not less than 1/4-inch high.

G. Laminate Adhesive Labels: Kroy, Duratype, or Brothers PeTouch 30 with 12-point or larger letters.

2.4 WELDING AND JOINING MATERIALS

A. Welding Materials: Comply with Section II, Part C, ASME Boiler and Pressure Vessel Code for welding materials appropriate for the wall thickness and chemical analysis of the pipe being welded.

B. Brazing Materials: Comply with SFA-5.8, Section II, ASME Boiler and Pressure Vessel Code for brazing filler metal materials appropriate for the materials being joined.

C. Soldering Materials: Solder shall not contain any lead, zinc, or antimony. Use 95-5 "no-lead" equal to Englehard "Silvabrite 100," Canfield "Water Safe."

D. Gaskets for Flanged Joints: Gasket material shall be full-faced for cast-iron flanges and raised-face for steel flanges. Select materials to suit the service of the piping system in which installed and which conform to their respective ANSI Standard (A21.11, B16.20, or B16.21). Provide gasket materials that will not be detrimentally affected by the chemical and thermal conditions of the fluid being carried.

E. Use Leak-Lock by RectorSeal Corp. as a pipe joint compound on all threaded connections, except for steam and condensate piping (see Section 15181).

2.5 ELECTRICAL EQUIPMENT

A. All electrical equipment shall conform to the electrical specifications and shall be suitable for operation on the voltage, phase, and altitude available at the building site. These characteristics shall be verified by the Division 15 Contractor with the Division 16 Contractor prior to ordering equipment. Division 15 Contractor shall provide documentation to show this coordination was completed.

1. References:
   a. NEMA Standard MG 1: Motors and Generators
   b. NEMA Standard ICS 2: Industrial Control Devices, Controllers, and Assemblies.
   c. NEMA Standard 250: Enclosures for Electrical Equipment
   d. NEMA Standard KS 1: Enclosed Switches
   e. NFPA 70: National Electrical Code

2. Electrical components and materials shall be UL listed for intended use.

3. This Contractor shall furnish all electrical motors, starters, disconnects, and controls required for Division 15 equipment unless specifically noted otherwise elsewhere.
B. All motors (except as noted) shall conform to the following specifications:

1. Acceptable Manufacturers:
   a. Baldor
   b. General Electric
   c. Reliance
   d. Toshiba

2. 1/2 hp and Smaller: Single-phase, permanent split capacitor or split phase. Shaded pole motors not acceptable without prior approval. Provide integral thermal overload protection.

3. Larger than 1/2 hp shall be three-phase, except where specifically noted otherwise.

4. Motor Construction:
   a. NEMA Standard MG 1, 1998, general purpose, continuous duty, Design "B" (premium efficiency), except "C" where required for high starting torque.
   b. Copper windings, 40°C ambient with Class F insulation, Class B temperature rise at 100% load, unless otherwise noted.
   c. Two-speed, three-phase motors shall have two separate windings.
   d. Frames: NEMA standard as required by application.
   e. Bearings:
      1) Ball or roller bearings with inner and outer shaft seals; minimum 40,000-hour L-10 life.
      2) Regreasable for 360T and larger, except permanently sealed where motor is normally inaccessible for regular maintenance.
      3) Designed to resist thrust loading where belt drives or other drives produce lateral or axial thrust in motor.
      4) Sleeve type bearings are permitted for fractional horsepower and light-duty motors.
   f. Enclosure Type:
      1) Open drip-proof motors for indoor use where satisfactorily housed and properly ventilated during operation.
      2) Weather protected Type I for outdoor use when enclosed or housed with adequate ventilation, or TEFC when exposed to weather or moist locations.
      3) Special enclosures required for hazardous areas (XP, etc.) per equipment schedules. XP motors shall be UL listed.
   g. Starting Capability: Frequency of starts not less than NEMA standard (two cold and one hot starts per hour).
   h. Service Factor: 1.15 for three-phase motors and 1.35 for single-phase motors, except 1.0 for inverter-rated motors.
   i. Noise Rating: 80 dba maximum for four or more poles.
   j. Motor Connections: Flexible conduit, except where plug-in electrical cords are specifically indicated or furnished as OEM with equipment.
   k. Belt drive motors 5 hp and above shall have motor mounts with dual push-pull adjustment screws

5. Motor Efficiency:
   a. All three-phase motors 1.0 hp or greater shall be NEMA Design B (premium efficiency) type as defined in NEMA Standard MG 1-1998, Part 12, Paragraph MG 1-12.60. Nameplate efficiency shall be equal to or greater than "nominal efficiency" values given in Table 12-11.
      Exceptions: Direct-drive motors 5 hp or less, furnished OEM on in-line and/or vertical pumps, condenser fans, furnaces, and other direct-drive applications. These motors shall be energy efficient as defined in Paragraph MG 1-12.59 whenever available from the manufacturer. No motors shall have efficiencies less than those mandated by EPACT.

6. Inverter Duty Motors:
a. Motors 5 hp and larger supplied for use with variable speed controllers (VSC's) shall be inverter duty rated and must include a stainless steel nameplate showing "Inverter Duty Motor."

b. Nameplate shall also show that motor is suitable for variable torque operation on VSC power from 6 to 60 Hz, and show rated torque in lb-ft on inverter power in addition to the standard nameplate data specified in NEMA standards.

c. Motor manufacturer shall supply certification with submittals that the motor is constructed to meet all requirements of NEMA MG1-1998, Part 31.

d. Motor shall include an ‘inverter grade’ insulation system using not less than triple insulation layer wire and other features necessary to meet the voltage spike specifications of NEMA MG1-1998, Paragraph 31.4.4.2. Insulation systems must use triple layer magnet wire or must use magnet wire which has a Pulse Endurance Index (PEI) greater than 50. Insulation systems utilizing heavy film and two-film wire with a Pulse Endurance Index less than 50 are not acceptable. Complete insulation of the slot, cell, and phase groups is required. The system shall be rated for Class F temperature rise or better at a service factor of 1.0.

e. Inverter duty stator core designs shall be of high rigidity type with reinforced end turn construction to minimize mechanical fatigue of the winding, and to reduce resonant noise. Single dip and bake cycles are not acceptable.

f. Rotor cores and/or assemblies shall be of a low vibration design that meets 1/2 of the NEMA MG1 recommended levels for balance.

g. Inverter duty motors shall include a normally closed winding over-temperature thermostat suitable for connection to the VSC panel for drive shutdown.

7. Motor Selection Criteria:
   a. Torque characteristics shall be sufficient to satisfactorily start and accelerate the driven loads.
   b. Motor sizes shall be large enough so that the driven load will not require the motor to operate above 80% of its rated horsepower. Minimum horsepower ratings are shown or scheduled on the drawings.
   c. Motors shall be selected so that operating limits (temperature rise, service factor, etc.) are not exceeded at operating altitude and rated load.
   d. Pump motors shall be "non-overloading"; i.e. shall not operate in service factor at any point on pump curve.
   e. Provide reduced voltage starting for motors 75 hp and larger or when required by local regulations, except when motor is controlled by a VSC. Maximum allowable current inrush shall not exceed 300% of motor full load amps unless specified otherwise.

8. Power Factor Correction:
   a. Capacitors shall be installed on all motors 25 hp and larger that have an uncorrected power factor of less than 90% at rated load. KVAR size shall be as required to correct motor power factor to 95% lagging.
   b. Capacitors shall have:
      1) Individual unit cells
      2) All welded steel housings
      3) Non-flammable synthetic liquid impregnant
      4) Craft tissue insulation
      5) Aluminum foil electrodes
   c. Each capacitor shall be internally fused.

9. Motor Submittal Data: The following data shall be submitted for all motors:
   a. Full load current and service factor at operating voltage.
   b. Locked rotor current, starting power factor, and power factor at full load.
   c. Efficiency at full load.
   d. Data to substantiate Class F insulation with Class B rise at 100% load.
   e. Capacitor size (KVAR) for maximum power factor correction at 95% lagging.
f. Synchronous and full load speeds (rpm).
g. Enclosure type (ODP, TEFC, EXP, TENV, WPI, etc.)
   Note: All tests (except locked rotor current) shall be made at full voltage and rated frequency.

C. Furnish individual combination type full NEMA-rated starters with HMCB breakers or fused disconnect
   switch for all motors provided (except for starters that are shown to be provided integral within packaged
   equipment, control panels with door mounted disconnects, or in Division 16 motor control centers). All
   combination starters shall be adequately braced for the fault current available. 42,000 AIC @ 480V,
   three-phase and 65,000 AIC @ 208V, three-phase shall be the minimum ratings.
   1. Approved manufacturers are Allen-Bradley Bulletin 500 and General Electric 300 Line.
   2. Enclosures: NEMA Type 1, general purpose enclosures with padlock ears, except in wet locations
      shall be NEMA Type 3R with conduit hubs, or units in hazardous locations that shall have NEC
      proper class and division explosion proof enclosure.
   3. All starters for three-phase motors shall be magnetic complete with the following accessories.
      a. Three-leg Class 10 trip-free electronic overload protection with externally operated manual
         reset and visual trip indicator. Trip setting shall be adjustable with locking cover.
      b. Built-in three-phase voltage monitor to provide quick-trip on single phasing, phase reversal,
         or high/low voltage, manual reset.
      c. Control transformers with fused primary and secondary per NEC.
      d. 120-volt holding coils.
      e. Integral Hand-Off-Auto switch for single-speed motors.
      f. Integral High-Low-Off-Auto switch in starter cover for two-speed starters.
      g. High- to low-speed compelling time delay relay for two-speed starters.
      h. Auxiliary contacts, one normally open and one normally closed minimum.
      i. "Run" pilot light.
   4. Two-speed, two-winding starters shall incorporate both mechanical and electrical interlocks
      between the high- and low-speed contactors and shall have individual overload current protection
      and auxiliary contacts for each speed.
   5. All starters shall be full NEMA-rated. IEC-rated and/or NEMA equivalent rated starters are not
      acceptable. All starters shall be listed and labeled by NEMA, UL, and CSA.
      a. Starters shall have inspectable contacts which are individually replaceable
      b. Magnetic coils shall be encapsulated and easily replaced (disassembly of entire starter shall
         not be required to change out the coil).
   6. Provide complete submittal data for all single- and three-phase starters.
   7. Starters for single-phase motors shall be horsepower-rated thermal overload switches.

D. Furnish all necessary control devices such as speed controls, transformers, and relays as required for
   proper operation of all equipment furnished under this Division.

E. Furnish all remote switches and/or maintained contact pushbutton stations required for manually operated
   equipment complete with low energy pilot lights of an approved type.

F. Motors, starters, and other electrical control equipment installed in moist areas or areas of special
   conditions, such as explosion proof, shall be designed and approved for installation in such areas.

G. Furnish circuit and purpose identification for each remote manual switch and/or pushbutton station
   furnished herein. Identification may be either engraved plastic sign for permanent mounting to wall below
   switch, or stamping on switch coverplate. All such identification signs and/or switch covers in finished
   areas shall match other hardware in the immediate area.

2.6 THROUGH-PENETRATION FIRE STOP MATERIALS
A. Provide fire stopping of all mechanical through penetrations and membrane penetrations of fire-rated assemblies.
   1. Systems or devices listed in the "UL Fire Resistance Directory" under categories XHCR and XHEZ may be used, providing that they conform to the construction type, penetrant type, annular space requirements and fire rating involved in each separate instance, and that the system be symmetrical for wall applications. Systems or devices must be asbestos-free.
   2. Fire stopping shall conform to both Flame (F) and Temperature (T) ratings as required by both local building codes and as tested by nationally accepted agencies per ASTM E814 or UL 1479.
   3. Fire stopping materials shall be selected for the specific application. Materials may be intumescent, latex, or silicone sealants, firestop putty, firestop collars, wrap strips, silicone foam, mortar, pillows, composite board or foaming/damming materials.

B. At rated-wall penetrations, all piping shall be protected with calcium silicate insulation extending at least 1” beyond the wall on both sides.
   1. Thickness shall match the specified insulation thickness (see 15080).
   2. The calcium silicate shall be installed in lieu of the specified insulation for the pipe.

2.7 DIELECTRIC PIPE FITTINGS AND ISOLATORS

A. Manufacturer:
   Perfection Corporation: Dielectric Waterway, Flow Design
   Available from Keystone and Victaulic distributors

B. Dielectric fittings shall conform to ASA B16.8, plated as applicable a minimum of .0005" and have no flow restriction when assembled.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Surveys and Measurements:
   1. Base all measurements, both horizontal and vertical, on established bench marks. All work shall agree with these established lines and levels. Verify all measurements at site and check the correctness of same as related to the work.
   2. If any discrepancy between actual measurements and those indicated is discovered which prevents following good practice or the intent of the drawings and specifications, the Architect shall be notified through the General Contractor, and work shall not proceed until instructions are received from the Architect.

B. Coordination and Cooperation with Other Trades:
   1. The Contractor for this work shall examine the drawings and specifications for other parts of the work, and if head room or space conditions appear inadequate or if any discrepancies occur between the plans and his work and the plans for the work of others, he shall report such discrepancies to the Owner and shall obtain written instructions for any changes necessary to accommodate his work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the Contractor to report such discrepancies shall be made by and at the expense of this Contractor.
   2. Where the mechanical work will be installed in close proximity to, or will interfere with work of other trades, the Contractor shall assist in working out space conditions to make a satisfactory adjustment. If so directed by the Engineer, the Contractor shall prepare composite working drawings and sections at a suitable scale not less than 1/4" = 1'-0", clearly showing how his work is to be installed in relation to the work of other trades. If the Contractor installs his work before
coordinating with other trades, or so as to cause any interference with work of other trades, he shall make the necessary changes in his work to correct the condition without extra charge.

3.2 PREPARATION

A. Old Pipe Lines: If any old sewer, water, gas, or other pipes are encountered which interfere with the proper installation of new work and which will not be used in connections with the new work, close all openings in proper manner or, if necessary, relocate or remove the pipes as shown on plans. Should any old pipes and/or electrical lines not shown on plans be encountered, immediately notify Owner's representative before taking any action.

B. Sleeves and Penetrations:
   1. This Contractor shall be responsible for the cost of cutting and patching walls and floors required for installation of pipes. Each Contractor shall do all drilling required for the installation of his hangers.
   2. Sleeves shall be provided for all mechanical piping passing through concrete floor slabs and concrete, masonry, tile, and gypsum wall construction. Sleeves shall be constructed as follows unless otherwise indicated on the drawings.
      a. Sheet Metal Sleeves: 10-gauge galvanized sheet metal, round tube closed with welded longitudinal joint.
      b. Pipe Sleeves: Schedule 40 galvanized welded steel pipe, ASTM A53, Grade A.
      c. Fill the annular space with an approved joint filler. Floor sleeves shall also be pointed with a joint sealer, struck off at the top of the sleeve to prevent trapping water. Refer to this Section for sealers and materials, Part 2 of this section for sound isolation at mechanical rooms, and Section 15080 for insulation materials.
   3. Sleeves in exterior walls below grade shall be Schedule 40 pipe per Item 2 above. Seals shall be modular mechanical type, consisting of interlocking synthetic rubber links shaped to continuously fill annular space between pipe and sleeve, connected with bolts and pressure plates which cause rubber sealing elements to expand when tightened, providing watertight seal and electrical insulation.
   4. Where pipe motion due to expansion and contraction will occur, make sleeves and penetrations of sufficient diameter to permit free movement of pipe. Where sleeves and penetrations pass insulated pipes, the opening shall be large enough to pass the pipe only and the insulation shall be made to butt against the construction except for pipes requiring insulation having a vapor barrier, in which case, the opening shall be large enough to pass the pipe and insulation. Check floor and wall construction finishes to determine proper length of sleeves for various locations and make actual lengths to suit the following:
      a. Terminate sleeves flush with walls, partitions, and ceiling.
      b. In areas where pipes are concealed (as in chases or within walls) or exposed, extend sleeves 1/2 inch above the finished floor. In rooms having floor drains, or where the penetration occurs in a wall or chase adjacent to such a room, the sleeves shall be extended 2 inches above the finished floor.
   5. Fasten sleeves securely in floors and walls, so they will not become displaced when concrete is poured or when other construction is built around them. Take precautions to prevent concrete, plaster, or other materials from being forced into the space between pipe and sleeve during construction.

C. Scaffolding, Rigging, and Hoisting: Provide all scaffolding, rigging, hoisting, and services necessary for delivery, erection, and placement within the premises of any equipment and apparatus furnished. Remove same from premises when no longer required.
D. Delivery and Storage of Materials: Make provisions for the delivery and safe storage of materials and make the required arrangements with other contractors for the introduction into the building of equipment too large to pass through finished openings.

3.3 INSTALLATION

A. General:
1. Unless otherwise specifically indicated on the plans or specifications, all equipment and materials shall be installed in accordance with the recommendations of the manufacturer. Maintain maximum head room and space conditions at all points.
2. Coordinate work with other trades prior to fabrication and installation of equipment, piping, and ductwork. Adjust ductwork and piping to fit into space available.

B. Equipment Installation:
1. Install equipment, accessories, and services to permit easy access to filters, motors, drives, and other items requiring maintenance. Relocation of equipment connections required to permit normal maintenance shall be accomplished at no additional cost to the Owner.
2. Provide housekeeping pads for all floor-mounted mechanical equipment (pumps, air handlers, water heaters, boilers, chillers, tanks, etc.). Pads shall be 4 inches high minimum; coordinate size and location with General Contractor.
3. All equipment installed on housekeeping pads shall be anchored with anchors which extend through the pad into the floor. Refer to details on the architectural and structural drawings.
4. Locate access doors to allow for maintenance or operation of concealed motors, valves, control devices, or specialties. Refer to Division 8.
5. Coordinate work with other trades with respect to access panel locations and, wherever practical, group mechanical and electrical equipment in such a way as to be accessible from a single panel to reduce number of doors required.
6. Make final piping connections to equipment with shutoff valves and unions or flanges to permit dismantling. Locate unions or flanges to allow coil removal. Provide flexible connectors for pipe connections to isolated equipment. Refer to Section 15070, "Mechanical Sound and Vibration Control."
7. Install removable protective covers (guards) at rotating or reciprocating parts per OSHA requirements. Provide openings in covers to allow measurement of rpm.
8. Install equipment vibration isolation as specified.

C. Piping Installation:
1. General:
   a. Piping shall be installed as shown on the drawings insofar as practical. When a pipe size is not indicated, the subcontractor shall request the pipe size from the Architect/Engineer.
   b. Install piping to conform to building conditions, offsetting to clear structural members and cuts. Run in furred spaces wherever possible. Run exposed piping parallel or at right angles to the building walls and as high as possible.
   c. Install pipe anchors, hangers, and guides as necessary to provide piping systems which are self-supporting and not dependent upon connection to equipment. All piping shall be adequately supported from the building structure with adjustable hangers to maintain uniform grading where required and to prevent sagging and pocketing.
   d. Prevent interference between piping and doors, windows, aisles, and passageways. Excessive cutting or other weakening of the building structure to facilitate piping installation will not be permitted.
   e. Allow flexibility in the erection of the piping system to prevent excessive stresses in materials and joints due to thermal expansion or equipment vibration. Provide sufficient swing joints, anchors, expansion loops, expansion joints, and/or devices as necessary, and install so as to permit free expansion and contraction without causing undue stresses. Make
all changes in direction with fittings. Support piping independently at all equipment so that its weight shall not be supported by the equipment. Provide bracing where necessary to prevent swaying.

1) Install manual air vents at high points of all piping consisting of a line size nipple - 6 inches long for an air collection chamber, pipe cap on top of nipple with 1/4-inch top, 1/4-inch copper tubing with gauge cock. Locate gauge cock at accessible location and anchor to adjacent pipe or wall. Provide access panels as required for access.

f. Provide pipe shields and insulated supports as specified in Part 2 of Section 15060, "Hangers and Supports," for all insulated piping, with continuous vapor barrier for all cold piping systems.

g. Provide shutoff valves and unions or flanges to isolate each item of equipment, branch circuit, or section of piping. Unions shall be provided at each screwed valve (manual or automatic) and at all equipment having screwed connections.

h. Arrange piping and valves near each piece of equipment to allow complete service and maintenance of the equipment without disturbing the shutoff valves.

i. Install all automatic temperature control valves furnished by the Temperature Controls Contractor.

j. Provide 1/2-inch hose end ball valves at all low points of each system to enable complete system drainage.

k. Provide dielectric waterways at all junctions of dissimilar metals in all water and glycol piping systems.

l. Use full lengths of pipe; short lengths with couplings will not be permitted. All pipe sections shall be de-burred to full I.D. before joining.

m. Allow for pipe insulation without cutting pipe or fitting coverings.

n. Extend chains for valve operators to 6'-6" above the floor or platform. Brace extension handles and provide a means of indicating open and closed positions.

o. Provide thermowells for thermometers and temperature control sensors in piping, installed where noted on the drawings.

p. Extreme care shall be exercised during construction to prevent all dirt and other foreign matter from entering the pipe or other parts of the system. Pipe stored on the project shall have the open ends capped and equipment shall have all openings fully protected. Before erection, each piece of pipe, fitting, or valve shall be visually examined and all dirt removed.

2. Pipe Joints:

a. Fabricate piping in accordance with the latest applicable sections of ASME Standard Code for Pressure Piping B31 and as more specifically defined herein.

b. Steel Pipe:

1) Weld-O-Let or Thread-O-Let type fittings may be used in lieu of tees for branch connections provided the main is at least one size larger than the takeoff.

2) Couplings or half couplings may be used at non-flow connections such as for thermometers and temperature sensor wells.

3) Threaded connections shall be tapered pipe threads in accordance with ANSI B2.1. Cut threads full and clean using sharp dies. Ream threaded ends to remove burrs and restore full inside diameter. Apply pipe joint lubricant or sealant suitable for the service for which the pipe is to be used on male threads at each joint and tighten joint to leave not more than three threads exposed.

4) Install flanges or unions on all valves, apparatus, and equipment. Clean flange faces and install gaskets. Tighten bolts to torque specified by manufacturer of flange and flange nuts and bolts to provide uniform compression of gaskets.

c. Non-Ferrous Metallic Pipe Joints:

1) Brazed and Soldered Joints: For copper tube and fittings, solder all joints, except for refrigeration piping, in accordance with applicable sections of the CDA Copper
Tube Handbook using a lead-free solder rated for pressures up to 10,000 psi. Braze all refrigeration piping joints in accordance with applicable sections of the CDA Copper Tube Handbook.

d. Joints for other piping materials are specified within the respective piping system sections.

3. Welding:
   a. All welding on piping, including tack welding, shall be performed by welders currently qualified and certified for the applicable welding process. See Part I of this section. A file shall be maintained for examination upon request of all qualified weld procedures and the names of the qualified welders performing this work.
   b. Examine the inside of each length of piping to make sure it is free from dirt and obstructions. If obstructed in any way, the pipe shall be swabbed out before being incorporated into the system.
   c. Before and after piping fabrication, all flanges, threaded connections, and beveled pipe ends shall be protected with end protectors and suitable grease to prevent corrosion and damage until installed into the system.
   d. Before welding, the end of the pipe and fittings shall be cleaned of rust, scale, dirt, grease, protective coating, or other foreign matter which might affect the quality of the welds.
   e. When pipes of different wall thicknesses are to be welded together, the end of the thicker pipe shall be smoothly tapered to the wall thickness of the thinner pipe. The taper angle shall not be more than 30° from the axis of the pipe.
   f. Before welding, the piping shall be aligned as required in ASME Code for Pressure Piping B31.
   g. Pipe, flanges, and fittings damaged during fabrication or shipment shall be repaired or replaced, as specified by the Engineer. Any damaged section shall be removed from the job site.
   h. The necessity of preheating of welds and the temperature used are a requirement of the weld procedure. If the metal temperature is below 32°F, local preheating to a temperature warm to the hand is required for materials which otherwise do not require preheating.
   i. The preparation of butt welding ends of pipe, welding neck flanges, pipe fittings, and any other piping component, including valves which are butt welded into the piping system, shall be in accordance with ANSI B16.25 with the following exceptions:
      1) No permanent backing rings shall be used.
      2) Use of consumable inserts is permitted and encouraged as a means of obtaining required weld quality.
   j. Spacers may be used in fitting up pipe and weld fittings for tack welding to a proper gap for full penetration welds. Small tack welds which penetrate to the bottom of the welding groove shall be used. Tack welds lacking full penetration are not acceptable and shall be removed.
   k. All pipe welds that allow visual inspection on the inside and that can be reached by hand shall be inspected by the welder immediately after welding, and the following action shall be taken:
      1) Weld spatter, flux, and debris shall be removed.
      2) Excessive penetration shall be removed by grinding.
      3) Areas without penetration or fusion shall be ground to sound-metal and repair welded.
   l. Cleaning of excessive flux shall be performed between welding passes using wire brushing or grinding.
   m. Flanges welded to pipe spools shall be oriented with the bolt-holes straddling the centerlines established on the piping drawings. Take precautions throughout fabrication not to mar the gasket face on flanges.

4. Non-metallic Piping Systems: Make connections and joints per appropriate piping standards. Refer to appropriate sections for acceptable materials, joining, and installation methods.
D. Mechanical Wiring:
1. Provide all temperature control wiring, all interlock wiring, and equipment control wiring for the equipment that is to be provided under this Division unless specifically shown on electrical drawings.
2. All line voltage interlock and control wiring shall be not less than No. 14 insulated color-coded wire in conduit or raceway. Conductors shall be labeled at both ends.
3. Refer to Division 1, "Coordination," and Division 16 for further information.
4. See Section 15950, "Controls," for temperature control wiring responsibilities.

E. Waterproofing:
1. Where any work pierces waterproofing, including waterproof concrete, the method of installation shall be as approved by the Architect before work is done. Contractor shall furnish all necessary sleeves, caulking, and flashing required to make openings absolutely watertight.
2. Flashing of all building penetrations to the outside shall be per applicable codes and standards. Refer to appropriate sections for acceptable materials and methods.

F. Guards: Provide removable OSHA guards for all belt drives and exposed rotating machinery.

G. Escutcheon Plates: Escutcheon plates shall be provided for all exposed pipes passing through walls, floors, and ceilings. Plates shall be nickel-plated of the split-ring type of size to match the pipe or conduit. Where plates are provided for pipes passing through sleeves which extend above the floor surface, provide deep recessed plates to conceal the pipe sleeves.

H. Roof Penetrations: Contractor shall coordinate with and assist the roofing contractor with all Division 15 roofing penetrations. All penetrations of the roof and all support legs for mechanical equipment, pipes and/or ducts mounted on the roof shall be in accordance with the roof manufacturer’s instructions. Provide counterflashings on all curbs and supports in accordance with roofing details.

I. Supporting Steel:
1. Provide structural steel framework for supporting mechanical equipment when required.
2. All steel work shall be in conformance with the requirements of the AISC Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings. Material shall conform to ASTM A36.
3. Bases and supports shall be constructed as detailed on approved shop drawings provided by the Contractor.
4. All structural steel shall receive one coat of industrial enamel primer in the shop after all fabrication welding is complete. Paint all field joints with one coat of industrial enamel primer. After all steel is properly primed, paint with two coats of exterior grade enamel. Color as selected by the Architect.

J. Accessibility: Locate all equipment which must be serviced, operated, or maintained in fully accessible positions. Equipment shall include, but not be limited to, valves, traps, clean-outs, motors, controllers, switchgear, and drain points. If required for accessibility, furnish access doors for this purpose. Minor deviations from drawings may be made to allow for better accessibility. Install all control devices in "Readily Accessible" locations as defined by Chapter 1, Article 100, of the most recent issue of the National Electrical Code.

K. Painting: Paint fabricated hangers and frames, unpainted equipment, and uninsulated exposed piping (interior and exterior) with one coat of primer and two coats of flat enamel paint in a color as selected by the Architect/Engineer.
L. Through-Penetration Fire Stops: Install firestop materials around ducts and/or pipes passing through all fire-rated walls and floors. Install materials in strict accordance with manufacturers' instructions and the "UL Fire Resistance Directory."

3.4 REPAIR/RESTORATION

A. Damaged Surfaces: At the completion of work, all mechanical equipment furnished under this contract shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any metal cabinet, jacket, or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

B. Cleanup:
1. At the completion of the work, all equipment on the project shall be checked and thoroughly cleaned including coils, plenums, under equipment and any and all other areas around or in equipment provided under this section. Clean all exposed surfaces of all piping, hangers, ducts, and other exposed metal of all grease, plaster, or other foreign material. Remove all stick-on labels and clean surfaces.
2. At the completion of the work, remove from the building, the premises, and surrounding streets, alleys, etc., all rubbish and debris resulting from this project and leave all equipment spaces absolutely clean and ready for use.
3. Any air or water filters used during construction shall be replaced with new filters during final cleanup.

3.5 FIELD QUALITY CONTROL

A. Responsibility of Contractor: The Contractor is responsible for the complete and satisfactory installation of the work in accordance with the true intent of the drawings and specifications. He shall provide, without extra charge, all incidental items required as a part of his work, even though not particularly specified or indicated. The installation shall be so made that its several component parts will function together as a workable system and shall be left with all parts adjusted and in working order.

3.6 CLEANING

A. Cleaning and Flushing:
1. All water circulating systems for the project shall be thoroughly cleaned before placing in operation to rid the system of dirt, piping compound, mill scale, oil, and any and all other material foreign to the water being circulated.
2. Extreme care shall be exercised during construction to prevent all dirt and other foreign matter from entering the pipe or other parts of the system. Pipe stored on the project shall have the open ends capped and equipment shall have all openings fully protected. Before erection, each piece of pipe, fitting, or valve shall be visually examined and all dirt removed.
3. Coordinate with Central Cooling Plant for cleaning, flushing and testing procedures.

3.7 PROTECTION

A. The Contractor shall protect all work and material from damage by his work or workmen, and shall be liable for all damage thus caused.
B. The Contractor shall be responsible for work and equipment until finally inspected, tested, and accepted; he shall protect work against theft, injury, or damage; and shall carefully store material and equipment received on site which is not immediately installed. He shall close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.
SECTION 15055 - VARIABLE SPEED CONTROLLERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: This section covers the general requirements for variable speed controllers (VSCs) for mechanical equipment.

B. Related Sections: Drawings and general provisions of the contract, including General and Supplementary Conditions, Division 1 Specification Sections, and Section 15050 apply to this section.
   1. Division 15 Sections for application of VSCs and reference to specific VSC requirements for motor-driven equipment.
   2. Section 15050, "Basic Mechanical Materials and Methods," for basic materials and methods and electrical equipment.
   3. Section 15950, "Instrumentation and Controls," for interface requirements to instrumentation and controls.
   4. Section 15990, "Testing, Adjusting, and Balancing," for calibration and set-up requirements.
   5. Section 15995, "System Starting/Commissioning," for commissioning requirements.
   6. Division 16 Sections for installation, wiring materials, and procedures.

1.2 SYSTEM DESCRIPTION

A. Performance Requirements:
   1. Compatibility: The drive shall be totally compatible with the type of load it shall power and control. The supplier of the drive equipment shall coordinate and insure this compatibility. Refer to NEC Table 430-150 for minimum drive amp requirements for various motor hp ratings.
   2. All VSC drives furnished per this section shall be of one manufacturer (furnished and serviced by one local vendor) regardless of the application (fans, pumps, etc.).

1.3 SUBMITTALS

A. Refer to Division 1 and Section 15050 for general requirements.

B. Product Data: Calculations and harmonic analysis as necessary to show compliance with the latest version of IEEE standards 519.

C. Shop Drawings: Outline drawings showing dimensions, sizes, weights, component locations, etc.

D. Wiring Diagrams:
   1. Connection diagrams identifying line, load, and external control connection points. Terminal and conductor identification shall correspond to power and control schematics submitted under other sections.
   2. Internal wiring diagrams showing internal components and associated interconnections. Drawings shall be sufficiently complete to allow the Engineer to determine compliance with specifications.

E. Quality Assurance/Control Submittals:
   1. Provide signed-off checklist and certification of full load performance specified under "Source Quality Control," this section.

F. Closeout Submittals: Operation and Maintenance Manual shall include:
1. Complete technical description of operation of the unit
2. Complete setup instructions
3. Troubleshooting guide
4. Complete parts list with part number identification
5. A list of recommended spare parts with pricing

1.4 QUALITY ASSURANCE

A. Regulatory Requirements:
   1. Refer to Section 15050 for general code, standard, and regulatory requirements.
   2. Standards: Chemical and physical properties of materials, performance characteristics, and methods of construction shall be in accordance with applicable sections of the following references and standards of current editions in effect 90 days prior to receipt of bids:
      a. IEEE 519-1992 Harmonic Distortion Standards

B. Certificates: Unit shall be UL and/or ETL Testing Laboratory listed.

1.5 WARRANTY

A. Provide three (3) year warranty for VSC's. Refer to Section 15050 for general warranty requirements.

1.6 SYSTEM START-UP

A. The VSC vendor shall provide, as a minimum, the following services:
   1. Service of certified factory-trained representative to supervise startup, adjustment, and fine-tuning of all VSC drives and to instruct Owner on proper operation and maintenance procedures.
   2. Each VSC manufacturer shall have a local representative specifically trained in troubleshooting and service and repair of its VSC. A statement of the length and extent of experience of the local service organization shall be included with the submittals.

1.7 OWNER'S INSTRUCTIONS

A. The variable frequency drive (VSC) vendor shall provide, as a minimum, the following services:
   1. Training of user personnel in basic troubleshooting. Training shall be on-site, shall be a minimum of one day's duration, and shall be performed in addition to startup of system.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Approved manufacturers:
   ABB
   Mitsubishi
   Reliance
   Robicon
   Toshiba
   Cutler-Hammer
   All are subject to full compliance with this specification.

2.2 VARIABLE FREQUENCY DRIVE

A. Variable Frequency Motor Control:
1. The control shall be PWM type and shall produce a three-phase output capable of providing efficient operation of standard NEMA, Design B, C, or E, induction motors.

2. The control shall consist of a power section made up of a fixed AC to DC converter, a fused filter, storage network, and an inverter, using either bipolar transistors or IGBTs in the power switching section. The drive shall incorporate power factor correction features as required to provide for a power factor of .95 or better at design load. The power section shall be isolated from the control section between the driver output of the control printed circuit card and the power switching devices.

3. Drives shall have a logic control section that is microprocessor based, using a 16- or 32-bit processor and LSI for minimum part count and maximum reliability.

4. Each VSC shall be provided with a two-line backlit liquid crystal display. During normal operation, the display shall simultaneously show the VSC mode of operation, VSC status, VSC speed, and VSC load (amps). If a fault occurs, the reason shall be displayed as an English message such as “OUTPUT OVERLOAD” rather than fault codes.

5. A digital keypad shall be provided to facilitate entry of all adjustments. All parameters shall be selected by clear English messages on the LCD screen, and shall be entered in engineering units. VSCs utilizing LED displays will not be considered equal to the type specified.

6. The drive shall use line reactors for motor noise and line harmonic reduction.

B. Specification:

1. NEMA 1 cabinet enclosure with a steel gasketed hinged door. Manual control and programming devices shall be door-mounted or accessible without opening door.

2. Input power: 460-volt, three-phase, 60 Hz or as noted on drawings.
   a. Nominal input voltage +/- 10%
   b. +/- 3% input frequency stability

3. Voltage harmonic distortion requirements:
   a. All VSCs shall meet the requirements as outlined in IEEE-519-1992 for individual and total harmonic voltage distortion. Individual or simultaneous operation of the VSCs shall not add more than 3% total harmonic voltage distortion to the normal bus. The point of common coupling shall be at the MCC bus or panelboard bus to which the VSC is connected. The short circuit current at point of common coupling under utility operation is as shown on the electrical one-line diagrams.
   b. If harmonic filters are required to meet these requirements, the VSC manufacturer must provide the filters and is responsible for the design and manufacturing of the filters. A full harmonic analysis must be submitted by the VSC manufacturer with the submittal package, which includes all harmonics up to the 50th. Analysis shall include computer-generated waveforms, a statement of all assumptions, a one-line diagram of the system as analyzed, and a spectrum analysis showing individual harmonics along with a statement showing compliance with the standards.

4. Comply to FCC Subpart J of Part 15 for Class A computing device from 7 mHz to 30 mHz for conduction limit without external modification.

5. Output Power: Three-phase, 6 to 60 Hz with variable voltage to give proper and efficient operation of variable torque load and capable of providing up to 110% startup torque.

6. Overload capacity minimum of 110% for one minute.

C. Provide an H-O-A switch and manual speed adjuster, door-mounted. The VSC drive shall be operable in three modes. In the “HAND” mode, the unit shall start and run at a speed as set on the manual speed adjuster. In the “AUTO” mode, the unit shall start in response to a contact closure and run at a speed established by a remote analog control signal. In the “OFF” modes, the run circuit shall be open and the VSC will not operate.

D. Minimum Requirements for Control Operation and Service:

1. Separate enclosures for the VSC and the bypass panel, reference item 2.3.
2. Digital annunciated fault and limit functions for:
   a. Thermal overload relay trip
   b. Microprocessor self-check function
   c. Output overcurrent trip
   d. DC bus overvoltage trip
   e. Inverse time overload trip
   f. Heat sink overtemperature trip
   g. DC bus fuse open
   h. DC bus overvoltage (regen. limit)
   i. Output ground fault
   j. Output line-to-line fault

3. Last 10 faults minimum shall be retained in memory for operator recall.

4. Isolated binary input circuits for:
   a. External safety lockout device
   b. Remote Run/Stop command

5. Isolated binary output circuits for:
   a. Remote VSC fault trip alarm
   b. VSC Run/Stop status
   c. VSC Auto/Manual mode status

6. Analog output signals for:
   a. 4-20 mA or 0-10 Vdc output for VSC speed
   b. 4-20 mA or 0-10 Vdc output for VSC load

E. Minimum Required Standard Features:

1. Door-mounted or visible components:
   a. VSC fault indication
   b. Alphanumeric liquid crystal display
   c. Input keypad for parameter input and display selection
   d. Manual speed adjustment means
   e. Hand/Off/Auto VSC selector

2. Provide the following VSC control features:
   a. Adjustable current limit circuit to prevent nuisance tripping during acceleration or run conditions.
   b. Active regeneration limit circuit to prevent nuisance overcurrent tripping during deceleration.
   c. Input power single-phasing and/or reverse-phasing protection.
   d. Minimum and maximum speed adjustments, separate and non-interactive.
   e. Power loss restart selectable for Auto Restart in auto mode only.
   f. Automatic restart from undervoltage, power failure, or control fault. If auto restart is unsuccessful after a maximum of five attempts, the drive shall shut down and require a manual reset/restart.
   g. Critical frequency lockout for up to three points, available from 10 to 100% speed with an adjustable band width.
   h. Provide I2t fuses or other protection for power-handling components. Control shall survive load side short circuits without component failure, and shall annunciate output phase-to-phase and phase-to-ground faults.
   i. Volts-per-hertz ratio shall be automatic, tracking motor load requirements to achieve most efficient operation within the parameters selected.

3. To reduce possible acoustical noise and electrical interference, drive control shall have an automatically variable carrier frequency of at least 1,600 to 8,000 Hz. There shall be no sudden frequency shifts which cause acoustical noise increases.
4. Complete system (drive and motor) dBA sound level shall not exceed bypass (60 Hz building power) sound level by more than 10%. Sound tests will be performed during startup; and corrective actions needed shall be at the expense of the VSC supplier.

5. Control must be capable of starting into a spinning motor, and also switching from inverter to bypass back to inverter without tripping off line. Must also be capable of stopping a motor rotating in the reverse direction and then accelerating that motor in the proper direction.

6. Control shall have a 4-20 mA or 0-10 Vdc isolated instrument control signal follower. Isolation shall be either optical or transformer type. Manufacturer shall include documentation with submittals that confirm the follower is isolated type.

7. All VSC drive components must be supplied in an integral NEMA 1 or better metal enclosure.

8. All drives shall carry ETL or UL nationally recognized testing laboratory approval.

2.3 BYPASS PANEL

A. The fixed-speed bypass panel shall be mounted and wired in a separate compartment from the VSC, and shall allow constant 60 Hz operation of the controlled motor while the VSC is out of service. The bypass components shall be mounted in a NEMA 1, gasketed enclosure with terminals for field connection to the three-phase power, the controlled motor, and the temperature control interface.

1. Cabinet door(s) where either door dimension is greater than 30 inches shall use 14-gauge or heavier steel with at least three hinges and one lock per door.

2. Provide a door interlocked main disconnect switch which shall kill all power to both the VSC and the bypass panel. Bypass motor and manual control devices shall be mounted inside the cabinet.

3. The prewired bypass panel shall include:
   a. A VSC output contactor and a constant speed bypass contactor, mechanically and electrically interlocked.
   b. A three-pole thermal motor overload relay with heaters connected to shut down the motor in both the VSC and bypass modes.
   c. Input 3-phase line reactors and I2 + buses.
   d. A VSC disconnect or transfer switch shall allow power-off maintenance of the VSC while the motor operates on bypass. Bypass circuitry in the same compartment as the VSC will not be allowed, and an input contactor to the VSC will not be considered equal to the VSC disconnect or transfer switch specified. This switch is in addition to the entire unit disconnect specified previously in Paragraph 2.
   e. A 120-volt control power transformer with fused secondary.
   f. Control relays as necessary to allow for remote start/stop, and remote safety interlocks.
   g. An interlock to allow a controlled VSC deceleration ramp to stop.
   h. An adjustable delay relay (1 to 30 seconds) to prevent rapid switching between bypass and VSC modes.

4. Door-mounted or visible status indicators:
   a. Power-on light
   b. Safety lockout indication
   c. Inverter run indication
   d. Bypass run light
   e. Furnish only non-filament type indicating lights.

5. A manual selector switch shall provide for the following operating mode:
   a. A manual, four-position oil-tight type “VSC-OFF-BYPASS (REMOTE)-BYPASS (TEST)” control selector switch shall be provided on the bypass compartment door. In VSC mode, the output of the VSC shall be connected to the motor allowing variable speed operation. OFF shall inhibit all motor operation. BYPASS (REMOTE) shall allow remote automatic control of the motor across the line from the same building automation system control contact that starts and stops the unit in VSC mode. BYPASS (TEST) shall start the motor across the line. Control relay(s) necessary to interface the single auto-start contact shall be provided.
2.4 SOURCE QUALITY CONTROL

A. The following quality assurance factory tests and procedures shall be conducted on the drive and its components prior to shipment.
   1. Solid-state components shall be load-tested to ensure correct function and highest reliability. Provide “signed off” checklist.
   2. Every controller will be functionally tested under designed motor load for at least two hours with written certification to ensure that if the drive is started up according to the instruction manual provided, the unit will run properly.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General: The drives shall be installed, wired, tested, and calibrated in cooperation with Section 15950 'Instrumentation and Controls', Section 15990, 'Testing, Adjusting, and Balancing,' Section 15995, "System Starting/Commissioning," and Division 16 requirements.

B. Provide one complete spare set of all fuses used in each VSC supplied.

END OF SECTION 15055
PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: This section covers hangers and supports for mechanical system piping and equipment.

B. Related Sections: Drawings and general provisions of the contract, including General and Supplementary Conditions, Division 1 Specification Sections, and Section 15050, "Basic Mechanical Materials and Methods," apply to this section.
   1. Division 15 piping and equipment sections for additional piping support and additional equipment support requirements.
   2. Section 15050, "Basic Mechanical Materials and Methods," for basic materials and methods and electrical equipment.
   3. Section 15070, "Mechanical Sound and Vibration Control," for additional mechanical sound and vibration control support requirements.
   4. Section 15080, "Mechanical Insulation," for insulation inserts to protect insulation.
   5. Section 15110, "Valves," for additional valve support requirements.
   6. Section 15120, "Piping Specialties," for additional piping specialties support requirements.

1.2 DEFINITIONS

A. MSS: Manufacturers Standardization Society for the Valve and Fittings Industry.

B. Terminology: As defined in MSS SP-90, “Guidelines on Terminology for Pipe Hangers and supports.”

1.3 PERFORMANCE REQUIREMENTS

A. Design heavy-duty steel channel trapezes to support multiple pipes. Trapezes shall be capable of supporting combined weight of supported systems, system contents and/or test water.

1.4 SUBMITTALS

A. Refer to Division 1 and Section 15050, "Basic Mechanical Materials and Methods," for general requirements.

B. Product Data:
   1. Provide submittal data for:
      a. Each type of pipe hanger, channel support system component, and thermal-hanger shield insert used.
      b. Shop Drawings: Signed and sealed by a qualified professional engineer for multiple piping supports and trapeze hangers which exceed prescriptive requirements. Provide point loads of for each designed hanger or support.

C. Quality Assurance/Control Submittals: Welding Certificates: Submit copies of certificates for welding procedures and operators. Reference Section 15050.

1.5 QUALITY ASSURANCE

A. Qualifications:
1. Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."

2. Engineering Responsibility: Design and preparation of shop drawings and calculations for each multiple pipe support and trapeze, by a qualified professional engineer.

3. Professional Engineer Qualifications: A professional engineer who is legally qualified to practice in jurisdiction where Project is located and who is experienced in providing engineering services of the kind indicated. Engineering services are defined as those performed for installations of hangers and supports for ductwork, piping and equipment systems.

B. Regulatory Requirements:
   1. Refer to Section 15050, "Basic Mechanical Materials and Methods," for general code, standard, and regulatory requirements.
   2. Chemical and physical properties of materials, performance characteristics, and methods of construction shall be in accordance with applicable sections of the following references and standards of current editions in effect 90 days prior to receipt of bids:
      a. Manufacturer's Standardization Society (MSS)

1.6 SCHEDULING

A. Plan the work so that it proceeds with a minimum of interference with other trades. Inform the General Contractor of space requirements for hangers and supports and coordinate mechanical equipment locations with the Structural Shop Drawings.

1.7 WARRANTY

A. Refer to Section 15050, "Basic Mechanical Materials and Methods," for general warranty requirements.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   1. Pipe Hangers:
      a. B-Line Systems, Inc.
      b. Grinnell Corp.
      c. Michigan Hanger Co., Inc.
      d. PHD Manufacturing, Inc.
      e. Tolco
   2. Channel Support Systems:
      a. B-Line Systems, Inc.
      b. Grinnell Corp.; Power-Strut Unit
      c. Michigan Hanger Co., Inc.; O-Strut Division
      d. Thomas & Betts Corp.
      e. Unistrut Corp.
   3. Thermal-Hanger Shield Inserts:
      a. Carpenter & Patterson, Inc.
      b. Michigan Hanger Co., Inc.
      c. Pipe Shields, Inc.
      d. Value Engineered Products, Inc.
   4. Powder-Actuated Fastener Systems:
      a. Hilti, Inc.
b. ITW Ramset/Red Head

c. Masterset Fastening Systems, Inc.

2.2 MANUFACTURED UNITS

A. Pipe Hangers, Supports, and Components: MSS SP-58, factory-fabricated components. Refer to "Hanger and Support Applications" Article in Part 3 for where to use specific hanger and support types.

B. Galvanized: All components G60 galvanized.

C. Nonmetallic Coatings: For electrolytic protection where attachment devices are in direct contact with copper tubing.

D. Factory-applied paint for outdoor use.

E. Channel Support Systems: MFMA-2, factory-fabricated components for field assembly.
   1. Coatings: All components G60 galvanized.
   2. Non-metallic Coatings: For electrolytic protection where attachment devices are in direct contact with copper tubing.

F. Thermal-Hanger Shield Inserts: 100-psi minimum compressive-strength insulation, encased in sheet metal shield. Use higher compressive-strength inserts as required for large pipe sizes.
   1. Material for Cold Piping: ASTM C 552, Type I cellular glass or water-repellent-treated, ASTM C 533, Type I calcium silicate with vapor barrier.
   2. Material for Hot Piping: ASTM C 552, Type I cellular glass or water-repellent-treated, ASTM C 533, Type I calcium silicate.
   3. For Trapeze or Clamped System: Insert and shield cover entire circumference of pipe.
   4. Clevis or Band Hanger: Insert and shield cover lower 180 degrees of pipe.
   5. Insert Length: Extend 2 inches (50 mm) beyond sheet metal shield for piping operating below ambient air temperature.
   6. Individual component parts shall not exceed a flame and smoke rating of 25/50.

2.3 MISCELLANEOUS MATERIALS

A. Powder-Actuated Drive-Pin Fasteners: Powder-actuated-type, drive-pin attachments with pull-out and shear capacities appropriate for supported loads and building materials where used.

B. Mechanical-Anchor Fasteners: Insert-type attachments with pull-out and shear capacities appropriate for supported loads and building materials where used.

C. Structural Steel: ASTM A 36/A 36M, steel plates, shapes, and bars, black and galvanized.

D. Grout: ASTM C 1107, Grade B, factory-mixed and -packaged, nonshrink and nonmetallic, dry, hydraulic-cement grout.
   1. Characteristics: Post hardening and volume adjusting; recommended for both interior and exterior applications.
   3. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT APPLICATIONS
A. Comply with MSS SP-69 for pipe hanger selections and applications that are not specified in piping system Specification Sections.

B. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Specification Sections, install the following types:
1. Adjustable Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated stationary pipes, 1/2-inch to 30-inch.
2. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of 120 to 450°F (49 to 232°C) pipes, 4-inch to 16-inch), requiring up to 4 inches of insulation.
3. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes, 3/4-inch to 24-inch, requiring clamp flexibility and up to 4 inches of insulation.
4. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes, 1/2-inch to 24-inch, if little or no insulation is required.
5. Pipe Hangers (MSS Type 5): For suspension of pipes, 1/2-inch to 4-inch, to allow off-center closure for hanger installation before pipe erection.
6. Adjustable Swivel Split- or Solid-Ring Hangers (MSS Type 6): For suspension of noninsulated stationary pipes, 3/4-inch to 8-inch.
7. Adjustable Steel Band Hangers (MSS Type 7): For suspension of noninsulated stationary pipes, 1/2-inch to 8-inch.
8. Adjustable Band Hangers (MSS Type 9): For suspension of noninsulated stationary pipes, 1/2-inch to 8-inch.
9. Adjustable Swivel-Ring Band Hangers (MSS Type 10): For suspension of noninsulated stationary pipes, 1/2-inch to 2-inch.
10. Split Pipe-Ring with or without Turnbuckle-Adjustment Hangers (MSS Type 11): For suspension of noninsulated stationary pipes, 3/8-inch to 8-inch.
11. Extension Hinged or Two-bolt Split Pipe Clamps (MSS Type 12): For suspension of noninsulated stationary pipes, 3/8-inch to 3-inch.
12. U-Bolts (MSS Type 24): For support of heavy pipe, 1/2-inch to 30-inch.
13. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
14. Pipe Saddle Supports (MSS Type 36): For support of pipes, 4-inch to 36-inch, with steel pipe base stanchion support and cast-iron floor flange.
15. Pipe Stanchion Saddles (MSS Type 37): For support of pipes, 4-inch to 36-inch, with steel pipe base stanchion support and cast-iron floor flange and with U-bolt to retain pipe.
16. Adjustable Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes, 2-1/2-inch to 36-inch), if vertical adjustment is required, with steel pipe base stanchion support and cast-iron floor flange.
17. Single Pipe Rolls (MSS Type 41): For suspension of pipes, 1-inch to 30-inch, from two rods if longitudinal movement caused by expansion and contraction might occur.
18. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes, 2-1/2-inch to 20-inch), from single rod if horizontal movement caused by expansion and contraction might occur.
19. Complete Pipe Rolls (MSS Type 44): For support of pipes, 2-inch to 42-inch, if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.
20. Pipe Roll and Plate Units (MSS Type 45): For support of pipes, 2-inch to 24-inch (DN50 to DN600), if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is not necessary.
21. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes, 2-inch to 30-inch, if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

C. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Specification Sections, install the following types:
University of Colorado at Boulder  
Music Building Delta-P Valve Upgrade Project (MUS-Delta P, CP133892)

1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers, 3/4-inch to 20-inch.
2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers, 3/4-inch to 20-inch, if longer ends are required for riser clamps.

D. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Specification Sections, install the following types:
1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.
2. Steel Clevises (MSS Type 14): For 120 to 450°F piping installations.
3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
4. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
5. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450°F piping installations.

E. Building Attachments: Unless otherwise indicated and except as specified in piping system Specification Sections, install the following types:
1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joist construction to attach to top flange of structural shape.
3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
6. C-Clamps (MSS Type 23): For structural shapes.
7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
8. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
9. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
11. Malleable Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
12. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:
   a. Light (MSS Type 31): 750 lb.
   b. Medium (MSS Type 32): 1,500 lb.
   c. Heavy (MSS Type 33): 3,000 lb.
13. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where head room is limited.

F. 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.
G. Spring Hangers and Supports: Schedule pre-compressed spring hanger settings to accommodate additional weight of water when piping systems are filled. Unless otherwise indicated and except as specified in piping system Specification Sections, install the following types:

1. Restraint-control Devices (MSS Type 47): Where indicated to control piping movement.
2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches (32 mm).
3. Spring-cushion Roll Hangers (MSS Type 49): For equipping Type 41 roll hanger with springs.
4. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
5. Variable-spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from hanger.
6. Variable-spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from base support.
7. Variable-spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from trapeze support.
8. Constant Supports: For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types:
   a. Horizontal (MSS Type 54): Mounted horizontally.
   b. Vertical (MSS Type 55): Mounted vertically.
   c. Trapeze (MSS Type 56): Two vertical-type supports and one trapeze member.

3.2 HANGER AND SUPPORT INSTALLATION

A. Pipe Hanger and Support Installation: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from building structure.

B. Hanger Spacing:

1. Hanger spacing and sizing shall per MSS SP-69 or local codes, whichever is more stringent.
2. Hanger spacing must be reduced to compensate for any valves and/or fittings installed in the pipe run.
3. Alternate span calculations may be used with a maximum deflection of 0.1 inch between hangers.
4. Minimum hanger spacing for fire suppression piping shall be per appropriate NFPA requirements.
5. Maximum hanger spacing for plumbing piping shall be per Uniform Plumbing Code requirements or MSS SP-69, whichever is more stringent.
6. Hanger spacing must be reduced if thermal hanger shield insert cannot support full span.

C. Channel Support System Installation:

1. Multiple pipe runs may be supported on channel support systems with rollers or heavy duty steel trapezes with rollers. Channel support systems shall be individually designed with the exception of the following.
2. For pipe configurations specified in Table 1, channel support system hangers shall be as described below. Channel support shall be Unistrut P-1000. Hanger rods shall be one size larger than MSS SP-69 requires for largest pipe on support. Where support length exceeds 42 inches, additional hanger rod shall be installed at mid-span and pipe quantities in Table I may be placed on each side. Rollers shall be Unistrut P2474 through 6 inches, or P2475 through 16 inches; equal by B-Line or Grinnell. Maximum number of pipes on one 42-inch P-1000 channel support is:
3. Channel Support System Installation: Arrange for grouping of parallel runs of piping and support together on field-assembled channel systems.

4. Field assemble and install according to manufacturer's written instructions.

D. Heavy-Duty Steel Trapeze Installation:
1. Arrange for grouping of parallel runs of horizontal piping and support together on field-fabricated, heavy-duty trapezes.
2. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified above for individual pipe hangers.
3. Field fabricate from ASTM A 36/A 36M, steel shapes selected for loads being supported. Weld steel according to AWS D-1.1.

E. Building Attachments:
1. Review structural drawings for details of methods of attachment. Coordinate support requirements with project structural engineer.
2. Install building attachments within concrete slabs or attach to structural steel. Space attachments within maximum piping span length specified herein or indicated in MSS SP-69. Install additional attachments at concentrated loads, including valves, flanges, guides, strainers, and expansion joints, and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.
3. Install powder-actuated drive-pin fasteners in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.
4. Install mechanical-anchor fasteners in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.
5. Attachments to bar joists shall be at panel points and shall comply with load limits and other requirements of the Structural Engineer.

F. Hanger and Support Installation:
1. Install hangers and supports complete with necessary inserts, bolts, rods, nuts, washers, and other accessories.
2. Install hangers and supports to allow controlled thermal movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.
3. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.
4. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and so maximum pipe deflections allowed by ASME B31.9, "Building Services Piping," is not exceeded.
5. Insulated Piping: Comply with the following:
   a. Attach clamps and spacers to piping.
   b. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.

Table 1

<table>
<thead>
<tr>
<th>Largest Pipe Size</th>
<th>Maximum Number of Pipes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 inches and larger</td>
<td>0</td>
</tr>
<tr>
<td>4 inches</td>
<td>2</td>
</tr>
<tr>
<td>3 inches</td>
<td>3</td>
</tr>
<tr>
<td>2 1/2 inches</td>
<td>5</td>
</tr>
<tr>
<td>2 inches</td>
<td>8</td>
</tr>
<tr>
<td>1 1/2 inches</td>
<td>12</td>
</tr>
<tr>
<td>1 1/4 inches and smaller</td>
<td>16</td>
</tr>
</tbody>
</table>

HANGERS AND SUPPORTS
c. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
d. Generator exhaust piping: Use thermal-hanger shield insert with clamp sized to match OD of insert.
e. Do not exceed pipe stress limits according to ASME B31.9.
f. Install MSS SP-58, Type 39 protection saddles, if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation. **Option:** Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe 4 inches and larger if pipe is installed on rollers.
g. Install MSS SP-58, Type 40 protective shields on thermal-hanger shield inserts with vapor barrier. Shields shall span arc of 180 degrees minimum.

**Shield Dimensions for Pipe:** Not less than the following:
- 1/4-inch to 3-1/2-inch: 12 inches long and 0.048-inch thick.
- 4-inch: 12 inches long and 0.06-inch thick.
- 5-inch and 6-inch: 18 inches long and 0.06-inch thick.
- 8-inch to 14-inch: 24 inches long and 0.075-inch thick.
- 16-inch to 24-inch: 24 inches long and 0.105-inch thick.
h. Install thermal-hanger shields with insulation same thickness as piping insulation.

### 3.3 EQUIPMENT SUPPORTS

A. Fabricate structural-steel stands to suspend equipment from structure above or to support equipment above floor.

B. Grouting: Place grout under supports for equipment and make smooth bearing surface.

### 3.4 METAL FABRICATION

A. Cut, drill, and fit miscellaneous metal fabrications for heavy-duty steel trapezes and equipment supports.

B. Fit exposed connections together to form hairline joints. Field-weld connections that cannot be shop-welded because of shipping size limitations.

C. Field Welding: Refer to Section 15050, "Basic Mechanical Materials and Methods."

### 3.5 ADJUSTING

A. Hanger Adjustment: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.

### 3.6 PAINTING

A. Touching Up: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.

B. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils.

C. Touching Up: Clean and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal.
D. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.3.1.

END OF SECTION 15060
SECTION 15080 - MECHANICAL INSULATION

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: This section covers mechanical insulation for piping and equipment.

B. Related Sections: Drawings and general provisions of the contract, including General and Supplementary Conditions, Division 1 Specification Sections, and Section 15050, "Basic Mechanical Materials and Methods," apply to this section.

1. Cold Piping Systems:
   a. Domestic cold water.
   b. HVAC chilled water - supply and return, including piping in air-handling units.
   c. HVAC makeup water
   d. Fittings, valves, strainers, and check valves

2. Cold Equipment:
   a. Chilled water pump housings

1.2 DEFINITIONS

A. The word "concealed" as used in this section refers to insulation in ceiling plenums, furred spaces, mechanical rooms, pipe and duct shafts, unheated spaces immediately below roof, unexcavated spaces, and crawl spaces. The word "exposed" refers to insulation in all other areas.

1.3 SYSTEM DESCRIPTION

A. Systems to be Insulated: All portions of the following systems, equipment, and accessories shall be insulated, except where noted otherwise or furnished by OEM as part of equipment.

1. Cold Piping Systems:
   a. Domestic cold water.
   b. HVAC chilled water - supply and return, including piping in air-handling units.
   c. HVAC makeup water
   d. Fittings, valves, strainers, and check valves

2. Cold Equipment:
   a. Chilled water pump housings

B. Fire Hazard Classification: All components of the insulation system including insulation facings, mastics, and adhesives (with the exception of the elastomeric material specified elsewhere) shall not exceed the following hazard ratings as determined by NFPA 255, or ASTM E84 (NFPA 225), and UL 723:

<table>
<thead>
<tr>
<th>Pipe and Equipment Coverings</th>
<th>Flame spread rating</th>
<th>Fuel contributed</th>
<th>Smoke developed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>25</td>
<td>50</td>
</tr>
</tbody>
</table>

1.4 SUBMITTALS

A. Refer to Division 1 and Section 15050, "Basic Mechanical Materials and Methods," for general requirements.
B. Product Data: Submit manufacturer's technical product data, installation instructions, and maintenance data for each type of mechanical insulation, including fittings and adhesives. Include a pipe insulation thickness schedule.

1.5 QUALITY ASSURANCE

A. Regulatory Requirements: Refer to Section 15050, "Basic Mechanical Materials and Methods," for general code, standard, and regulatory requirements.

B. Installer qualifications: Three years minimum successful installation experience on projects with mechanical insulation similar in scope and nature to that required for the project.

C. Requirements for energy conservation: All insulation shall be in accordance with ASHRAE Standard 90A.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Storage and Protection: Protect insulation against dirt, water, chemical, or mechanical damage before, during, and after installation. Any such insulation or covering damaged prior to final acceptance of the work shall be satisfactorily repaired or replaced.

B. Packaging: Ship insulation materials in containers marked by manufacturer with appropriate ASTM specification designation, type and grade, and maximum use temperature.

1.7 WARRANTY

A. Refer to Section 15050, "Basic Mechanical Materials and Methods," for general warranty requirements.

PART 2 - PRODUCTS

2.1 MANUFACTURER

A. Approved manufacturers for insulation products are Armaflex, Armstrong World Industries, CertainTeed, CSG, Knauf Fiber Glass, Manson, Nomaco, Owens-Corning, and Johns Manville Products.

B. Approved manufacturers for adhesives, sealants, and coatings are Foster and Childers Product Co.

2.2 PIPE INSULATION

A. Preformed fiberglass conforming to ASHRAE 90.1-1999 and ASTM C-547, Class I or II, with "K" factor of 0.23 maximum at 75°F mean temperature. See schedule for thickness.

B. Jacket shall be factory-applied ASJ/SSL type, ASTM C921, or C1136, Type I with vapor barrier for cold piping (below ambient), or Type II for hot piping (above ambient). Type I may be used for both at Contractor's option. Factory-applied flap adhesive (SSL) or conventional staple and tape seal at Contractor's option.

C. Pipe Insulation Thickness Schedule:
### Mechanical Insulation

<table>
<thead>
<tr>
<th>Piping System Type</th>
<th>Minimum Insulation Thickness for Pipe Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Runouts up to 1&quot;</td>
</tr>
<tr>
<td>1. Domestic cold water piping</td>
<td>0.5</td>
</tr>
<tr>
<td>2. Chilled water supply and return</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Note: Runout piping is the piping extending to individual terminal units from mains, maximum length 4 feet.

- **D.** Fittings and valves shall be covered with premolded one-piece PVC-insulated covers. This product is not to be installed in locations where its use is prohibited by local codes.
- **E.** Cover all exposed piping inside occupied spaces with Zeston 2000 PVC or equal jacketing, factory cut and curled to size. Do not provide PVC jacketing inside baseboard covers.

#### 2.3 Equipment Insulation

- **A.** Specification "A": 2-inch-thick fiberglass board equal to CSG Group IB600. The board insulation shall be preformed, flat, rectangular, rigid material with a minimum density of 6 lb./cu. ft. and a maximum "K" value of 0.22 at 75°F mean temperature.
- **B.** Specification "B": 2-inch-thick fiberglass equal to CSG Group IB600. The board insulation shall be preformed, flat, rectangular, rigid material with a minimum density of 6 lbs./cu. ft. and a maximum "K" value of 0.22 at 75°F mean temperature. The insulation board shall have a factory-applied FSK vapor barrier facing laminate of aluminum foil and Kraft paper reinforced with fiberglass scrim.
- **C.** Equipment Insulation Schedule:
  1. Chilled water air purger and similar devices Spec B
  2. Chilled water pump housings* Spec *

* Provide removable insulation jacket made from Armaflex insulation.

#### Part 3 - Execution

#### 3.1 Installation

- **A.** General:
  1. Apply full-length units of insulation on clean, dry surfaces free of any foreign matter. Apply only after tests and approvals required by the specifications have been completed.
  2. Insulation on all cold surfaces must be applied with a continuous, unbroken vapor seal. Supports, anchors, etc., that are secured directly to cold surfaces must be adequately insulated and vapor sealed to prevent condensation.
  3. All raw edges shall be finished with finishing cement.

- **B.** Pipe Insulation:
  1. Pipe insulation shall be continuous through walls and floor openings except where walls and floors are required to be fire-stopped or required to have a fire-resistance rating. Where this occurs in floors, the open space remaining between the sleeve and pipe shall be filled with fire-stop insulation. Where this occurs in walls, no sleeves are required; however, calcium-silicate
insulation shall be used (in lieu of fiberglass) and extend 1” beyond the wall. The perimeter of the cal-sil shall be fire caulked at the wall.

2. Butt all joints firmly together and smoothly, secure all self-sealing jacket laps and joint strips with monel staples at 6-inch O.C. and cover with lap adhesive or factory (SSL) adhesive.

3. Ends of cold pipe insulation shall be sealed off with a vapor barrier coating at all fittings and valves and at intervals of 21 feet on continuous runs of pipe.

4. Insulated cold pipes shall be insulated continuously through hangers. Rigid insulation inserts are to be provided at all pipe hangers and supports per Section 15060, “Hangers and Supports.” Pipe insulation shall abut the rigid insulation insert. Apply a wet coat of vapor barrier lap cement on all butt joints and seal the joints with 3-inch-wide vapor barrier tape or band. Coat staples with heavy coat of brushed on vapor barrier lap cement.

5. Pipe installed below grade shall be spiral wrapped with 10 mil PVC tape (Scotchwrap No. 50 or equal) with 50% overlap and laid in bed of sand with 3-inch minimum cover on all sides.

a. Fittings shall be double-wrapped with second layer extended a minimum of 12 inches beyond fittings.

C. Insulation on Fittings and Valves:

1. Where the factory premolded one-piece PVC insulated fitting covers are to be used, the proper factory precut insulation shall be applied to the fitting using two layers for pipe temperatures above 250°F or below 35°F, single layer insulation is suitable between 35°F and 250°F. The ends of the insulation shall be tucked snugly into the throat of the fitting and the edges adjacent to the pipe covering, tufted and tucked in, fully insulating the pipe fitting. Covers shall overlap the adjoining pipe insulation and jackets and on cold pipes shall be sealed at all seam edges with vapor barrier adhesive. The circumferential edges of all covers shall be sealed with pressure sensitive tape. The tape shall overlap the jacket and the cover at least 1 inch.

2. At locations where the PVC covers are prohibited, the Contractor may use as an alternate one of the following methods: one-coat insulation cement, premolded fiberglass fitting covers, or mitered segments of pipe insulation. Finish shall be glass fabric embedded in fire-retardant mastic. Mastic shall be vinyl acrylic mastic Childers CP-10/11 or equal for hot piping and shall be Childers CP-30 or Fosters 30-35 for cold piping.

3. Valves may be insulated with sections of Fiberglass pipe insulation complete with All Service Jacket. Raw ends shall be coated with vinyl acrylic mastic CP-10/11 for hot piping or shall be coated with vapor barrier mastic (CP-30 or Fosters 30-35) for cold piping.

D. Blanket Insulation:

1. All insulation shall be applied with edges tightly butted with facing overlapping all joints at least 2 inches. Where vapor seal is required, the joints shall be sealed with fire-retardant adhesive. The insulation shall be secured to the duct with approximately 4-inch-wide strips at 8-inch o.c. of fire-retardant adhesive. Where the duct width exceeds 30 inches, the underside insulation shall be additionally held in place with mechanical fasteners on about 18-inch maximum centers.

2. Where vapor seal is required, all breaks and punctures shall be sealed with vapor barrier tape and fire-retardant adhesive.

E. Board Insulation:

1. All insulation shall be applied with edges tightly butted and fastened to duct with mechanical fasteners spaced on 12-inch to 18-inch centers or as required to hold insulation firmly against the duct surface. Insulation shall be tightly secured in place with washers. Insulation may be secured to the top of the duct with adhesive.

2. Where vapor seal is not required, apply a tack coat of a fire-retardant adhesive; embed into wet tack coat glass cloth. Smooth membrane to avoid wrinkles and overlap all seams at least 2 inches. Apply finish coat of fire-retardant adhesive in sufficient thickness to completely cover glass cloth.
3. Where vapor seal is required, seal all joints, breaks, and punctures in facing with fire-retardant vapor barrier adhesive over which 3-inch-wide tape similar to that of the facing material shall be placed.

F. Cold Equipment Insulation:
   1. Removable covers for chilled water pumps per 2.3-C.

G. Other Requirements:
   1. Do not insulate ASME stamp and manufacturer's nameplate. Provide neatly beveled edge at interruptions of insulation.
   2. Provide removable insulation sections to cover parts of equipment that must be opened periodically for maintenance; include metal vessel covers, fasteners, flanges, frames, and accessories.
   3. Replace damaged insulation that cannot be repaired satisfactorily, including units with vapor barrier damage and moisture saturated units.

END OF SECTION 15080
SECTION 15090 - MECHANICAL IDENTIFICATION

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Identification of mechanical products installed under Division 15.

1.2 REFERENCES

A. American National Standards Institute (ANSI).
   1. ANSI A13.1 "Scheme for the Identification of Piping Systems".
   2. ANSI Z53.1 "Safety Color Code for Marking Physical Hazards".

B. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

1.3 DEFINITIONS (Excerpts from ANSI A13.1-1981)

A. Materials Inherently Hazardous:
   1. Flammable or Explosive:
      a. Materials which are easily ignited, including materials known as fire producers or those
         creating an explosive atmosphere.
   2. Chemically Active or Toxic:
      a. Materials which are corrosive, or are in themselves toxic or productive of poisonous gases.
   3. At Temperatures or Pressures:
      a. Materials which, when released from the piping, would have a potential for inflicting injury,
         or property damage by burns, impingement, or flashing to vapor state.
   4. Radioactive:
      a. Materials which emit ionizing radiation.

B. Materials of Inherently Low Hazard:
   1. All materials which are not hazardous by nature, and are near enough to ambient pressure and
      temperature that people working on systems carrying these materials run little risk through their
      release.

C. Fire Quenching Materials:
   1. This classification includes sprinkler systems, and other piped fire fighting or fire protection
      equipment. This includes water, chemical foam, CO2, Halon, etc.

PART 2 - PRODUCTS

2.1 IDENTIFICATION MATERIALS FOR PIPING AND EQUIPMENT

A. Metal Tags:
   1. Round brass discs, minimum 1-1/2" diameter with edges ground smooth.
   2. Each tag punched and provided with brass chain for installation.

B. Engraved Nameplates:
   1. Laminated three-layer plastic with engraved black letters on light contrasting background color.
C. Paint Stencils:
   1. Of size and color per ANSI/ASME A13.1 using clean cut letters and oil base semi-gloss enamel paint.
   2. Paint material shall comply with Section 09900-Painting.
   3. Size of Legend and Letters for Stencils:

<table>
<thead>
<tr>
<th>Insulation or Length of Color Field</th>
<th>Size of Letters</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4” to 1-1/4”</td>
<td>8”</td>
</tr>
<tr>
<td>1-1/2” to 2”</td>
<td>8”</td>
</tr>
<tr>
<td>2-1/2” to 6”</td>
<td>12”</td>
</tr>
<tr>
<td>8” to 10”</td>
<td>24”</td>
</tr>
<tr>
<td>over 10”</td>
<td>32”</td>
</tr>
</tbody>
</table>

D. Pressure Sensitive Markers: Brady Type 350 flexible vinyl film identification markers and tape, with legend, size and color coding per ANSI A13.1.

E. Semi-rigid Plastic Identification Pipe Markers: Seton Setmark with legend, size and color coding per ANSI A13.1. Direction of flow arrows are to be included on each marker, unless otherwise specified.
   1. Setmark Type SNA markers to be used on diameters 3/4” thru 5”.
   2. Setmark Type STR markers to be used on diameters 6” or larger.

PART 3 - EXECUTION

3.1 IDENTIFICATION OF PIPING AND EQUIPMENT

A. General:
   1. Provide pipe identification, valve tags, stencils, or engraved name plates to clearly identify the mechanical equipment, piping and controls of the various mechanical systems and direction of flow in piping.
   2. Time of Application: No identification shall be done until all painting required under the Architectural section of these specifications has been accomplished.

B. Methods for identification as follows:
   1. Metal Tags:
      a. Stamp tags with letter prefixes to indicate service, followed by a number for location in system.
   2. Engraved Nameplates:
      a. Attach nameplates with brass screws.
      b. Pressure-sensitive embossed labels are not acceptable.
      c. Nameplates shall bear the same identifying legend used on the Contract Documents.
   3. Painted Stencils:
      a. Pipes and equipment to be stenciled shall first be wiped clean of dirt, dust, rust, grease and moisture.
      b. Pipes and equipment shall be painted with required color code to a smooth hard surface in the area the stencil is to be applied.
      c. Stenciled markings shall be neatly performed with no overspray, drips, or other imperfections.
      d. Legend Letters and Color Field size as specified for Paint Stencils in Part 2 of this Section.
4. Pressure Sensitive Markers: Apply pressure sensitive markers in accordance with manufacturer's recommendations with complete wrap around. Marker adhesion will be tested for permanence. Any markers showing dog ears, bubbles, or other failings shall be replaced.

5. Semi-Rigid Plastic Identification Markers: Seton Setmark pre-molded (not pressure sensitive) identification markers may be used at Contractor's option on service piping which is accessible for maintenance operations (but not on piping in finished spaces). This type marker shall not be installed on bare pipe when surface temperature exceeds 180 deg. F unless a 1” thick insulation band is first provided under marker for protection from the hot pipe.

C. Classification of Hazards of Materials, Designation of Colors and University Legend:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Color of Field</th>
<th>Color of Letters</th>
<th>University Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials Inherently Hazardous: Flammable or Explosive:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Yellow</td>
<td>Black</td>
<td>NG</td>
</tr>
<tr>
<td>Chemically Active or Toxic</td>
<td>Yellow</td>
<td>Black</td>
<td></td>
</tr>
<tr>
<td>Acid Waste</td>
<td>Yellow</td>
<td>Black</td>
<td>AW</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Yellow</td>
<td>Black</td>
<td>C</td>
</tr>
<tr>
<td>Extreme Temperatures or Pressures</td>
<td>Yellow</td>
<td>Black</td>
<td></td>
</tr>
<tr>
<td>Boiler Feed Water</td>
<td>Yellow</td>
<td>Black</td>
<td>BFW</td>
</tr>
<tr>
<td>Chilled-Water Supply/with Glycol</td>
<td>Orange</td>
<td>Black</td>
<td>CWS/G</td>
</tr>
<tr>
<td>Chilled-Water Return/with Glycol</td>
<td>Orange</td>
<td>Black</td>
<td>CWR/G</td>
</tr>
<tr>
<td>Distilled Water</td>
<td>Orange</td>
<td>Black</td>
<td>DW</td>
</tr>
<tr>
<td>Domestic Hot Water</td>
<td>Orange</td>
<td>Black</td>
<td>HW</td>
</tr>
<tr>
<td>Domestic Hot Water, Circulating</td>
<td>Orange</td>
<td>Black</td>
<td>HWC</td>
</tr>
<tr>
<td>180 deg. Domestic Hot Water</td>
<td>Yellow</td>
<td>Black</td>
<td>HHW</td>
</tr>
<tr>
<td>180 deg. Domestic Hot Water, Circulating</td>
<td>Yellow</td>
<td>Black</td>
<td>HHWC</td>
</tr>
<tr>
<td>Heating Water Supply/with Glycol</td>
<td>Yellow</td>
<td>Black</td>
<td>HWS/G</td>
</tr>
<tr>
<td>Heating Water Return/with Glycol</td>
<td>Yellow</td>
<td>Black</td>
<td>HWR/G</td>
</tr>
<tr>
<td>Low-Pressure Steam</td>
<td>Yellow</td>
<td>Black</td>
<td>LPS</td>
</tr>
<tr>
<td>Low-Pressure Steam Condensate</td>
<td>Yellow</td>
<td>Black</td>
<td>LPSC</td>
</tr>
<tr>
<td>High-Pressure Steam</td>
<td>Yellow</td>
<td>Black</td>
<td>HPS</td>
</tr>
<tr>
<td>High-Pressure Steam Condensate</td>
<td>Yellow</td>
<td>Black</td>
<td>HPSC</td>
</tr>
<tr>
<td>Sanitary Sewer</td>
<td>Orange</td>
<td>Black</td>
<td>SAN</td>
</tr>
<tr>
<td>Storm Sewer</td>
<td>Orange</td>
<td>Black</td>
<td>SS</td>
</tr>
<tr>
<td>Tower-Water Supply</td>
<td>Orange</td>
<td>Black</td>
<td>TWS</td>
</tr>
<tr>
<td>Tower-Water Return</td>
<td>Orange</td>
<td>Black</td>
<td>TWR</td>
</tr>
<tr>
<td>Waste Vent</td>
<td>Orange</td>
<td>Black</td>
<td>V</td>
</tr>
<tr>
<td>High Pressure Compressed Air (over 90 psig)</td>
<td>Yellow</td>
<td>Black</td>
<td>CA</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>Yellow</td>
<td>Black</td>
<td>REF</td>
</tr>
</tbody>
</table>

Materials of Inherently Low Hazard:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Color of Field</th>
<th>Color of Letters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid or Liquid Admixture</td>
<td>Green</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td>Domestic Cold Water</td>
<td>Green</td>
<td>White</td>
<td>W</td>
</tr>
<tr>
<td>Gas or Gaseous Admixture</td>
<td>Blue</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td>Medium Pressure Compressed Air (30 to 90 psig)</td>
<td>Blue</td>
<td>White</td>
<td>CA</td>
</tr>
<tr>
<td>Low Pressure Compressed Air (less than 30 psig)</td>
<td>Blue</td>
<td>White</td>
<td>CA</td>
</tr>
<tr>
<td>Vacuum</td>
<td>Blue</td>
<td>White</td>
<td>VAC</td>
</tr>
</tbody>
</table>
D. Piping:
   1. Identify all piping accessible for maintenance in crawl spaces, tunnels, above ceilings, and access spaces as well as exposed to view utilizing stenciled markings according to the following procedures:
      a. Use an arrow marker for each pipe-content legend. The arrow shall always point away from the pipe legend and in the direction of flow: color and height of arrow to be same as content legend lettering.
      b. If flow can be in both directions, use a double-headed arrow indication.
      c. Apply pipe legend and arrow indication at every point of pipe entry or exit where line goes through wall or ceiling cut.
      d. Apply pipe legend and arrow indication within 3" of each valve to show proper identification of pipe contents and direction of flow.
      e. The legend shall be applied to the pipe so that lettering is in the most legible position. For overhead piping, apply legend on the lower half of the pipe where view is unobstructed, so that legend can be read at a glance from floor level.
      f. For pipes under 3/4" O.D., fasten brass tags securely at specified legend locations.
      g. Legend on steam piping, condensate return, compressed air, gas, and vacuum systems shall include working pressure or vacuum.

E. Valves:
   1. Label control valves as noted on the drawings.

F. Controls:
   1. Magnetic starters and relays, shall have nameplates or be stenciled to identify connecting or controlled equipment.
   2. Manual operating switches, fused disconnect switches and thermal over-load switches which have not been specified as furnished with indexed faceplates shall also have nameplates or be stenciled as to "connected" or "controlled" equipment.
   3. Automatic controls, control panels, zone valves, pressure electric, electric pressure switches, relays, and starters shall be clearly identified.

G. Pumps:
   1. Pumps shall be identified as to service and zones served.
   2. Base mounted pumps shall be stenciled or have system served nameplates.
   3. Brass tags secured by tie wires may be used on small in-line pumps.

H. Storage Tanks, Water Treatment Equipment and Heaters:
   1. Tanks and heaters shall be stenciled as to service.
   2. The connecting pipes to each shall be identified and the service temperature entering and leaving the tank or heater shall be indicated.

I. Fans:
   1. Supply and exhaust fans and air handling units and connecting ductwork supplying one or more areas from an equipment room or isolated crawl or furred space shall have nameplate or be stenciled as to plan code number, service and areas of zones served.

J. Air Conditioning Equipment:
1. Equipment such as chillers, pumps, condensers, or roof-top equipment shall be identified by stencils, or system nameplates. Labels of remote equipment shall also indicate the space(s) being served and the location of their electrical breaker (Panel ID, Room No., and Circuit).

2. Refrigeration equipment shall be labeled with the type and approximate quantity of refrigerant.

K. Lift-Out Ceilings & Access Doors:
   1. Provide Kroy type adhesive labels on ceiling tee or access door to identify concealed valves, air terminal units, fire/smoke and fire dampers, or similar concealed mechanical equipment which is directly above nameplate in ceiling space.
   2. Label shall be installed oriented to read towards the ceiling tile that needs to be removed for access.

L. Terminal Units:
   1. Identify all units with unique numbers corresponding to the drawings, and indicate the space being served.

M. Motors Controlled By Energy Management System:
   1. The University shall furnish the following self-adhering signs which the Contractor shall install as indicated:

   CAUTION

   THIS EQUIPMENT IS UNDER COMPUTER CONTROL AND MAY CYCLE AT ANY TIME.

   BEFORE WORKING ON IT, DISCONNECT THE ELECTRICAL POWER AND CONTACT THE UNIVERSITY SERVICE DESK AT EXT. 2-5522.

END OF SECTION 15090
SECTION 15110 - VALVES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: This section covers general requirements for valves and specialties that are used with piping systems as specified elsewhere in Division 15.

B. Related Sections: Drawings and general provisions of the contract, including General and Supplementary Conditions, Division 1 Specification Sections, and Section 15050, "Basic Mechanical Materials and Methods," apply to this section.
   1. Division 15 sections for piping system specification and specialty valves related to systems.
   2. Section 15050, "Basic Mechanical Materials and Methods," for basic materials and methods and piping installation.

1.2 SUBMITTALS

A. Refer to Division 1 and Section 15050, "Basic Mechanical Materials and Methods," for general requirements.

B. Submit product data sheets for all types of valves being furnished.
   1. Submit valve schedules for all manual valves. Schedules shall include:
      - Plan Code (BV, BFV, CV, DV, etc.)
      - Body Style/Type
      - Make
      - Model
      - Pressure Rating
      - Size Range
      - Connections (Flanged, Screwed, Weld, etc.)
      - Actuator (Petcock, Lever, Lever with Memory Stop, Hand Wheel, etc.)

C. Closeout Submittals: Submit operating instructions and maintenance data for all valves.

1.3 QUALITY CONTROL

A. Regulatory Requirements:
   1. Refer to Section 15050, "Basic Mechanical Materials and Methods," for general code, standard, and regulatory requirements.
   2. Standards: Chemical and physical properties of materials, performance characteristics, and methods of construction shall be in accordance with applicable sections of the following references and standards of current editions in effect 90 days prior to receipt of bids:
      American Welding Society (AWS)
      Commercial Standards, National Bureau of Standards (CS)
      Compressed Gas Association (CGA)
      Copper Development Association (CDA)
      Federal Specifications (FS)
      Manufacturers Standardization Society (MSS)
1.4  WARRANT

A. Refer to Section 15050, "Basic Mechanical Materials and Methods," for general warranty requirements.

PART 2 - PRODUCTS

2.1  VALVES AND CHECK VALVES

A. All valves of any one kind, except as otherwise specified in detail specifications, shall be of one manufacturer, and where possible, all valves shall be of one manufacturer and are to be manufactured in accordance with the Manufacturers' Standardization Society (MSS) of the Valves and Fittings Industry Standards wherever applicable.

B. Provide extended handles or chain wheel operators for all valves that are located more than 7'-0" above the floor.

C. Provide valve handle extensions for all valves in insulated systems.

D. Butterfly Valves (water only):
   1. Acceptable Manufacturers:
      - Crane
      - DeZurik
      - Fisher
      - Grinnell
      - Hammond
      - Posi-Seal
      - Jamesbury
   2. 2 inches and smaller - Use ball valve.
   3. 2-1/2 inches and larger - Full-lug type 200 psi non-shock WOG, MSS SP-67, extended neck, cast or ductile iron body, aluminum bronze disc or nickel plated ductile iron, stainless steel shaft, EPDM seat and seal, 10-position lever locking handle through 6 inches, worm gear actuator for 8 inches and larger valves. Valves shall be capable for use as isolation valves and be recommended by the manufacturer for dead-end service at the full-rated operating pressure, without the need for downstream blind flanges. Keystone Fig. 222, Milwaukee ML-133-E, NIBCO LD2000 or equal.

E. Ball Valves:
   1. Acceptable Manufacturers:
      - Apollo
      - Conbraco
      - Hammond
      - Jamesbury
      - Jomar
      - Milwaukee
      - Dynaquip
      - Powell
      - Victaulic
      - Watts
      - Worester
   2. Water:
      a. 2 inches and smaller: Cast bronze; full port; two-piece body design; stainless steel, solid ball; stainless steel trim; gland nut; reinforced Teflon seats. 150 SWP, non-shock 600 WOG, MSS SP-110. Stem packing shall be adjustable for wear with adjusting screw.
         1) Screwed ends - Apollo 77-100 Series, Jomar T-100, Conbraco 64 series.
         2) Solder ends (water only) - Apollo 77-200 Series, Jomar T-100, Conbraco 64 series.
         3) Grooved joint (water only) - Victaulic Series 721
      b. Bronze valve material composition shall meet ASTM-B-584.

F. Eccentric and Plug Valves:
   1. Acceptable Manufacturers:
DeZurik, Keystone, Milliken

2. Balancing Service: Corrosion-resistant, permanently lubricated plug-type or multi-turn hand wheel with suitable seals for intended service, lever or multi-turn operator for valves through 6 inches, worm gear or multi-turn actuator for 8 inches and larger valves, adjustable memory stops all sizes.
   a. 2 inches and smaller - 250 psi SWP DeZurik Fig. 425 screwed or Milliken MILLCENTRIC Class 250.
   b. 2-1/2 inches and larger - Class 125 or 250 flanged, DeZurik Fig. 118, Milliken MILLCENTRIC Class 125 or equal by Keystone.
   c. Grooved joint - Milliken MILLCENTRIC Class 125 or 250.

3. Shutoff Service: Corrosion-resistant square head plug with double seal; bronze to 2-1/2 inches, C.I. to 4 inches. UL listed, DeZurik Fig. 425, screwed, flanged, or victaulic, ANSI 125 psi. Equal by Milliken.

4. See Section 15120 for combination flow measuring and balancing valves.

G. Silent Spring-Loaded Check Valves:
   1. Class 125 wafer-type, center-guided, bronze or cast iron body, aluminum bronze disc, EPDM seats. Monel or stainless steel springs. Milwaukee Series 1400, Nibco W910, Metraflex, Streamflow CT 125, Technocheck 5050, or Valmatic.

H. Swing Check Valves:
   1. Water (Class 150 and 125):
      a. 2 inches and smaller - Class 150 bronze swing check, renewable bronze disc, 150 psi SWP, 300 psi non-shock WOG, MSS SP-80.
         1) Screwed ends - Nibco T-433 or Milwaukee 510T, Stockham B-321.
         2) Solder ends (water only) - Nibco S-433 or Milwaukee 1510T
      b. 2-1/2 inches and larger - Class 125 iron body, bronze trim swing check, 125 psi SWP, 200 psi non-shock WOG, MSS SP-71 Type 1
         1) Flanged ends - Nibco F-918-B or Milwaukee F2974, Stockham G-931

I. Hose End (Boiler Drain) Valves: Provide ball valve specified above rated for duty with hose end thread adapter with cap on a chain by Hammond, Nibco, Prier, or United Brass.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General: Unless otherwise specifically indicated on the plans or specifications, all equipment and materials shall be installed in accordance with the recommendations of the manufacturer. Maintain maximum headroom and space conditions at all points. Include manufacturer's recommended lubrication.

B. Utilize appropriate pressure rating for system pressure. Refer to specific Division 15 sections for specific requirements.

C. Valves:
   1. All valves shall be installed so the stem position is not more than 90-degrees from the vertical up position.
   2. All valves shall be installed so they are accessible and serviceable, and such that full length operating handles may be used without interference from structure or other pipes and/or equipment.
   3. Isolation valves shall be installed:
      a. In piping at each and every piece of equipment
      b. In piping whenever said pipe enters or leaves an equipment room
c. At all branch take-offs from mains

d. Where shown on Drawings

4. Where butterfly valves are located five pipe diameters or less from an elbow, install the valve with its shaft parallel to the plane of the elbow.

D. Accessibility: Locate all equipment that must be serviced, operated, or maintained in fully accessible positions. Equipment shall include, but not be limited to, valves, traps, cleanouts, motors, controllers, switchgear, and drain points. If required for better accessibility, furnish access doors for this purpose. Minor deviations from drawings may be made to allow for better accessibility.

END OF SECTION 15110
SECTION 15120 - PIPING SPECIALTIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: This section covers general requirements for valves and specialties that are used with piping systems as specified elsewhere in Division 15.

B. Related Sections: Drawings and general provisions of the contract, including General and Supplementary Conditions, Division 1 Specification Sections, and Section 15050, "Basic Mechanical Materials and Methods," apply to this section.
1. Division 15 equipment specification sections for equipment and systems requiring piping specialties.
2. Section 15050, "Basic Mechanical Materials and Methods," for basic materials and methods and piping installation.
3. Section 15060, "Hangers and Supports" for pipe hangers
4. Section 15070, "Mechanical Sound and Vibration" for spring isolation pipe hangers
5. Section 15080, "Mechanical Insulation" for pipe insulation
6. Section 15110, "Valves," for general valve specification relative to Division 15 sections.
7. Section 15180, "Heating and Cooling Piping," for heating and cooling piping systems.

1.2 SUBMITTALS

A. Refer to Division 1 and Section 15050 for general requirements.

B. Product Data:
   1. P&T test plugs and accessories
   2. Thermometers
   3. Gauges
   4. Flow measuring devices
   5. Hydronic Specialties

C. Closeout Submittals:
   1. Operating and Maintenance Data for listed products.

1.3 QUALITY ASSURANCE

A. Regulatory Requirements:
   1. Refer to Section 15050, "Basic Mechanical Materials and Methods," for general code, standard and regulatory requirements.
   2. Chemical and physical properties of materials, performance characteristics, and methods of construction shall be in accordance with applicable sections of the following references and standards of current editions in effect 90 days prior to receipt of bids:
      American Welding Society (AWS)
      Commercial Standards, National Bureau of Standards (CS)
      Compressed Gas Association (CGA)
      Copper Development Association (CDA)
      Federal Specifications (FS)
      Manufacturers Standardization Society (MSS)

1.4 WARRANTY
PART 2 - PRODUCTS

2.1 PRESSURE TEMPERATURE TEST PLUGS AND ACCESSORIES

A. Approved manufacturers are as follows:
   1. Test plugs - Peterson Equipment No. 710 or 710-XL, Universal Controls Corp. No. 45 PT-N, Sisco BNO Series, or equivalent by Fairfax or Terise.
   2. Portable test pressure gauge - Duro Instrument Corp. No. 105 with adapter
   3. Pocket Thermometers - Peterson Series 600, or Tel-Tru Manufacturing Co. No. 39R.

B. Pressure temperature test plugs shall have brass body with Nordel valve core, gasketed cap with retaining strap, 1/4-inch or 1/2-inch male pipe thread and insulation extension where required. Rated 250 psi at 275°F to 20°F.

2.2 PERMANENT THERMOMETERS


B. Shall be Vari-angle digital type, 40°F to 300°F, with LCD readout (no batteries). Weiss Instruments Model DVU 35.

C. Stem length shall be sufficient for 40% - 60% insertion. Accuracy 1% full scale or better. All thermometers inserted in piping systems shall be provided with a thermowell for isolation. Well shall be filled with temperature conducting grease before insertion of thermometer bulb.

2.3 PRESSURE GAUGES

A. Approved manufacturers are Crosby, Dwyer Instruments, Inc., H. O. Trerice Co., Ametek U. S. Gauge Division, Marshalltown, Weksler, Weiss Instruments.

B. Single input hydronic pressure gauges shall have stainless steel case; 4-1/2-inch dial with suitable range; phosphorous bronze Bourdon tube; corrosion-resistant movement; adjustable steel pointer; 1% of full scale accuracy; 1/4-inch NPT brass connection, Trerice Model 600C, or approved equal.

C. Differential pressure gauges shall have forged brass case, 4-inch dial, 500 psi WOG, accuracy of ±3% of full scale. Dwyer Series 4000 with ASF adjustable signal flag. Model 4635B for flat plate, condenser, and evaporator pressure drops.

2.4 HYDRONIC FLOW MEASURING DEVICES

A. Line sizes and design flow rates are shown on the drawings.

B. Flow measuring devices 2 inches and smaller may be a combination measuring device and balancing valve assembly or a separate Venturi with a remote balancing valve.
   1. One-piece combination orifice (1 inch and smaller) or Venturi (2 inches and smaller) and ball type balancing/shutoff valve as follows:
      a. Bronze or forged brass construction with sweat or threaded ends, rated at 250 psi SWP at 250°F.
      b. Full-port, ball valve with chrome-plated ball and blowout-proof stem with Teflon seals and packing, 100% shutoff at rated pressure.

PIPING SPECIALTIES 15120-2
c. Quick-connect type color-coded fittings for flow measurement connection, with both fittings on one side of shutoff valve.
d. Tamper-resistant adjustable "memory" device for valve setting stop
e. Metal tag with orifice/Venturi size, station designation, and gpm/meter reading.
f. Readout ports and valve handles shall have 2 inches or greater extensions when pipes are to be insulated.
g. Selected for meter readout of 7 inches to 50 inches w.g. maximum at rated flow.

C. Flow measuring devices 2-1/2-inches and larger shall consist of a venturi unit as follows:
1. Sizes 2-1/2-inch diameter and larger may be cast steel with weld ends, machined steel for butt welding, or grooved joint type. Sizes 10-inch diameter and larger may be fabricated steel with weld ends. Device to be rated for 150 psi SWP at 250°F, unless otherwise noted.
2. Venturi unit shall include manual shut-off valves and quick-disconnect fittings at meter taps and shall be furnished with tags marked with Venturi size, station designation, gpm, and meter reading for gpm.
3. Bore sizes shall be selected so the meter readout at specified flow rate is between 7 inches and 50 inches w.g. unless otherwise noted.
4. See Section 15110 "Valves" for balancing valve specifications.
5. Acceptable manufacturers are Barco, Gerard, Flow Set, Presso Model B or V, and Victaulic Style 733.

2.5 HYDRONIC SPECIALTIES

A. Air Vents:

B. Diaphragm Type Expansion Tanks:
1. Seven Gallons or Less: Amtrol "Extrol" combination unit with air purger and float-type vent. Amtrol 6000 series or Watts series ET-ASF, charged at 12 psi.
2. Ten to 34 Gallons: ASME 125 psi construction, Amtrol AX series, B&G D series, Taco CAX series, equal by Armstrong, American Tube, or John Wood Co.
3. 37 Gallons and Larger: ASME 125 psi construction, full acceptance type, Amtrol L series, B&G B series, Taco CA series, equal by Armstrong, American Tube, or John Wood Co.

C. High Volume Air Vents: Amtrol 720, B&G Model 107, equal by Taco, Armstrong, Adamson, or John Wood Co. Cast iron, 150 psi minimum.


E. Automatic Fill and Pressure Regulating Valves:
1. Automatic Fill Valves: Pressure reducing, fast fill type, bronze body, monel screen, integral check valve, inlet pressure up to 75 psi, fill pressure adjustable 8 to 25 psi. Amtrol 10F or 11F, B&G Model FB-3, Taco 335, equal by Armstrong, Conbraco, or Watts. May be combined with Item F relief valve. Note: If incoming water pressure is greater than 75 psi, use high pressure PRV in series with fill valve.
2. High-pressure Water Regulating Valve: Bronze body, up to 200 psi inlet pressure, diaphragm type with replaceable seat, cleanable monel strainer, 50 psi "no flow" pressure. Amtrol S series, Watts U5 series, equal by B&G, Taco, Watson McDaniel, or Armstrong.
ASME Pressure Relief Valves: Bronze or iron body, ASME safety type labeled for 125 psi maximum pressure, relief pressure selectable from 30 to 100 psi. (See plans for relief pressure settings.) B&G Models 790, 1170, 3301, or 4100; equal by Kunkle, Lonegren, Lunkenheimer, McDonnel/Miller, or Watts.

Strainers (Hydronic):
1. Water:
   a. Bronze Y-type strainers with stainless steel screens. 2 inches or smaller shall be screwed or sweat, 400 psi WOG with 20 mesh screen, equal to Conbraco Series 59 BT/TBT, Sarco, or Streamflow T-250.
   b. 2-1/2 inches and larger shall be cast iron flanged, Class 125, or 200 psi non-shock WOG with 3/64-inch perforated screen, equal to Conbaco F-1, Sarco CI-125, or Streamflow YF-125.
   c. Provide threaded fitting for blow-down valve.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:
1. Unless otherwise specifically indicated on the plans or specifications, all equipment and materials shall be installed in accordance with the recommendations of the manufacturer. Maintain maximum headroom and space conditions at all points.

B. Air Vents:
1. Install manual air vents at high points of all piping consisting of a line size nipple - 6-inches long for an air collection chamber, pipe cap on top of nipple with 1/4-inch tap, 1/4-inch copper tubing with gauge cock. Locate gauge cock at accessible location and anchor to adjacent pipe or wall. Provide access panels as required for access.
2. Install manual air vents at all heat transfer devices, coils, etc.

C. Hydronic Specialties:
1. Install hydronic specialties of types and sizes as shown and/or scheduled on the plans.

D. Other Devices:
1. Install a pressure-temperature tap on each side of each pump and heat transfer device such as coils, heat exchangers, radiation, and radiant panel loops.
2. Install thermometers and gauges where shown on drawings. Locate them so they are easily visible from the floor level without use of ladders, etc. Provide a P&T tap at each thermometer, sensor, and gauge location.
3. Provide heat transfer grease in each thermometer well and a pressure snubber and shutoff valve for each pressure gauge.
4. Install one flow measuring device in the return water from (to) each heat transfer or generation device (such as boilers, chillers, pumps, coils, heat exchangers, radiation circuits, etc.). The balancing valve may also serve as an isolation valve provided it has adjustable memory stops.

E. Accessibility: Locate all equipment that must be serviced, operated, or maintained in fully accessible positions. Equipment shall include, but not be limited to, valves, traps, cleanouts, motors, controllers, switchgear, and drain points. If required for better accessibility, furnish access doors for this purpose. Minor deviations from drawings may be made to allow for better accessibility.

END OF SECTION 15120
SECTION 15130 - PUMPS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: This section covers general requirements for HVAC pumps and accessories of the following types:
   1. In-line circulators and booster pumps
   2. Base-mounted, separately-coupled, end-suction pumps

B. Related Sections: Drawings and general provisions of the contract, including General and Supplementary Conditions, Division 1 Specification Sections, and Section 15050, "Basic Mechanical Materials and Methods," apply to this section.
   1. Division 15 piping system sections for related piping systems and special pump requirements.
   2. Section 15050, "Basic Mechanical Materials and Methods," for basic materials and methods; motors and electrical equipment; one equipment and piping installation.
   3. Section 15055, "Variable Frequency Drives (VFDs)," for variable frequency drives.
   4. Section 15060, "Hangers and Supports," for pipe hangers and supports.
   5. Section 15080, "Mechanical Insulation," for equipment insulation.
   6. Section 15120 “Piping Specialties” for water piping accessories.

1.2 SYSTEM DESCRIPTION

A. Performance Requirements: Pump types and capacities are as shown and/or scheduled on the drawings.

B. Design Criteria: The drawings indicate sizes, profiles, connections, and dimensional requirements of HVAC pumps and are based on the specific manufacturer types and models indicated. Pumps having equal performance characteristics by other manufacturers may be considered, provided deviations in dimensions, profiles, electrical requirements, and efficiencies do not change the design concept or intended performance as judged by the Engineer. The Contractor shall be responsible for any subsequent costs associated with pumps by other manufacturers. A stamped submittal will not relieve the Contractor of this responsibility.

C. Pumps as described in this section shall be furnished for Chilled water systems.

1.3 SUBMITTALS

A. Refer to Division 1 and Section 15050, "Basic Mechanical Materials and Methods," for general requirements.

B. Product Data:
   1. Include Manufacturer's Standard Pump and Motor balance (vibration) criteria.
   2. Product data including certified performance curves, selection operating point, furnished accessories, and motor data. Motors shall be selected for operation at site altitude per Section 15050, "Basic Mechanical Materials and Methods." Pump curves shall include ISO-hp curves to determine overload potential.

C. Shop Drawings: Provide shop drawings for all pumps furnished under this section. Shop drawings shall include certified dimension drawings with shipping, installed and operating weights, weight distribution, and installation recommendations.
D. Closeout Submittals: Provide operating and maintenance data for all HVAC pumps.

1.4 QUALITY ASSURANCE

A. Regulatory Requirements:
   1. Refer to Section 15050, "Basic Mechanical Materials and Methods," for general code, standard and regulatory requirements.

B. Certifications:
   1. All pump motors shall be NEMA rated and UL listed.
   2. Certified performance data shall be furnished for all custom and non-cataloged pumps.
   3. Fabricate and label pumps to comply with UL 778, "Motor Operated Water Pumps" for construction requirements.

1.5 WARRANTY

A. Refer to Section 15050, "Basic Mechanical Materials and Methods," for general warranty requirements.

PART 2 – PRODUCTS

2.1 GENERAL

A. Provide factory-tested pumps, thoroughly cleaned and painted with one coat of machinery enamel prior to shipment.

B. Provide all pumps of same type by the same manufacturer.

C. Fabricate casings to allow removal and replacement of impellers without necessity of disconnecting piping. Type, sizes, and capacities shall be as indicated.

D. Motors shall conform to NEMA Standard MG-1, general purpose, continuous duty, with type of enclosure and electrical characteristics as indicated, and grease-lubricated ball bearings.
   1. Select motors that are non-overloading within the full range of the pump performance curve.
   2. Select motors for continuous duty at altitude.
   3. Reference Section 15050 for additional motor requirements. Only manufacturer’s listed in Section 15050 may be used.

E. All pump motors 1 hp or larger shall be of Design E premium efficiency type per Section 15050, "Basic Mechanical Materials and Methods," except motors controlled by variable speed controllers (VSC’s) shall be inverter duty rated.

F. Vibration shall be such that the value of self-excited vibration velocity is less than 0.10 inch/second when measured with a vibration meter on the frame or bearings of the pump assembly in any of the three axes. The pump and motor assemblies shall be both statically and dynamically balanced so as not to exceed the vibration limits specified.

G. Nameplates showing pump manufacturer's name, model and/or serial number, impeller size, and motor data shall be clearly visible. If impeller has been trimmed from standard size, this information shall appear on nameplate also.
2.2 MANUFACTURERS

Subject to compliance with requirements, products that may be incorporated in the work include, but are not limited to, the following:

A. Wet-Rotor In-Line Circulators:
   "Top S," series Wilo Pumps
   "UP Series," Grunfos Pumps

B. Base-Mounted, Separately-Coupled, End-Suction Pumps:
   "Series 4030," Armstrong Pumps, Inc.
   "340 Series," Aurora Pumps
   "Series 1510," Bell & Gossett, ITT
   "Type LF," Paco Pumps
   "Series F," Peerless Pump
   "FM Series," Taco, Inc.
   "Uni-Pumps, Types GB, GLB, KB, KHB, and KLB," Weinman, Mueller Pump

2.3 WET-ROTOR IN-LINE CIRCULATORS

A. General: Circulators shall be horizontal, in-line, direct-drive, cartridge type, system-lubricated, low maintenance pumps, UL listed and rated for 125 psig (860 kPa) working pressure at 225°F (102°C).

B. Casings: Bronze or Cast iron, flanged.

C. Impeller: Stainless steel or non-metallic, statically and dynamically balanced.

D. Shaft: Stainless steel or ceramic.

E. Rotor Can and Faceplate: Stainless steel.

F. Bearings: Carbon or aluminum oxide ceramic.

G. Motors: Permanent split capacitor with integral thermal overload protection minimum Class H insulation.

H. Capacity Selection: Minimum of three selectable motor speeds or at least six different motor/impeller combinations.

2.4 BASE-MOUNTED, SEPARATELY-COUPLED, END-SUCTION PUMPS

A. General: Pumps shall be base-mounted, centrifugal, separately-coupled, end-suction, single-stage, bronze-fitted, radially split-case design, and rated for 175 psig working pressure and 225°F continuous water temperature.

B. Casings: Cast iron with flanged piping connections, vent and drain plugs, and threaded gauge tappings at inlet and outlet flange connections.

C. Impeller: Statically and dynamically balanced, closed, overhung, single-suction, fabricated from cast bronze conforming to ASTM B584, keyed to shaft and secured by a locking capscrew. Replaceable bronze wear rings.
D. Pump Shaft and Sleeve Bearings: Steel shaft with bronze sleeve.

E. Seals: Mechanical seals consisting of carbon steel rotating ring, stainless steel spring, ceramic seat, and flexible bellows and gasket.

F. Pump Couplings: Flexible, capable of absorbing torsional vibration, complete with metal OSHA-approved coupling guard. Flexible couplings shall not be used to compensate for misalignment of pump.

G. Mounting Frame: Factory-welded frame and cross members, fabricated of steel channels and angles conforming to ASTM B36. Fabricate for mounting pump casing, coupler guard, and motor. Grind welds smooth prior to application of factory finish. Motor mounting holes for field-installed motors shall be field-drilled.

H. Motor: Secured to mounting frame with adjustable alignment on mounting frame, ODP with regreasable ball bearings.

2.5 SUCTION DIFFUSERS

A. Furnish pump suction diffusers on base-mounted end suction pumps.

B. Cast iron angle body, Class 125 with removable straightening vane cylinder, pressure gauge tappings, adjustable support leg, magnetic plug/blowdown connection, and removable operational strainer (in addition to a startup strainer).

C. Steel vane cylinder with minimum free area equal to five times cross-sectional area of pump suction opening.

D. Equal to Bell & Gossett Model FPT (screwed) or FLG (flanged).

PART 3 – EXECUTION

3.1 PREPARATION

A. Equipment Bases:
   1. Coordinate construction of concrete equipment pad type and location.

3.2 INSTALLATION

A. General:
   1. Comply with the manufacturer's written installation and alignment instructions.
   2. Install pumps in locations and arranged to provide access for periodic maintenance, including removal of motors, impellers, couplings, and accessories.
   3. Support pumps and piping separately so that the weight of the piping system does not rest on the pump.
   4. Set base-mounted pumps on concrete foundation. Disconnect coupling halves before setting. Do not reconnect couplings until the alignment operations have been completed.
      a. Support pump baseplate on rectangular metal blocks and shims or on metal wedges having a small taper at points near the foundation bolts to provide a gap of 3/4 to 1-1/2 inches between the pump base and the foundation for grouting.
      b. Adjust the metal supports or wedges until the shafts of the pump and driver are level. Check the coupling faces and suction and discharge flanges of the pump to verify that they are level and plumb.
B. Connections:
1. Install suction and discharge pipe sizes equal to or greater than the diameter of the pump nozzles.
2. Install a non-slam check valve, balancing valve and a shutoff valve on the discharge side of all pumps, unless noted otherwise on the drawings. Valves shall be same size as system piping.
3. Install a shutoff valve and strainer on the suction side of all pumps. Valves shall be same size as system piping.
4. Install a pump suction diffuser on the suction side of base-mounted, end-suction pumps where there is less than 5 pipe diameter of straight at suction or where shown on drawings.
5. Install flexible connectors on the suction and discharge side of each base-mounted pump. Install flexible connectors between the pump casing and the discharge valves and upstream from the pump suction diffuser.
6. Install pressure/temperature test plugs on the suction and discharge of each pump housing using the integral pressure gauge tappings provided.
   a. Install pressure gauge with snubbers and shutoffs at pump inlet and at pump discharge
   b. Install other pressure/temperature test plugs in piping around pumps where shown. Pressure/temperature test plugs and gauges are specified in Section 15120, "Piping Specialties."

C. Alignment:
1. Align pump and motor shafts and piping connections after setting on foundations, after grout has been set and foundation bolts have been tightened, and after piping connections have been made.
   a. Adjust alignment of pump and motor shafts for angular and parallel alignment by one of the two methods specified in the Hydraulic Institute "Centrifugal Pumps - Instructions for Installation, Operation, and Maintenance."
   b. Alignment tolerances shall meet manufacturer's recommendations.
   c. Provide test report.
2. After alignment is correct, tighten the foundation bolts evenly, but not too firmly. Fill the baseplate completely with non-shrink, non-metallic grout, with metal blocks and shims or wedges in place. After grout has cured, fully tighten foundation bolts.

3.3 FIELD QUALITY CONTROL

A. Check suction line connections for tightness to avoid drawing air into the pump.

3.4 STARTING AND ADJUSTING

A. Final Checks Before Startup: Perform the following preventative maintenance operations and checks before startup:
   1. Lubricate oil- and/or grease-lubricated bearings.
   2. Check that pump is free to rotate by hand. For pumps handling hot liquids, pump shall be free to rotate with the pump hot and cold. If the pump is bound or even drags slightly, do not operate the pump until the cause of the trouble is determined and corrected.
   3. Check motor for proper rotation. Rotation shall match direction of rotation marked on pump casing.
   4. Check to see that the check valve is operational, the discharge balancing valve is open, and that there is some downstream flow called for.

B. If the pump is to be started against a closed check valve with the discharge gate valve open, the steps are the same, except that the discharge gate valve is opened some time before the motor is started.

C. If the pump is noisy, it must be repaired or replaced to meet the Owner’s satisfaction.
3.5 TESTING, ADJUSTING, AND BALANCING

A. Refer to Division 15, Section 15990, "Testing, Adjusting, and Balancing," for detailed requirements for testing, adjusting, and balancing hydronic systems.

END OF SECTION 15130
PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: Work under this section shall include furnishing and installing HVAC piping systems as shown on the drawings and as specified hereinafter. Systems shall include:
   1. HVAC chilled water piping
   2. Makeup water piping

B. Related Sections: Drawings and general provisions of the contract, including General and Supplementary Conditions, Division 1 Specification Sections, and Section 15050, "Basic Mechanical Materials and Methods," apply to this section.
   1. Section 15050, "Basic Mechanical Materials and Methods," for basic materials and methods and piping and equipment installation, and welding and joining.
   2. Section 15060, "Hangers and Supports," for pipe supports, product description, and installation requirements.
   5. Section 15110, "Valves," for general duty gate, globe, ball butterfly, and check valves.

1.2 SUBMITTALS

A. Refer to Division 1 and Section 15050, "Basic Mechanical Materials and Methods," for general requirements.

B. Product Data: Submit product data on piping materials, methods, and specialties.

C. Quality Assurance/Control Submittals: Welding certifications (refer to Section 15050, "Basic Mechanical Materials and Methods").

1.3 QUALITY ASSURANCE

A. Qualifications: Welding shall be by certified welders only.

B. Regulatory Requirements:
   1. Refer to Section 15050, "Basic Mechanical Materials and Methods," for general code, standard and regulatory requirements.
   2. Standards: Materials and methods shall conform to the Building Services Piping (ASME/ANSI B31.9) section of the ASME Code for Pressure Piping.

C. Certifications: All safety valves and pressure vessels shall bear the appropriate ASME label and stamp.

PART 2 - PRODUCTS

2.1 PIPING
A. Specification A:
1. Pipe: ASTM B88, Type L drawn temper seamless copper tube.
2. Fittings: ASME B16.22, wrought copper or ASME B16.18 cast-copper alloy
3. Flanges: ASME B16.24, Class 150 cast bronze flanges with solder joint ends
4. Unions: ASME B16.18, cast-copper alloy, hexagonal stock body with ball-and-socket joint, metal-to-metal seating surfaces, and solder joint and/or threaded ends
5. Solder Filler: ASTM b32, Alloy Sn95, Sn94 or E; lead-free
6. Brazing Filler Metal: AWS A5.8 BcuP, copper phosphorus or BAg, silver classification

B. Specification B:
1. Pipe: ASTM B88, Type M drawn temper seamless copper tube
2. Fittings: ASME B16.22, wrought copper or ASME B16.18 cast-copper alloy
3. Flanges: ASME B16.24, Class 150 cast bronze flanges with solder joint ends
4. Unions: ASME B16.18, cast-copper alloy, hexagonal stock body with ball-and-socket joint, metal-to-metal seating surfaces, and solder joint and/or threaded ends
5. Solder Filler: ASTM b32, Alloy Sn95, Sn94 or E; lead-free
6. Brazing Filler Metal: AWS A5.8 BcuP, copper phosphorus or BAg, silver classification

C. Specification C:
1. Pipe: ASTM A53, seamless Grade B weight carbon steel pipe
   a. 1/2 inch and smaller: Schedule 80
   b. 3/4 inch to 10 inches: Schedule 40
   c. 12 inches and larger: Standard weight
2. Fittings:
   a. 2 inches and smaller: ASME B 16.4, Class 125 cast-iron threaded fittings, ASME B 16.3, Class 150 malleable-iron threaded fittings
   b. 2-1/2 inches and larger: ASTM A 234, Grade WPB, butt weld standard weight forged carbon steel
3. Unions: A105, Class 150 forged steel, ground joint
4. Flanges: ASME B 16.5, Class 150, ASTM 181 Gr. II, carbon steel, raised face


PART 3 - EXECUTION

3.1 PREPARATION SURVEYS

A. Surveys – Measurements, Lines, and Levels:
1. Check dimensions at the building site and establish lines and levels for the work specified in this section.
2. Establish all inverts, slopes, and elevations by instrument, working from an established datum point. Provide elevation markers and lines for the Owner’s use to determine that slopes and elevations are in accordance with drawings and specifications.

B. Pipe Cleaning:
1. Clean interior of all piping before installation. Remove any fugitive dust, dirt, and/or threading debris.
2. Flush sediment out of all completed piping systems. Refer to Section 15185, "Chemical Treatment," for cleaning and flushing requirements.

3.2 PIPING APPLICATIONS
A. **Chilled Water:**
   1. 2 inches and smaller: Pipe specification A
   2. 2-1/2 inches and larger: Pipe specification C

B. **Coil Condensate, Blowdown (except steam), Drain, and Vent:**
   1. 2 inches and smaller: Pipe specification A or B
   2. 2-1/2 inches and larger: Pipe specification C

C. **Make-Up Water:**
   1. 2 inches and smaller: Pipe specification A

### 3.3 INSTALLATION

#### A. Piping Installation - General:
   1. **Locations and Arrangements:** Drawings (plans, schematics, and diagrams) indicate the general location and arrangement of piping systems. Locations and arrangements of piping take into consideration pipe sizing and friction loss, expansion, pump sizing, other design considerations. So far as practical, install piping as indicated. Ductwork shall take precedence over piping when coordinating work with other trades.
   2. Provide a complete piping installation, including connections to equipment and installation of automatic control valves furnished by the Temperature Control Contractor. Install control valves with a minimum length equivalent to four pipe diameters of straight pipe entering valve and two pipe diameters leaving the valve, with the stem upright.
   3. Support piping at connections to pumps so there is no strain on pump flanges.
   4. Pitch piping to obtain required air relief and drainage.
   5. Make an allowance for expansion in the installation of piping so the variation in temperature will not cause undue stress at any point. Securely anchor pipes where necessary to properly distribute expansion stresses. Support branch mains and risers in a way that will permit expansion and contraction of risers and to relieve runouts of all weight.
   6. Provide unions or flanges at each control valve and at each piece of equipment.
   7. Conceal all pipe installations in walls, pipe chases, utility spaces, above ceilings, below grade or floors, unless indicated to be exposed to view.
   8. Refer to Section 15060, "Hangers and Supports," for hanger spring and additional installation requirements.

#### B. Condensate Drain Piping:
   1. Provide condensate drain piping where required by mechanical equipment (air handling units, unit ventilators, etc.).
   2. Pitch drain at 1/8 inch per foot toward discharge location.
   3. Daylight condensate drain to nearest floor drain or service sink, or as shown on plans.

### 3.4 FIELD QUALITY CONTROL

#### A. Pipe Testing:
   1. All piping systems shall be tested and proven tight prior to insulation or concealment. The tests shall be witnessed by the Owner's Representative or his designee.
   2. Ensure that the test pressure, which might damage equipment, does not reach such units by valving them off or otherwise isolating them during the test.
   3. Open and close all system valves at least once while system is pressurized to test valve packing. Tighten as required.
   4. All hydrostatic tests shall be held for a minimum of four hours without loss of system pressure. All air tests shall be held for a minimum of one hour without loss of air pressure.
   5. When job site conditions do not permit the use of water, air may be used in lieu of water.
6. Test pressures shall be as follows:
   a. Hot Water/Chilled Water: 100 psig hydrostatic or 1.5 times operating pressure, whichever is greater
   b. Condensate Drain and Blow-Down Drain Piping: plug outlet, fill pipe with water to inlet, and visually inspect for leaks
   c. Makeup Water Piping: 100 psig hydrostatic

END OF SECTION 15180
SECTION 15950 - INSTRUMENTATION AND CONTROLS

PART 1- GENERAL

1.1 RELATED WORK SPECIFIED ELSEWHERE

A. General Requirements Divisions 0 and 1
   Mechanical Division 15
   Testing, Balancing, and Adjusting Section 15990
   Electrical Division 16

B. The General Conditions of the Contract, Supplementary Conditions, and General Requirements bound herewith are a part of these Specifications and shall be used in conjunction with this Division as a part of the Contract Documents. Consult them for further instructions pertaining to this work. Contractors shall be responsible for, and be governed by, all requirements thereunder.

C. All wiring required for proper operation of the automatic temperature system shall be performed by this Contractor in accordance with Division 16 requirements.

1.2 CONTROL SYSTEM TYPE

A. This system shall be a Type I system using pneumatic and electric components.

1.3 SPECIAL CONDITIONS

A. This project uses only Andover Infinity Controls for all DDC applications.

B. The University of Colorado at Boulder has a National Account Agreement with Andover Controls Corporation. This agreement provides for an Andover list price multiplier of 0.400. Ensure that this multiplier is reflected in the bid price of equipment.

C. Each approved Temperature Controls Contractor will make his own determination (required panel types are shown on the I/O summaries) of the Andover products required for the job. It is acceptable to use one expansion module (EMX unit) per controller, but not more than one. Each Contractor can determine the cost for purchasing Andover hardware by using the UCB price for each component.

D. There are three approved Controls Contractors allowed to bid on projects utilizing Andover Controls products on the University of Colorado Boulder campus. They are Arkay Services, Colorado Automation, and Westover Controls. These three companies competitively bid against each other for the entire Andover controls portion of the project; including design, programming, component purchasing, installation, and startup. The cost of any Andover equipment will be included in their price, along with the cost of all other items for which the Controls Contractor is responsible.

E. A licensed electrician shall perform all wiring above 50 volts.

1.4 SCOPE

A. The automatic control system shall be direct digital control (DDC) with electric components as required.

B. All digital and analog control loops shall be (DDC) controlled unless otherwise shown on the drawings.
C. Coordination: This Contractor shall interface with controls furnished with equipment. Provide additional control devices, interlock relays, and signal conditioners when necessary to accomplish specified sequences.

D. The distribution of points and the type of controllers shown on the control panels depicted on the Contract Documents show the actual layout to be used by the Contractor when bidding and installing the controls. It is the Contractor's responsibility to include in the bid the cost of any additional controllers necessary for a complete job, conforming to specifications.

E. Operating Andover controllers that are not connected to the University Andover Network shall not be accepted.

F. The system shall include all interlocks, field devices, wiring, piping, hardware, and software required to provide a complete and functional system in accordance with these specifications and drawings.

G. The automatic temperature control valves, separable wells for immersion sensors, and taps for flow and pressure instruments shall be provided by the Controls Contractor for installation by the Mechanical Contractor under the Controls Contractor's supervision.

H. Electrical wiring in connection with the automatic temperature control system where shown on the Division 16 drawings shall be performed by the electrical contractor. Electrical contractor shall terminate control wiring at motor starters. All other wiring required for proper operation of the automatic temperature system shall be performed by the Control Contractor.

I. The Andover network must be connected to the main fiber backbone. Provide all required Infilink hardware and network wiring between controllers. The University Control Shop shall approve all network routing prior to starting installation. The routing of all network connections shall be the Contractor’s responsibility. All network topology and connections shall be in accordance with the manufacturer's instructions. Routing of conduits shall be this Contractor’s responsibility.

J. Adjustments of manual balancing devices, as required to obtain design air and/or water flows, shall be by the Balancing Contractor. The Controls Contractor shall provide assistance to the Balancing Contractor with control adjustments as required to obtain design flows by:
1. Providing on-site instruction on the proper interfacing and operation of their equipment
2. Providing the necessary software for use with the balancer's personal computer for interfacing with their control equipment. Where proprietary equipment/gateways are required, this equipment shall be provided for the Balancing Contractor's use.

K. Flow meters and other control devices furnished by other contractors shall have all necessary connections to the control system made by the Controls Contractor.

1.5 WORK INCLUDED

A. Furnishing and installing a complete, fully functional control system per this specification and the Construction Documents (specifications, addenda, etc.). This Contractor shall name the points in the controller and set up the point information.

B. Pre-assembled control panels.

C. Actuators, thermostats, sensors, transmitters, thermowells, and mounting hardware as applicable.

D. Construction supervision.
E. Startup and performance testing.

F. Demonstration and training.

G. Warranty.

1.6 DEFINITIONS

A. These specifications and drawings require finished work, tested, and ready for operation. Wherever the word "provide" is used, it shall mean "furnish and install complete and ready for use."

B. "Contractor" shall mean the Controls Contractor performing work under this Division of the Specifications.

C. Where this specification states work to be performed by the words "shall" or "secure" or other performance functions, it shall be assumed that such work shall be performed by this Contractor unless stated otherwise.

D. The word "Mechanical" applies to all work specified herein wherever applicable.

E. The phrase "Architect/Engineer" implies that either may perform the task at hand.

F. The terms "University Engineer" or "Owner's Representative" implies an engineer from the UCB Facilities Management Department.

G. The term “UCB Controls Shop” or “CU Controls Shop” implies a representative of the control shop of the University of Colorado Boulder.

H. The words “or Approved Equal” when referring to parts manufactures shall require written approval by Control Shop Supervisor.

1.7 DRAWINGS AND SPECIFICATIONS

A. The mechanical drawings are diagrammatic in character and do not necessarily indicate every required offset, valve, fitting, etc.

B. All drawings relating to this structure, together with these specifications, shall be considered in bidding. The drawings and specifications are complementary, and what is called for in either of these shall be as binding as though called for by both. Should any conflict arise between drawings and specifications, such conflict shall be brought to the attention of the Architect/Engineer for resolution.

C. Unless otherwise indicated, all equipment and performance data listed is for job site conditions (elevation 5,400 ft.).

D. Drawings are not to be scaled.

1.8 SUBMITTAL DATA AND SHOP DRAWINGS

A. All shop drawings, I/O schedules, point lists, system schematics, and product data shall be submitted for approval per Division 1, Section 01300.
B. Contractor agrees that shop drawings and/or submittals processed by the Engineer are not change orders and that the purpose of shop drawings and/or submittals by the Contractor is to inform the Engineer which equipment and material he intends to furnish and install.

C. Submittal data and shop drawings shall conform to the following requirements:

1. All shop drawings shall be prepared according to the requirements in the most current version of Division 00050 of the University of Colorado at Boulder Construction Standards (Computer-Aided Drafting and Facilities Management Standards). A copy is available upon request. Some of the requirements in this document are listed below.
   a. Shop drawings shall be developed using the most current version of AutoCAD (Autodesk, Inc.) or a version that is 100% compatible with the current version.
   b. Specific information shall be added to the title block of each sheet to aid in the UCB archiving/retrieval process for construction documentation. A copy of the specific requirements is available from the Facilities Management CAD Office.
2. All final or as-built shop drawings for temperature control will become permanent record documents and shall be prepared on four-mil Mylar of the same size (36” x 24”).
3. All submittal data shall be bound or in a three-ring binder as appropriate. All the information shall be indexed and tabbed with reference to the specific section of these specifications. Product data sheets shall be marked with the tag number as indicated on the drawings. All options, ranges, and voltages (which will be provided) shall be clearly indicated on each product data sheet.
4. The format for submittal information shall be as follows:
   a. Control drawings and building plans shall be CAD-prepared drawings. Drawings that cannot represent the total information on one drawing (i.e., a building plan) shall be noted with appropriate match lines, cross references, and key plans.
   b. The control drawing package shall consist of:
      1) A title sheet listing the project title, an index of all the control drawings, and a network schematic showing all DDC Panels and network connections on the project. The network diagram shall indicate all communication devices. The following information shall be provided for each network device:
         a) Location (room number)
         b) Power source (breaker panel I.D. and breaker number)
         c) Panel software name and serial number
         d) Type of controller: The network diagram shall depict the actual connection sequence of the devices, including distances between devices, type of wire used and serial number of controller.
      2) The second drawing in the control package shall consist of typical installation details, a valve schedule, and a damper schedule. The valve schedule shall have entries for: Valve tag, system served, quantity type (3w, 2w), GPM, actual CV, actual pressure drop, size, close off rating, spring range, part number, and manufacturer. The damper schedule shall have entries for: Damper tag, system served, quantity, type (PB, OB), CFM, size, actual pressure drop, quantity of actuators, spring range, damper model number, and, and actuator model number.
      3) Subsequent drawings shall depict complete systems (air handler, chiller, boiler, etc.). The drawing shall show the system schematic, all wiring of the DDC controller, all wiring of field devices, starters, and connections to equipment. Each drawing shall have a bill of materials and a sequence of operation.
      4) Floor plans shall depict equipment location, sensor, and panel locations. The duct and space static pressure monitor points shall be shown.

D. Submittal data and control drawings for all equipment and systems shall be submitted to the Architect/Engineer for review prior to ordering or fabrication of the equipment. The following information shall be included in these submittals:
1. Control valve and damper schedules which include size, Cv (valves), closeoff pressure rating (valves), at 0 psi for N.C., two-way valves; at 20 psi for N.O., two-way valves; and at 0 psi between ports A and B for three-way valves, gpm or cfm, spring range of the actuator, quantity of actuators (dampers), and actual pressure drop for each item.
2. Technical specification data sheets of each system component and device that includes all data needed to show compliance with this specification.
3. Control drawings with detailed piping and wiring diagrams; system schematics with controlled/monitored device locations; and connections to all enclosures, panels, and controllers, including a bill of material for all systems. Ladder-type electrical schematic diagrams shall be provided for all interlock wiring with magnetic starters, control relays, safety devices, etc.
4. Sequence of operation for all controlled and monitored points for each system. Sequence shall be on same drawing as corresponding system schematic.
5. A complete input/output schedule for each DDC panel and dedicated controller including point name (the same name to be used in software), functional description of each point, point type, complete wiring diagram for each point from controller to input or output device, field device type, and location, etc.
6. Communications cable schematic showing panel and controller locations, controller power source, and all interconnecting data and communication conductors. Arrange the panels in the order in which they will actually be interconnected in the field.
7. On control drawings show sensor, panel, and equipment locations by referring to room number.
8. DDC network configuration complete with interconnection diagrams for all peripheral devices, batteries, power supplies, etc.
9. A bill of material shall be shown on each drawing. The bill of material shall include the device code used on the controls drawings, description of the product, name of the manufacturer, complete model number, measurement range (if applicable), and quantity.
10. Identify the electrical power source for each DDC panel by location (room number), panel designation, and breaker number. Include the identification on the drawing and at the DDC panel itself.
11. Submittals shall also include a complete test plan and procedures. Test plan shall be coordinated with the (Section 15990) Testing, Adjusting, and Balancing Contractor. The test plan shall delineate the methods of testing and recording the results of the point-by-point verification and calibration of the hardware and the testing and tuning of the software. The test plan shall include a listing of all hardware points with columns for calibration, test and certification. There shall be a similar record for software.
12. 14 Days Prior to System Demonstration and Acceptance Testing: Provide software programs and sequences written in the program language and in English.

1.9 PROJECT RECORD DOCUMENTS

A. Upon completion of the installation, provide a complete set of record (as-built) drawings on a clear and legible set of Mylar transparencies. The content and format of the drawings shall be as described previously.

B. Prior to Final Completion of the installation, prepare complete Operation and Maintenance manuals. Refer to Division 1, Section 01300, and Division 15, Section 15050, for requirements. Also provide one set of magnetic media containing all CAD-prepared drawings. The file format shall conform to the requirements in the most current version of Division 00050 of the University of Colorado at Boulder Construction Standards (Computer - Aided Drafting and Facilities Management Standards). A copy is available upon request.
1. Temperature control diagrams including an explanation of the control sequence of each system along with the following instruction wherever applicable.
   a. Emergency procedures for fire or failure of major equipment.
   b. Normal starting, operating and shutdown.
c. Summer or winter shutdown.
2. The temperature control diagrams are to be wall-mounted on an aluminum plan-holding stick in a location approved by the University, preferably in the main mechanical equipment room.
3. A reduced copy of the controller drawing, listing all input and output points with functional description shall be placed inside the door to each controller enclosure in a plastic pocket attached to the door. The sheet shall be laminated. One sheet is required for each controller housed in the enclosure.
4. All CAD drawings and controller dumps, generated for operation of the system, shall be included as part of the system documentation. This information shall be submitted in a machine-readable format 3 ½ inch disc.
5. Input/output schedules, data sheets, and all other items required. Describe all regular maintenance that will need to be performed on the DDC hardware. Provide list of recommended spare parts. List all replacement parts with part numbers.
6. Complete original-issue documentation, installation, operation manuals, and supporting software for all third-party hardware and software furnished and installed as part of the system or required for the operation of the system, including remote terminals, user's computer work station, monitors, graphics and memory boards, network servers, printers, and modems.
7. A diagram of the wiring layout for the communication network showing the room number of the location of all junction boxes shall be shown on the diagram. Distances between termination points shall be indicated with a description of routing.

1.10 DEMONSTRATION AND TRAINING

A. This Contractor shall provide a minimum of 4 hours of control system training and demonstration time at the job site for the Owner's personnel.

B. All demonstration and training sessions shall be coordinated with the University Engineer, where applicable.

1.11 WARRANTY

A. The warranty period shall begin as authorized by the Owner's representative in writing. Authorization will not be given before the following conditions are met. Under no conditions will the Controls Warranty begin before the starting date of the General Warranty for the overall project.
1. Completion of the tests required in Part 3 and correction of all problems discovered during the testing process.
2. Completion of all punch list items that are the direct responsibility of the Controls Contractor.
3. Conduction of a preliminary training session for personnel of the CU Controls Shop. A copy of the most current control drawings shall be provided to the CU Controls Shop at this time as well. Other, more detailed, training sessions (such as for review of the control programs) may be held at a later date during the warranty period
4. Completion and distribution of the as-built control drawings, including correction of all items noted by the Owner and Engineer after review of the documents.

B. The control system shall be guaranteed to be free from original defects in material and workmanship and in software design and operation for a period of one year after completion of the contract. The Contractor shall provide the necessary skills, labor, and parts to assure that all system and component failures are promptly repaired.

C. The Contractor shall receive calls during the warranty period for all problems or questions experienced in the operation of the installed equipment and shall take steps to correct any deficiencies that may exist. The response time to critical problems shall be four (4) hours maximum.
D. During the warranty period, the Contractor shall maintain a backup of all software installed in the system. The backup shall be updated monthly or whenever the Contractor makes a change to the software. A reload of backup software into the system shall be performed by the Contractor immediately upon notification by the Owner. The reload shall be free of charge unless it is due to a power failure of duration longer than the battery backup.

E. The Contractor shall optimize all control software to assure acceptable operating and space conditions and peak energy efficiency. This shall include changes needed to optimize operation of the systems even if not explicitly described in Control Strategies.

F. The Contractor shall include the extended warranty for upgrades of ethernet controllers installed in the building for the warranty year.

G. At the end of the warranty period, the Contractor shall supply updated copies of the latest versions of all project record documentation as described in Part 3, Project Record Documents. This includes final updated drawings, software documentation, and magnetic media backups that include all changes that have been made to the system during the warranty period.

H. Coordinate with the CU Controls Shop in advance before connecting new DDC control system to campus network.

I. Once the building DDC is connected to the network, the Contractor shall notify a representative of the CU control shop before and after performing any work on the DDC components, and report any changes made.

J. During the warranty period, University personnel shall make a reasonable effort to determine if a problem is due to the control system or some other source not the responsibility of the Controls Contractor, before requesting warranty service. However, if the Controls Contractor is called out and determines that the problem is not due to the controls system or other building components, the Contractor shall not charge the University for a service call if it is determined that the source of the problem is not his responsibility.

1.12 QUALITY ASSURANCE

A. This installation shall not be used as a test site for any new products unless explicitly approved by the Owner's representative in writing. This requirement is not intended to restrict the Contractor to the use of outdated equipment.

B. All products used in this installation shall be new and currently under manufacture. Spare parts shall be available for at least 10 years after completion of this contract.

C. All DDC components shall be compatible with the rest of the DDC network at the beginning of the warranty period.

1.13 OWNERSHIP OF PROPRIETARY MATERIAL

A. All project developed hardware and software shall become the property of the Owner. These include but are not limited to:
1. Project graphic images
2. Record drawings
3. Project database
4. Job-specific application programming code
5. All other documentation
PART 2 – PRODUCTS

2.1 MANUFACTURERS

A. Regardless of the manufacturer, the specific products and design chosen shall meet the requirements of this specification.

2.2 CONTROL VALVES

A. Control valves shall be two-way or three-way type for two-position or modulating service as scheduled, shown on drawings, or as specified in Sequence of Operation.

B. Flow Control Valves:
   1. The modulating control valves shall be pressure independent. The flow rate thru the valve shall not vary more than ± 5% due to system pressure fluctuations across the valve in the selected operating range. The control valves shall control the flow from 0 to 100% full rated flow
   2. The rangeability of the valve shall be 100:1 minimum
   3. The valve bodies shall be of cast iron or bronze rated for 150 psi working pressure. All internal parts shall be stainless steel, Teflon, brass, bronze or cast iron. The valves shall be serviceable without removing them from the system. The valve flow characteristics shall be able to be changed without removing the valves from the piping system.
   4. Flow performance curves shall be provided with each valve.
   5. Three pressure/temperature ports (Pete's plugs) shall be installed at the factory in each valve. Two ports shall be used to measure inlet and outlet pressure to the valve. The third port is used to measure the internal pressure within the valve.
   6. The valve/pressure regulator assembly shall be factory assembled.
   7. The valve actuator shall be supplied by the control contractor. Torque requirements shall not exceed 20 ft-lbs. for a 6-inch valve and 10 ft-lbs. for a 3-inch valve.
   8. The flow control valves shall be manufactured by Delta P valve or Belimo.

2.3 ACTUATORS AND POSITIONERS - ELECTRIC

A. Quarter-Turn Actuators (for ball and butterfly valves):
   1. Motor: Suitable for 120 or 240 Volt single-phase power supply. Insulation shall be NEMA Class F or better. Motor shall be rated for 100 percent duty cycle. Motors shall have inherent overload protection.
   2. Gear Train. Motor output shall be directed to a self locking gear drive mechanism. Gears shall be rated for torque input exceeding motor locked rotor torque.
   3. Wiring: Power and control wiring shall be wired to a terminal strip in the actuator enclosure
   4. Failsafe Positioning: Actuators shall be spring return type for failsafe positioning.
   5. Enclosure: Actuator enclosure shall be NEMA-4 rated, and shall have a minimum of two threaded conduit entries. Provide an enclosure heater for actuators located outside of buildings.
   6. Limit Switches: Travel limit switches shall be UL and CSA approved. Switches shall limit actuator in both open and closed positions.
   7. Mechanical Travel Stops: The actuator shall include mechanical travel stops of stainless steel construction to limit actuator to specific degrees of rotation.
   8. Manual Override: Actuators shall have manual actuator override to allow operation of the valve when power is off. For valves 4 inches and smaller the override may be a removable wrench or lever or geared handwheel type. For larger valves, the override shall be a fixed geared handwheel type. An automatic power cut-off switch shall be provided to disconnect power from the motor when the handwheel is engaged for manual operation.
9. Valve Position Indicator: A valve position indicator with arrow and open and closed position marks shall be provided to indicate valve position.

10. Torque Limit Switches: Provide torque limit switches to interrupt motor power when torque limit is exceeded in either direction of rotation.

11. Position Controller: For valves used for modulating control, provide an electronic positioner capable of accepting 4-20 mA, 0-10 Vdc, 2-10 Vdc, and 135 Ohm potentiometer.

12. Ambient Conditions: Actuator shall be designed for operation from –140 to 150 °F ambient temperature with 0 to 100 percent relative humidity.

13. Acceptable Manufacturers are Siemens or Belimo.

2.4 CONTROL WIRING

A. Cables shall be shielded when so recommended by manufacturer. Conductor size shall be in accordance with manufacturer's recommendations subject to specified minimum size. Refer to Part 3 for allowable types.

B. All insulated wire to be copper conductors, UL labeled for 90°C minimum service.

C. Raceway for wiring shall be per Division 16.

D. The Contractor shall provide and install:

   1. TVSS surge protectors for incoming 120 VAC power to all controllers. Surge protectors furnished shall be UL 1449 listed.
   2. Transient voltage protection for all twisted pair and coaxial data communication lines between controllers. Provide all required repeaters to assure signal integrity.

2.5 LOCAL CONTROL PANELS

A. All indoor control cabinets shall be fully enclosed, NEMA-3 construction, with hinged door, key-lock latch, baked-enamel finish, removable sub-panels, UL-listed, wall-mounted or free-standing as indicated. Size shall be 38x26 or 42x30.

B. Control cabinet mounted indoors shall be Hoffman NEMA 1 or KELE RET3826 OR, RET4230 OR.

C. Internal components shall be securely mounted on removable sub-panels. Each component shall be individually labeled with function and device identification, as shown on control/interlock shop drawings.

D. Interconnections between internal and face-mounted devices pre-wired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL-listed for 600-volt service, individually identified per control/interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.

E. Provide on/off power switch with overcurrent protection for control power sources to each local panel. Provide a 120-volt duplex outlet inside each control panel that houses a DDC controller (except VAV controllers) if there is not an outlet within 5 feet of the enclosure.

F. Panels shall house the microprocessor, modem, communication interface, all controllers (except those required at VAV boxes), relays, indicators, clocks, switches, pilot lights, override timers, etc., to allow quick access for adjustment and troubleshooting.

2.6 SOLID-STATE SENSING DEVICES
A. Temperature sensors shall be thermistor or platinum RTD type, 1000 ohm wire-wound or 10,000 ohm thin film. Accuracy shall be ±0.5°F with stability of 0.25°F over five years. RTD sensors shall be provided complete with transmitters. Sensors used for BTU calculations shall be accurate to ±0.2°F or 1% of span, whichever is less, and matched.

1. Space sensors shall be surface-mounted and shall have an exposed sensing bead mounted behind a suitable protective enclosure. Sensors mounted to the back of a blank junction-box cover are not acceptable.
2. Duct and immersion sensors shall be immune to moisture and shall have a junction box for electrical connections. Sensing element shall be suitable for the application.
   a. Provide averaging elements for all air temperature-measuring applications, except for return air applications and where noted otherwise.
   b. Provide separable wells and insulation extension for immersion applications.
   c. Provide sun shields for outdoor sensors.
3. Thermowells for all immersion sensors shall be brass or stainless steel as recommended by the manufacturer for the application. They shall have ½-inch or ¾-inch external NPT threads and shall provide for extension of sensor electrical junction box on insulated pipes.

2.7 TRANSMITTERS - SOLID STATE

A. Transmitters shall have sensing elements suitable for the application.

B. Differential pressure transmitters shall have direct-acting, linear 4-20 mA output signal compatible with controller, with full-scale accuracy of ±0.5% or better, 450 psig (3103 KPa) maximum static pressure rating, 200 psid maximum overpressure rating for 6 through 60 psid range, 450 psid for 100 through 300 psid range. Zero and span shall be field-adjustable, stainless steel wetted parts.

1. General: Two-wire smart DP cell type transmitter, 4-20 mA or 1-5 Vdc user-selectable linear or square root output. Accuracy less than 0.1 percent of span.
2. Environmental limits: –40 to 250 °F (–40 to 121°C), 0 to 100% RH.
3. Output Damping: Time constant user selectable from 0 to 36 seconds.
4. Vibration Effect: Less than ±0.1% of upper range limit from 15 to 2000 Hz in any axis relative to pipe mounted process conditions.
6. Approvals: FM, CSA.
7. Acceptable Manufacturers: Rosemount Inc. 3051 Series, Foxboro, Johnson-Yokagawa, Setra, or Mamac

C. Provide a three or five valve bypass kit for protection of DP sensors where the static on the pipe can cause over pressure when connected to one port with the other at atmospheric pressure. Kit shall include high and low pressure isolation valves, high and low pressure vent valves (five valve kit) and a bypass valve contained in a NEMA-1 enclosure. Enclosure shall be mounted no higher than 6 feet above floor level.

2.8 FIELD-MOUNTED ELECTRIC AND SOLID STATE DEVICES

A. Safety Controls:
   1. Low-temperature Detection Elements (Freezestats): Shall be UL-listed, manual reset type, with 20-foot, non-averaging elements and auxiliary contacts for alarm purposes. Any one foot of element sensing a temperature below setpoint shall trigger fan shutdown. Provide one freezestat for each coil section of each coil bank (e.g., one coil with three sections requires three freezestats). Wire freezestats to protect unit in both hand and automatic operation. Wire one set of contacts directly to the fan starter circuit and the other to an alarm input. Manufacturers: Johnson or Penn, model A70HA-1.
   2. Flow-proving or equipment-operating-status switches shall be paddle, differential-pressure, or current-sensing types as indicated below.
University of Colorado at Boulder  
Music Building Delta-P Valve Upgrade Project (MUS-Delta P, CP133892)

a. Paddle-type switches (water service only) shall be UL-listed, SPDT snap-acting with pilot duty rating (125 VA minimum). Adjustable sensitivity with NEMA 1 enclosure unless otherwise specified.
   1) Paddle switches shall be used to prove flow through boilers, chillers, and other applications where actual flow must be confirmed to protect equipment, or for other safety reasons.

b. Flow-proving or Equipment-operating-status Switch Manufacturers:
   1) 3/4-inch - 2-inch pipe: Flotect V-6 or approved equal.
   2) 2-inch and up pipe: Penn F61KB-11 or approved equal.

c. Differential-pressure-type switches (air or water service) shall be UL-listed, SPDT snap-acting, pilot duty rated (125 VA minimum), NEMA 1 enclosure, with scale range and differential suitable for intended application, or as specified.
   1) Manufacturers:
      a) Pump operation: Barksdale Model EPDIH
      b) Fan operation: Johnson or approved equal

d. Current-sensing-type switches shall be used to prove equipment operation in those applications where differential-pressure switches are not applicable or do not function well. They shall be used to prove operation of propeller-type fans, fans with a geometry that does not lend itself to insertion of inlet and/or exit pressure sensing probes, compressors, etc., and as specified. Current-operated switches shall be self-powered, solid state with adjustable trip current. The switches shall be selected to match the current of the application and output requirements of the DDC system. When used with VFDs the switch shall be rated for VFD operation. Manufacturer: Neilsen-Kuljian or SD100 or approved equal.

e. Pressure switch shall be diaphragm-operated with fully adjustable setpoint. Switch shall have visible set point indicator. Operating range shall be as required by the process. Manufacturer: Barksdale Mercoid series 1000 or approved equal.

f. Control relays shall be UL-listed, plug-in type with dust cover and a "energized" indication light. Contact rating, configuration, and coil voltage suitable for application. Provide diodes to limit back EMF on all DC relays and MOVs on AC. Manufacturer: IDEC or approved equal.

g. Time-delay relays shall be UL-listed, solid-state, plug-in type with adjustable time delay. Delay shall be adjustable plus or minus 200% (minimum) from setpoint shown on plans. Contact rating, configuration, and coil voltage suitable for application. Provide NEMA 1 enclosure when not installed in local control panel.

h. Control transformers shall be UL-listed, Class 2 current-limiting type, or shall be furnished with overcurrent protection in both primary and secondary circuits for Class 2 service. Manufacturer: Johnson Control or approved equal.

i. Manual control switches shall be UL-listed for use in NEMA 1 enclosures with contact arrangement and rating suitable for application. Bat handle or knob actuator with nameplate clearly identifying function of each switch position. Manufacturer: Allen Bradley or approved equal.

j. Electrical Three-Phase Power Monitors:
   a) Shall be 1% accuracy, UL-listed split core current transformers.
   b) Shall provide a selectable rate pulse output for kWh reading and a 4-20 mA output for kW reading. Shall operate with 5.0-amp current inputs with a maximum error of plus or minus 2% at 1.0 power factor or 2-1/2% at 0.5 power factor.
   c) Shall incorporate undervoltage/phase monitor circuitry.
   d) Shall be furnished with NEMA 4 enclosure.
   e) Installation shall be by the Controls Contractor

k. Transmitters - Solid State:
   a) Water, Compressed Air, Steam pressure transmitters 4 to 20 mA. Manufacturers: Kele or approved equal
b) Water Differential Pressure Transmitters: Manufacturers: Rosemount model 3051 Series or approved equal.

1. Air Differential Static Pressure Transmitters: Manufacturers: Dwyer Magnehelic Series 605, Air Monitor, or approved equal.

m. Temperature RTD: Manufacturer: Kele or approved equal.

PART 3 – EXECUTION

3.1 GENERAL

A. The Control Contractor shall provide all required control interface relays, including control contactors for single-phase pumps and fans (generally 1/3 hp or less) and any isolation relays required for interface to three-phase magnetic starter control circuits.

B. Accessibility: Install all control devices in readily accessible locations as defined by Chapter 1, Article 100, Part A of the NEC.

C. Hand-Off-Auto switches shall energize equipment in both the “hand” and “auto” mode (when auto is commanded on for auto mode). Safeties shall protect equipment in the hand and auto modes. Where fans are interlocked with damper end switches, the hand and auto positions shall open the dampers and the damper end switch shall energize the fan.

D. Safety Shutdowns – General: All safety shutdowns of electrical equipment shall be hard wired. All shutdowns shall occur directly through interconnection of contacts on the safety device with the controlling circuit of the electrical equipment. Safety shutdowns through software are not acceptable. Interposing relays may be used only with prior approval of the Engineer and Owner's representative when no alternative exists.

E. This Contractor shall notify the CU Controls Shop one month in advance of when connection to the BAS network will be beneficial to the system so the work can be scheduled.

F. Remote control devices and sensors: metal tags; plastic laminate labels; or, on non-porous surfaces only, permanent label tape as produced by the Brother "Easy Touch" label maker. Do not attach tag or label to removable covers, etc. Rivet or stick to device or adjacent surface.

G. Test ports on the air lines connected to a differential air pressure sensor shall consist of a tee in the line with a removable cap on the branch port. Test ports on water lines connected to a differential pressure sensor shall consist of a 1/4-inch size, quick-connect type, quick disconnect on a branch line with a shutoff valve.

H. Standard Nomenclature for Valve Position Description:
   1. Set up the conversion table for each valve control output so that 100% OPEN = open and 0% OPEN = closed.

I. Averaging Sensor Elements, Low-temperature Detection Elements:
   1. The elements of averaging sensors shall be long enough to serpentine across the area served. The element shall cover the duct area completely and shall be equally spaced. Use copper radius clips at the bends and protect sensor elements at duct penetrations and other points of contact with poly FR tubing.
   2. Low-temperature detection devices shall fully cover the coil face as described in Paragraph 2.8 Safety Controls. Mount and protect elements as described above.
3. Sensing elements shall be located so as not to interfere with filter changing or other maintenance activities. The elements shall be mounted downstream of the coil served.

J. Setup of Setpoints: The Setpoint Box in the CX and SX-8000 software shall be checked for all numerical points to be used as setpoints or any type of constant value point.

K. Setup of Inputs – Thresholds: The threshold shall be filled-in with the following value. Where a particular application is not listed, enter a reasonable value based on the application.
   1. Temperature (Space, OAT, MAT, DAT, RAT, etc.) .1°F
   2. Space Static Pressure 0.01"W.C.
   3. Duct Static Pressure 0.2W.C.
   4. Relative Humidity (Space, OAT, MAT, DAT, RAT, etc.) 1%

L. Provide thermal-conducting compound for all sensors in thermowells.

M. Protect all points where pneumatic tubing or sensing elements come in contact with metallic surfaces by enclosing the tubing or sensor with a section of FR poly-tubing. This applies at such locations as duct penetrations, points where tubing is attached to ductwork, points where sensing elements come into contact with or are attached to coil frames, etc.

N. Seal all penetrations into ductwork or air-handling units with duct sealant or other means to make the installation airtight.

O. Mount all control valves so that the stem is vertical. Prior approval is required from the Owner's representative for all installations where this cannot be achieved.

P. Install sensor tubing to both the high and low pressure side of a fan when installing DP switches.

Q. Averaging type sensing elements shall be firmly supported in ductwork or air handling units using 1/2-inch EMT or other auxiliary support.

R. For all applications utilizing outside-air, relief, isolation or exhaust dampers; install an E/P to automatically close the dampers when its associated air handling unit or fan is turned off. The E/P shall be wired so the damper is closed when the fan or AHU is turned off with the starter switch in the OFF or AUTO position (or in either the Bypass or VFD modes when a variable-frequency drive is used.) The dampers shall open, or return to automatic control, as required, when the fan or AHU is turned on, whether the started switch is in the HAND or AUTO position (or in either the Bypass or VFD modes when a variable-frequency drive is used.)

S. Naming Points. The name of each point shall conform to the requirements of the University of Colorado at Boulder Standard Point Naming Scheme. A copy is available upon request. The standard contains a list of acceptable abbreviations and instructions on how they are to be combined to form a name for each point. The intent is to utilize standard point names within a project and from one project to another.

T. Programming. Utilize standard programs prepared by the CU Controls Shop whenever possible. Programs are available for mixed-air temperature control, discharge air temperature reset, control of steam/water heat exchangers for heating water generation, and others. Coordinate with the CU Controls Shop to get copies of the programs and to find out the latest modules that are available. The Temperature Controls Contractor is responsible for modifying the program for the specific application and also for verifying that it is acceptable for the specific application.
Layout of Points on Controllers. The points on controllers shall be arranged by the CU control Shop so that the associated output (controlled device) for a given input (controlled variable) shall both be on the same controller. This also applies in cases where there are multiple outputs for a controlled variable (such as when both the heating coil control valve and the chilled water coil control valve are used to control the discharge air temperature for an AHU).

3.2 CONTROL DEVICE LOCATIONS

A. Remote control devices not in local panels shall be accessible for adjustment and service below 6 ft above finished floor whenever possible.

B. Locate all control devices wired by the Electrical Contractor under Division 16.

C. Freezestats shall be mounted downstream of the first steam or hot water coil of an air handling unit.

3.3 CONTROL PIPING (LIQUIDS)

A. All control piping (sense lines) for liquid service shall be copper or stainless steel with compression fittings.

B. Piping shall be installed so as not to trap air and shall pitch towards the main line.

C. Where pressure is measured in hot liquids or steam, extend the sense tubing to allow the liquid to cool below the operating range of the instrument. The required tubing length can be found in the Data Instruments or Kele catalogs.

D. Isolate all steam pressure instruments with steam siphons (pigtails).

E. Provide ball valves to isolate the instruments from the process.

F. Impulse Line piping for flow transmitters. The following information to be used for proper location & piping of differential pressure transmitters.
   1. For liquid flow measurement taps should be made to the side of the line to avoid sediment deposits, with transmitter below the taps so gases or air will vent.
   2. Make impulse lines short as possible. (Loops in impulse line piping not allowed.)
   3. Slope piping at least 1 inch per foot or (per manufacture recommendations), up toward the process connection for liquid.
   4. Impulse lines shall run parallel so as to keep legs in balance.
   5. Transmitters shall have three-valve manifold for servicing.
   6. Transmitter sensor body shall be mounted vertical to keep liquid leg heights equal.

G. Install the body of the transmitter or switch in such a way that the connecting points for the sensing lines are level, so that the liquid leg heights are equal.

3.4 WIRING

A. General:
   1. A dedicated power, 20-amp, 120-volt circuit shall be provided to each control panel. The Controls Contractor shall terminate the incoming power wiring to the devices in the control panel.
   2. The Controls Contractor shall provide control conduit and wiring to all Motor Starters. The Electrical Contractor shall terminate the control wiring to the motor starters.
   3. Each control panel shall use a separate disconnect with a fuse of the proper amperage. Provide a 120-volt duplex outlet inside each control panel.
4. A TVSS Surge Suppressor shall be located in each control panel containing DDC controllers to condition 120-volt power to all devices in the panel. Manufacturer: Leviton 51020WM or pre-approved equal.
5. Input, output or communications wiring shall be run in a separate conduit from 120-volt wiring.
6. All wiring shall be labeled within two inches of each termination using the wire name shown on the controls drawing.
7. All control and interlock wiring shall comply with the national and local electrical codes and Division 16 of these specifications. Control wiring shall be concealed except in equipment rooms.
8. All Class I (line voltage) wiring shall be UL-listed in approved raceway per NEC and Division 16 requirements.
9. All low-voltage wiring shall also be in metal raceway. Metal raceway type, sizing, and installation requirements shall conform to NEC and Division 16.
10. Line-voltage power and interlock wiring conductors shall be THHN, 14-gauge minimum. Size wire in accordance with NEC.
11. All wire shall be color-coded and labeled for ease of identification.
12. All control wiring shall be installed in a neat and workmanlike manner parallel to building lines, with adequate support. Install without splices between terminal points.
13. The Control Contractor shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.
14. Interconnections between internal and face-mounted devices pre-wired with color-coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL-listed for 600-volt service, individually identified per control/interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.
15. Flexible metal conduits and liquid-tight, flexible metal conduits shall not exceed 3 feet in length and shall be supported at each end. Flexible metal conduit less than 1/2-inch electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal conduits shall be used.
16. Label all temperature control wiring and pneumatic tubing junction box covers with an adhesive backed water proof flexible Mylar label with the letters T/C using an white background with black letters to differentiate them from junction boxes installed by the electrical and fire alarm contractor.

The label shall be 3 inches by 3 inches.

B. Communication:
1. Fiber Optic Cable:
   a. CU Boulder will provide fiber optic cables.
   b. The Controls Contractor shall provide 1-inch EMT conduit for fiber optic cable.
   c. All fiber optic cable shall be one continuous run. Splices are not allowed.
   d. The Controls Contractor shall furnish a Black Box Fiber to UTP Converter, Part # LE61 1A-ST-R3, to connect fiber to each CX9200 Panel. The CU Control Shop shall furnish a cross-over cable to connect converter to the CX9200 panel.
   e. The Controls Contractor shall furnish a black box fiber to UTP Twister Converter, Part #LE7314C, to connect fiber optic cable to the Smart Switch located in the University of Colorado Telecommunications building switch room.
   f. When connecting Infilinks between buildings, use Infilink 210s. Connect fiber optic cable to Port 1 or Port 2 on each Infilink.
   g. The length of each run of Fiber optic cable shall be shown on the control drawings.
   h. The Controls Contractor shall furnish a Black Box Fiber to UTP Converter, Part #LE611A-ST-R3 to connect Fiber to each CX9200 Panel. CU Control Shop shall furnish a cross-over cable to connect converter to the CX9200 Panel.
   i. The Controls Contractor shall furnish a Black Box Fiber to UTP Twister Converter, Part #LE7314C to connect Fiber optic cable to the Smart Switch located in the University of Colorado Telecommunications building switch room.
j. When connecting Infilinks between buildings use Infilink 210’s. Connect fiber optic cable to port 1 or port 2 on each Infilink.

2. Copper:
   a. The Controls Contractor shall follow the specifications shown in the Andover Hardware Installation Guide unless stated otherwise herein.
   b. Communication wire shall be installed in a dedicated Conduit. Other wiring in communications conduit is not allowed.
   c. Cables for Infinet communication wiring shall be 24-gauge, single twisted pair, tinned, shielded copper wire, impedance 100 ohms, velocity of propagation 78%, and capacitance below 12.5 Pico farads/ft. between conductors. Manufacturer: Quabbin Part # 860211.
   d. All communication wire shall be one continuous run. Splices are not allowed.
   e. The length of each run of communication wire shall be shown on the control drawings.
   f. Contact UCB Control Shop for approved communication wire part number.

C. Input and Output: The Controls Contractor shall follow the specifications shown in the Andover Hardware Installation Guide unless stated otherwise herein.

1. Low-voltage wires shall be run in separate conduit from 110 volts or higher wiring.
2. Input and output wiring shall be one continuous run. Splices are not allowed.
3. The Controls Contractor shall use the following wire insulation color-code for input and output wiring (solid colors only wire insulation shall be continuously colored as indicated):

   Input terminal 1 and Output terminal 1 = brown
   Input terminal 2 and Output terminal 2 = red
   Input terminal 3 and Output terminal 3 = orange
   Input terminal 4 and Output terminal 4 = yellow
   Input terminal 5 and Output terminal 5 = green
   Input terminal 6 and Output terminal 6 = blue
   Input terminal 7 and Output terminal 7 = violet
   Input terminal 8 and Output terminal 8 = gray

   For terminal numbers higher than 8 repeat sequence.
   Common for inputs and outputs shall be white.
   120 VAC shall be black = hot, white = neutral, green = ground
   24 VAC shall be (+) black with white tracer, (-) white with black tracer
   24 VDC shall be (+) red with black tracer, (-) black with red tracer

4. All cable conductors shall be minimum 18 AWG TFFN stranded, except 20 AWG TFFN may be used for home runs to central control panels, and for resistance type sensors. Cables shall be shielded when so recommended by the manufacturer.
5. Use proper size wire nut type connectors on all sensor wiring. Crimp connectors not allowed.
6. Metal Oxide Varistors (MOV): Install MOVs across all inductive loads being switched by an output from an Andover controller. This includes all relay coils, solenoid coils (E/Ps), etc. Install the MOV across the coil of the device. Use an MOV rated for the voltage of the coil.

3.5 INSTALLATION PROCEDURES

A. Control Cabinets:
1. Control cabinet mounted indoors shall be Hoffman NEMA 1 or KELE RET3826 or, RET4230.
2. Control cabinet mounted outside shall be Hoffman NEMA 3.
3. Control cabinet shall contain only DDC controllers, surge protectors, and terminal strips.
4. A control cabinet separate from the control containing DDC controllers shall contain output devices (I/Ps, E/Ps, Relays, etc.)
5. Each device mounted in a control panel shall be identified with ½-inch-wide permanent label tape. Brother label maker.
6. Labels shall correspond with the devices shown on the control drawings.
7. Relay bases only shall be labeled, not the removable relay itself.
8. Labels shall not be mounted on removable surfaces, such as cable tray covers.
9. Each control panel shall be identified from the outside with a 1-inch-wide permanent label stating the panel number and system served. Brother label maker.
10. Each component shall be individually labeled with function and device identification, as shown on control/interlock shop drawings.
11. All control panel locks shall conform to the CU Control Shop standard lock for control cabinets. Contractor shall furnish control panel keys to the CU Control Shop at the completion of training.
   a. Utilize Hoffman Lock Kit A-Lizar, DNB No 783510-34630 with Hoffman Panels
   b. Utilize CU Control Shop Standard Lock on Kele Panels

3.6 DDC HARDWARE INSTALLATION REQUIREMENTS

A. Controllers:
   1. The Controls Contractor shall follow the specifications shown in the Andover Hardware Installation Guide unless stated otherwise herein.
   2. Controller power shall have a separate disconnect (or fuse) for each controller.
   3. Follow color code (in Wiring section) for input and output terminations.
   4. Inputs with no corresponding output should be put on Terminals 9 through 16.
   5. Only two pair of communication wires shall be connected to the communication terminal on the controller.
   6. Provide controllers so that all points associated with and common to one unit or other complete system/equipment shall reside within a single control unit.
   7. All SX 810 and SX 920s will have display.

B. Expansion Modules: Andover DDC:
   1. The Controls contractor shall follow the specifications shown in the Andover Hardware Installation Guide unless stated otherwise herein.
   2. The use of Andover DCC expansion Modules shall be pre-approved by the University Engineer.
   3. Expansion modules not approved by the University Engineer shall not be accepted.

C. Infilinks:
   1. The Controls contractor shall follow the specifications shown in the Andover Hardware Installation Guide unless stated otherwise herein.
   2. Use an Infilink 200 to connect controllers in a building together.
   3. Use an Infilink 210 to connect controllers between buildings.
   4. When Infilink 210s are required, Controls Contractor shall supply two Infilinks.
   5. To series Infilinks together, communication wires shall be connected to port 1.
   6. Only 2 pair on port 1.
   7. Only 1 pair on ports 2-5.

3.7 CONTROL PANELS

A. Refer to Part 2 - Products for construction details.

B. Field wiring to panels shall be enclosed in metal raceway.

C. Panels shall be wall-mounted at eye level for accessibility and service.
D. Local control panels shall be located within same room of system served otherwise location shall be approved by CU Control Shop.

E. Control devices shall be installed in panels. Electro pneumatic switches (EPs) and relays shall be grouped together and installed in a single, central panel located next to the enclosure housing the associated controller. Remote mounted (PEs) are acceptable. Remote mounted relays and EPs are not acceptable.

F. Electrical power for each panel shall be from a dedicated circuit. For retrofit applications, where connecting to existing control-power wiring, it is the Contractor's responsibility to verify that the power source is from a dedicated circuit. Notify the Owner if the source is not from a dedicated circuit. Where available in a building, utilize emergency power circuits for all controls.

G. Mount panels on solid, non-vibrating surfaces. Where such surfaces are not readily accessible, mount the panel on a rigid, Unistrut stand attached to the floor. The sides of ducts and air handling units are not acceptable mounting surfaces.

3.8 NETWORK COMMUNICATIONS

A. All network wire and fiber shall be in raceway. Network raceway shall be a minimum of 3/4-inch.

B. Where network raceway penetrates a floor place a junction box at the underside of the floor penetration.

3.9 CLEANUP

A. At the completion of work, all equipment on the project shall be checked and thoroughly cleaned including under equipment and any and all other areas around or in equipment provided under this section. Clean exposed surfaces of all equipment and panels of all grease, plaster, or other foreign material. Remove all stick-on labels and clean surfaces.

B. At the completion of the work, remove from the building, the premises, and surrounding streets, alleys, etc., all rubbish and debris resulting from this project, and leave all equipment spaces clean and ready for use.

C. At the completion of work, all equipment furnished under this contract shall be checked for paint damage, and any factory finished paint that has been damaged shall be repaired to match the adjacent areas. Any metal cabinet, jacket, or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.10 TESTING

A. Upon completion, the control system shall be inspected and tested to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his own inspection, tests.

B. The Contractor shall inform the University Engineer in writing that the control system has been inspected, tested and is ready for inspection and testing to verify operation and compliance with this specification.

C. The tests described in this section shall be performed after to the tests that the Contractor performs as a necessary part of the installation, startup, and debugging process. Control system testing shall be coordinated with the Commissioning Agent and scheduled with the Owner's Representative.

D. The Contractor shall provide at least two technicians equipped with two-way communication, and shall demonstrate actual field operation of each control and sensing point for all modes of operation including
day, night, summer, winter, occupied, unoccupied, fire/smoke alarm, and power failure modes. The purpose is to test the setup, calibration, response, and action of every point. Any test equipment required to prove the proper operation shall be provided by and operated by the Contractor. The Commissioning agent and the Owner's representative shall observe, direct and review these tests.

1. The system software shall be complete such that each control loop shall function as specified in the Sequence of Operation. This contractor shall be required to furnish the software program and test the operation of every control loop.

2. After all field connections, communications links with the university Andover network have been made and control power is available to the control panel, the Commissioning of the mechanical system, automatic control system systems shall begin.

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

E. Operational logs for each system which indicate all setpoints, operating points, valve/damper positions, mode, and equipment status shall be submitted to the Architect/Engineer upon request.

F. Control loops shall maintain setpoint within the following tolerances:

   Temperature        +1.0°F
   Fluid Pressure     +2.0 psi  range 1-150 psi

   Control loops that do not meet the above tolerances shall be re-tuned.

G. This Contractor shall demonstrate all alarms prior to placing the control system in service.

H. The control system shall not be accepted as meeting the Requirements of Completion until all tests described in this section have been performed to the satisfaction of both the Engineer and Owner. Any tests that cannot be performed due to circumstances beyond the control of the Contractor may be exempt from the Completion Requirements if stated as such in writing by the Owner's representative. Such tests shall then be performed as part of the warranty.

I. After the system has operated properly for 90 days following control system startup any software upgrading or enhancements to improve the system operation or as required for proper operation of the system during the first year of operation is the responsibility of this contractor.

J. Install the body of the transmitter or switch in such a way that the connecting points for the sensing lines are level, so that the liquid leg heights are equal.

3.11 PROTECTION

A. The Contractor shall protect all work and material from damage by his work or workmen and shall be liable for all damage thus caused.

B. The Contractor shall be responsible for work and equipment until finally inspected, tested, and accepted. They shall protect work against theft, injury, or damage; and shall carefully store material and equipment received on site which is not immediately installed. They shall close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.12 WORKSTATION PROGRAMMING
A. The University has multiple workstations networked across the campus. The main file server is located in the Facilities Engineering Offices in the Stadium Building. All workstation programming will be performed by the University.

3.13 FIBER OPTICS - NETWORKING

A. Provide all required translators and power connections required to connect DDC panels to the University network. Fiber will be routed from the main telephone closet in the building to the enclosure in the mechanical room where the Infilink will be mounted. Translators will also be required at Hubs as noted on the I/O summaries. The fiber will be provided under separate contract. This contractor shall provide 1-inch minimum conduit for the fiber.

B. The fiber network is duplex (two strands of fiber). At least one spare set of fiber strands is included with each run.

C. The temperature controls contractor shall be responsible for connecting the new Infilink in the building. Final connection of the building controls to the campus Andover Network and bringing them on-line shall be supervised by and be the responsibility of the Temperature Controls Contractor. The Contractor shall confirm that the communication network linking controllers within the building functions properly, before connecting the new controllers to the campus network.

3.14 DDC SOFTWARE

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

B. Time schedules and other user programming for the digital outputs will be done by the University. This contractor shall setup the point types and names in the controller.
SECTION 15990 - TESTING, ADJUSTING, AND BALANCING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: This section covers the general requirements for testing, adjusting, and balancing (TAB) the Division 15 environmental systems including (but not limited to) central cooling plant hydronic distribution systems and the equipment and apparatus connected thereto.

B. Related Sections: Drawings and general provisions of the contract, including General and Supplementary Conditions, Division 1 Specification Sections, and Section 15050 "Basic Mechanical Materials and Methods" apply to this section.

1. Section 15050 "Basic Mechanical Materials and Methods" for basic materials and methods and submittal and documentation requirements.

2. Section 15950 "Instrumentation and Controls" for control criteria.

1.2 SUBMITTALS

A. Refer to Division 1 and Section 15050 "Basic Mechanical Materials and Methods" for general requirements.

B. Samples: Submit proposed TAB forms and report formats to Owner or his representative for approval at least 120 days prior to commencing field work.

C. Quality Assurance/Control Submittals:

1. Qualifications: Within 30 days after contract award, submit the name(s) of the professional engineer and/or the NEBB certified supervisor who will be supervising this work. Submit the name(s) of the TAB technician(s) who will be performing the work.

D. Balancing Contractor shall review the contract documents and submittals for location and type of balancing devices being installed by the mechanical and sheet metal contractors, and shall issue a letter to UCB that s/he is in agreement with them, or shall identify deficiencies needing attention.

E. Closeout Submittals:

1. TAB Report: After all balancing is complete, and all coordination with the Commissioning Contractor and the Owner or his representative is complete, the balancing firm shall furnish five bound reports which shall contain the following information:

   a. Pump and motor nameplate information, amperage and voltage to all motors, flow and pressure drop across all system terminals, pressure rise across the pump in psi and feet of head, both operating and shut-off, and maximum operating gpm.

   b. Overload protection data for all motors shall be recorded. Starter and/or VFD brand, model, enclosure type, installed overload devices, original ratings and set points (and revised device ratings and set points when applicable) shall be recorded. If the starters (and/or VFDs) were furnished by the Mechanical Contractor, the overloads shall be verified and changed to the correct size when necessary, and so noted in the report. If the starters were furnished by the Electrical Contractor, the correct overload device sizes and settings shall be noted in the report and the Electrical Contractor shall be advised of all discrepancies.

   c. The method of balance, the instruments used with calibration history, the project altitude, and any correction factors used in the calculations shall be reported.
d. The TAB Contractor shall submit bound copies of the final testing and balancing report to the Owner or his representative at least 15 days prior to the Mechanical Contractor's request for final inspection. All data shall be recorded on applicable reporting forms. The report shall include all operating data as previously listed, a list of all equipment used in the testing and balancing work, and shall be signed by the supervising registered engineer or certified TAB supervisor and certified TAB technician, and affixed with his certification seal. Final acceptance of this project will not take place until a satisfactory report is received.

2. Balance report shall not be submitted until all improperly configured or installed systems are corrected and improperly installed or missing balance devices are corrected and tested reports submitted with incomplete information will be returned unreviewed.

1.3 QUALITY ASSURANCE

A Qualifications:
1. Pre-qualified TAB firms for this project are:
   - Checkpoint Balance, LLC 303-670-3650
   - Finn & Associates 303-353-8210
   - JPG Engineering 303-688-9044
   - Tab Services 303-649-1213
2. The balancing work, including air and hydronic portions, shall be performed by the same firm having total professional responsibility for the final testing, adjusting, and balancing of the entire system.
3. The TAB field work shall be performed under the direct supervision of a registered Professional Engineer who has had at least five years of balancing experience in the state in which the work is being done or a NEBB or AABC certified TAB supervisor. The PE or certified supervisor may:
   a. Perform the TAB work or be on-site at least 33% of the total time the TAB work is in progress, or
   b. Be on site a minimum of 10% of the total time the TAB work is in progress with the work performed by a full-time certified TAB Technician who has been certified by the Sheet Metal Industry National Certification Board.

B. Certifications:
1. Testing, adjusting, and balancing shall be done by a firm using NEBB or AABC certified supervisors, or by an independent firm specializing in this work. A definition of independent shall mean the firm is not associated with the Mechanical Contractor performing work under Division 15; the firm derives its income solely from testing, adjusting, and balancing and/or commissioning mechanical systems, and the work is performed in a professional manner.
2. TAB firm shall own or rent and have available for this project all necessary balancing instruments as required to maintain NEBB or AABC certification. Instrument calibration shall have been checked and verified as per NEBB requirements. Provide instrument list with calibration date for each instrument listed.

C. Regulatory Requirements:
1. Refer to section 15050 "Basic Mechanical Materials and Methods" for general code, standard and regulatory requirements.
2. Comply with procedural standards for testing, adjusting, and balancing of environmental systems as outlined in the latest edition of SMACNA, NEBB, and/or AABC procedural manuals.

1.4 SCHEDULING
A. Coordinate scheduling of work with the General Contractor and the appropriate subcontractors.
   1. Schedule TAB work to coincide with testing and verification of control systems where practical.

B. Provide written notification (within 24 hours) to General Contractor, Engineer, and Owner or his representative of any component and/or system deficiencies.

1.5 RETAINAGE

A. Contract payment retainage may be withheld against the General Contractor until the final completion of this section of work has been demonstrated by the submission of the TAB report, and an evaluation of its contents has been made by the Owner or his representative.

PART 2 - PRODUCTS

2.1 EQUIPMENT

A. Provide all necessary tools, scaffolding, and ladders.

B. Provide all necessary instruments. Calibration and maintenance of instruments shall be in accordance with SMACNA, NEBB, AABC, and/or the manufacturer's standards and recommendations.
   1. Calibration histories for each instrument shall be available for examination.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Testing and balancing shall not begin until the system to be tested has been cleaned and flushed, and is in full working order. Where glycol is used, it shall be installed prior to hydronic balancing.

B. Preliminary TAB requirements shall be ascertained prior to the commencement of work through a review of available plans and specifications for the project. In addition, visual observations at the site during construction shall have been made to determine the location of required balancing devices, that they are being installed properly, and access is provided for.

C. Prior to and during testing and balancing, TAB contractor shall immediately notify the Contractor of all balancing devices not yet installed and those portions of the system unable to be balanced. The Contractor shall correct the deficiencies and shall notify the Engineer of situations requiring additional instruction.

D. Before any hydronic balancing work is done, the system shall be checked for:
   1. Proper cleaning and flushing; glycol installed when specified
   2. Dirty strainers
   3. Correct pump rotation
   4. Proper control valve installation and operation
   5. Proper system static pressure to assure a completely filled system
   6. Air in system eliminated
   7. Proper flow meter and check valve installation
   8. Manual balancing devices, control and shut-off valves are open at this time.

E. Put heating, ventilating, and air conditioning systems and equipment into full operation and continue operation of same during each working day of testing and balancing.
3.2 REQUIREMENTS OF WORK

A. Adjust hydronic systems to the following tolerances:

1. Cooling System:
   a. Supply water temperature 45°F to 55°F: -5% to +10% of design value.

B. Hydronic Balance:
   1. Record all steam and/or water inlet and leaving temperatures, pressure drops, and flows.
   2. Record inlet and outlet water temperatures of all air handling unit coils, unit heaters, convectors, finned tube radiation, and other heat release equipment, as well as the corresponding media flows and pressure drops.
   3. Chilled Water Systems: Measure and record the campus (CCWS/R) and building (CWS/R) chilled water inlet and leaving fluid temperatures and flows.
   4. Circulating Pumps: Record flow rates, pressures, running amperage, and full load amperage at design flow and shutoff conditions. Verify impeller size and shutoff head.
   5. Final adjustments shall include but not be limited to the following:

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<tbody>
<tr>
<td>Campus Chilled Water System</td>
<td>GPM: Measure and adjust water flow rates from the campus system to design values. Record inlet and leaving fluid temperatures and pressure drops under full-load conditions.</td>
</tr>
<tr>
<td>AHU and Terminal Units</td>
<td>GPM: Measure &quot;wide-open&quot; water flow rate; adjust branch gpm to the listed values. Variable water flow systems with two-way control valves shall be adjusted to peak flow values to confirm overall system performance. Verify coil performance by measuring and recording air and water flow rates, pressure drops and temperatures, and comparing with manufacturer's data.</td>
</tr>
<tr>
<td>Pumps</td>
<td>Direct Drive: Verify impeller size and shutoff head. Measure and adjust water flow rate to design gpm with all system control valves full open. Record pump inlet and outlet pressure at design flow. If pump must be severely restricted, report immediately so that impeller may be investigated and trimmed if necessary.</td>
</tr>
<tr>
<td></td>
<td>VSC Drive: Coordinate VSC startup with Section 15055 vendor. Adjust maximum and minimum rpm settings as necessary to obtain design gpm and/or required system pressure difference at last heat transfer point in system. Verify that ramp-up and down adjustments are made as necessary to prevent overshoot and &quot;hunting.&quot; Verify that overload trip settings are properly adjusted as necessary to protect the motor. Verify pump performance as compared to manufacturer's data at both shut-off and maximum water flow rates.</td>
</tr>
</tbody>
</table>

6. Variable volume, constant volume and mixed (with 2-way and 3-way valves) hydronic systems with flow measuring devices: Systems/ devices shall be balanced proportionally using the flow measuring devices. On completion of the balance, the following information shall be recorded in the report: Flow meter size and brand, measuring device orifice size, required flow rate and pressure drop, valve settings on balancing valves with a readable scale, flow rate in both full coil flow and full bypass modes.
7. Variable flow hydronic systems with flow measuring devices: With all system balancing devices, manual shut-offs, and control valves in full-open position, check main flow and pump motor amperage(s) to verify that full load motor current ratings are not exceeded. If excessive flow at main pumps results in motor overload, reduce main system flow as necessary so that motor FLA is not exceeded and recheck main flow. Using local FMS devices, verify and record full-open flow rates at terminal devices. Close at least 50% of the system control valves and verify that system differential pressure controls are functional and setpoint is proper to obtain full flow at furthest terminal unit. With most (98%) of main flow shut off by local control valves, verify that close-off rating of control valves is not exceeded.

10. When all hydronic balancing is done, all balancing valve positions shall be marked and the locking devices set. Confirm in report.

3.3 FIELD QUALITY CONTROL

A. Upon request of the Commissioner or Engineer, a representative of the balancing firm performing the work shall demonstrate to him fluid flow quantities shown in the report by reading back outlets or terminals selected at random by the Engineer. It is understood that the operating mode of the system shall be the same for readback as it was during balancing, and the number of readings verified will not exceed 10% of the total in the report.

B. When deemed necessary by the Owner or Engineer, the balancing firm shall run temperature, pressure, and/or humidity recordings, and shall be prepared to verify any of the report test results in the presence of the Owner and/or Engineer when requested.

C. When deemed necessary by the Engineer, a 24-hour space temperature recording shall be taken and any required partial rebalance of the system shall be performed without any additional cost.

END OF SECTION 15990
SECTION 15995 - SYSTEM STARTING AND TESTING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. This section covers the general requirements for the Division 15 responsibilities for system startup.
   2. Mechanical system installation, startup, testing, balancing, preparation of O&M manuals, and operator training are the responsibility of the Division 15 Contractor(s). The Division 15 Contractor(s) shall complete all portions of the work in a satisfactory and fully operational manner.
   3. Work of Division 15 includes:
      a. Testing and startup of the equipment.
      b. Testing, adjusting, and balancing of hydronic systems.
      c. Providing qualified personnel for participation in system start-up.
      d. Providing equipment, materials, and labor as necessary to correct construction and/or equipment deficiencies found during the start-up process.
      e. Providing training and demonstrations for the systems specified in this Division.

B. Related Sections: Drawings and general provisions of the contract, including General and Supplementary Conditions, Division 1 Specification Sections, and Section 15050 "Basic Mechanical Materials and Methods" apply to this section.
   1. Section 15050, "Basic Mechanical Materials and Methods" for basic materials and methods and submittal and documentation requirements.
   2. Section 15950, "Instrumentation and Controls" for specification of the instrumentation and temperature control contractor responsibilities.
   3. Section 15985, "Control Sequence of Operation" for specification of the equipment sequences and the temperature control contractor responsibilities.

1.2 TRAINING

A. In addition to the requirements of Division 1, provide training of the Owner’s engineering and maintenance staff on each system and related components.

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

A. Provide test equipment as necessary for testing and startup of the mechanical equipment and systems.

2.2 TEST EQUIPMENT - PROPRIETARY

A. Proprietary test equipment and software required by the equipment manufacturer for programming and/or startup, whether specified or not, shall be provided to the Contractor at no cost by the manufacturer of the equipment. Manufacturer shall provide the test equipment and demonstrate its use. Proprietary test equipment (and software) shall become the property of the Owner upon completion of the system start-up.

B. Controls contractor/manufacturer shall provide print-out of:
   1. All software code
   2. All user interface screens
PART 3 - EXECUTION

3.1 WORK PRIOR TO FUNCTIONAL TESTING

A. Complete all phases of work so the systems can be started, tested, balanced, and otherwise Commissioned. Division 15 has startup responsibilities for all mechanical systems so they are functional. This includes the complete installation of all equipment, materials, pipe, duct, wire, insulation, controls, etc., per the contract documents and related directives, clarifications, change orders, etc.

B. Prepare pre-functional test forms within ten calendar days of receipt. Complete and sign functional test forms within ten days of substantial installation and in advance of testing, adjusting, and balancing.

C. Start-up responsibilities are as follows:
   1. Factory startup services for the following items of equipment:
      a. Air handlers, fans, and heating equipment
      b. Chemical water treatment
      c. Pumps
      d. Control systems
      e. Heat exchangers
   2. Normal startup services required to bring each system into a fully operational state. This includes motor rotational check, belt and alignment checks, cleaning, filling, purging, leak testing, control sequences of operation, full-load and part-load performance, etc.

3.2 FUNCTIONAL TESTING

A. Provide skilled technicians to start up and debug all systems within Division 15. Contractor will ensure that the qualified technician(s) are available and present during the agreed-upon schedules and of sufficient duration to complete the necessary tests, adjustments, and/or problem resolutions.

B. Develop, complete and sign functional performance test forms.

C. System performance problems and discrepancies may require additional technician time, reconstruction of systems, and/or replacement of system components. The additional technician time shall be made available for subsequent testing periods until the required system performance is obtained.

D. The Owner/Engineer reserves the right to question the appropriateness and qualifications of the technicians relative to each item of equipment, system, and/or subsystem. Qualifications of technicians will include expert knowledge relative to the specific equipment involved and a willingness to work with the associated staff to get the job done. Division 15 Contractor shall also provide adequate documentation and tools as necessary to start up and test the equipment, system, and/or subsystem.

3.3 WORK TO RESOLVE DEFICIENCIES

A. In some systems, misadjustments, misapplied equipment, and/or deficient performance under varying loads will result in additional work being required to commission the systems. This work will be completed under the direction of the Owner’s representative with input from the Contractor, equipment supplier, and Engineer. Whereas all members will have input and the opportunity to discuss, debate, and work out problems, the Owner will have final jurisdiction over any additional work done to achieve performance.
B. Division 15 corrective work must be completed in a timely fashion to permit the timely completion of the testing process. Experimentation to demonstrate system performance may be permitted. The Owner reserves the right to obtain supplementary services and/or equipment to resolve the problem if not completed in a timely manner. Costs incurred to solve the problems in an expeditious manner will be the Contractor’s responsibility. These costs may be deducted by the Owner from payments to the Contractor.

3.4 ADDITIONAL COMMISSIONING

A. Additional testing activities may be required after system adjustments, replacements, etc., are completed. The Contractor and suppliers shall include a reasonable reserve to complete this work as part of their contractual obligations.

3.5 SEASONAL COMMISSIONING

A. Seasonal testing pertains to testing under full-load conditions during peak heating and cooling seasons, as well as part-load conditions in the spring and fall. Initial testing will be done as soon as contract work is completed, regardless of season. Subsequent testing shall be undertaken at any time thereafter to ascertain adequate performance during the different seasons.

B. Cooling equipment will be tested as close to summer design extremes as possible (subject to school schedule limitations) with a fully occupied building. Each Contractor and supplier will be responsible to participate in the initial and the alternate peak season tests of the systems as required to demonstrate performance.

C. Training will be conducted by the Contractor(s) and vendors. The Contractor will be responsible for highlighting system peculiarities specific to this project.

3.6 SYSTEMS DOCUMENTATION

A. Refer to the requirements of Division 1 and Section 15050 "Basic Mechanical Materials and Methods." Division 15 Contractor(s) shall update contract documents to incorporate field changes and revisions to system designs as required to show actual constructed configurations.

B. Provide all required shop drawings, as-builts, and O&M data to the Engineer for review and editing. See Section 01650 for more information.

3.7 COORDINATION

A. Provide copies of all initial and final “no exceptions taken” or “make corrections noted” shop drawing submittals to the Engineer.

B. Provide copies of all start-up and testing related communication and documentation to the Engineer and Owner.

END OF SECTION 15995
SECTION 16010 – BASIC ELECTRICAL REQUIREMENTS

PART 1 – GENERAL

1.1 SECTION INCLUDES

- Provisions, Description, and Definitions
- Quality Assurance
- Work Included and Not Included
- Related Work Specified Elsewhere
- Coordination with other work
- Standards for Materials
- Prior Approval or Substitution of Equipment and Materials
- Code Compliance, Fees and Permits
- Drawings and Specifications
- O&M Manual and Instruction
- General Project Execution Requirements
- Guarantee
- Safety and Indemnity

1.2 PROVISIONS

A. The general provisions of the contract, including General and Supplementary Conditions and General Requirements, apply to the work specified in this section.

B. Provisions of this section shall apply to all sections of Division 16.

C. Submit product data and shop drawings of all electrical equipment, complying with the requirements in Division 1 and with the specific requirements of appropriate sections of Division 16 specifications.

1.3 DESCRIPTION

A. Furnish all materials, equipment, tools, and labor and install electrical work as indicated on the drawings and as specified herein. Connect all new facilities to be installed for a completely coordinated and integrated electrical system. It is the intent and purpose of these contract documents that upon completion of the project, the electrical installation, including all systems, shall be complete and operable in all respects. Completely connect all systems, equipment, motors, heaters, lighting fixtures, outlets, devices, etc., shown, noted, or required, from source of power to final connections and leave ready for satisfactory operation. Furnish and install any minor items omitted from design but obviously necessary to accomplish the above intent.

B. One prime electrical subcontractor shall be responsible for all materials, equipment, and labor under Division 16.

C. It shall be the responsibility of the General Contractor to coordinate the work of the electrical contractor with the work of other contractors on the project. This shall include, but not be limited to the responsibility for the coordination of the concrete and landscaping.

1.4 DEFINITIONS

A. The term "Electrical Contractor" or "Contractor" used throughout Division 16 shall mean the Prime Electrical Subcontractor, and/or the General Contractor.
B. Instructions such as "Provide the outlets" shall mean the same as though the words "This Contractor shall" preceded each such instruction. "Provide" shall mean "Furnish and Install."

C. Where the words "Accepted" or "Acceptable" are used, such "Accepted" or "Acceptable" action by the Engineer and/or Architect denotes that the work or equipment item is in conformance with the design concept of the project and, in general, complies with pertinent information given in the Contract Documents.

1.5 QUALITY ASSURANCE

A. Only quality workmanship will be accepted. Haphazard or poor installation practice will be cause for rejection of work.

B. Where specifications call for an installation to be made in accordance with Manufacturer's recommendations, a copy of such recommendations shall at all times be kept in job superintendent's office and shall be available to Architect's/Engineer's and/or Owner's representative.

C. Upon completion of work, all equipment and materials shall be installed complete, thoroughly checked, correctly adjusted, and left ready for intended use or operation. All work shall be thoroughly cleaned and all residue shall be removed from surfaces. Exterior surfaces of all material and equipment shall be delivered in a perfect unblemished condition.

D. Contractor shall provide a complete installation, including all required labor, material, transportation, insurance, permits, and taxes.

E. The electrical contractor shall have been registered continuously in the state of Colorado for a minimum of five years as an electrical contractor, and shall maintain such registration in good standing throughout the duration of the project.

F. The electrical contractor shall perform a minimum of 50% of Division 16 work with direct employees; the remaining work may be performed by subcontractors to the prequalified Electrical Contractor.

G. Within 4 weeks of shop drawing approval, the Contractor shall submit a detailed sequence of work for review and approval by the University. This report will detail all work proposed by the Contractor, including time sequence, tasks, responsibility, and estimated completion times. The report will include a detailed breakdown of University/Contractor coordination checkpoints and proposed safety measures (lockout/tag-out, grounding, tailgate meetings, etc.).

H. Electrical Contractor shall not have any pending OSHA violations against the company at the time of bidding.

I. The Electrical Contractor shall guarantee that all work will be completed in accordance with the NESC, National Electrical Code (2008), OSHA, and any other applicable codes.

1.6 SPECIAL ELECTRICAL PROVISIONS

A. Bidding Requirements:
   1. Electrical Contractor shall give evidence of being able to be bonded to 1-1/2 times the job value. A letter shall be provided by the bonding agency assuring capability of bonding this level and associated rates.
   2. The successful firm shall be capable of starting work immediately upon receipt of contract award and shall have the resources to complete the outage-related work over one weekend. This includes the
shutdown of existing equipment and installation, testing, and load transfer to new transformers and panelboards.

B. Qualification Requirements:
1. Contractors bidding this project must complete AIA Document A305-1986, “Contractor’s Qualification Statement” and submit it with their proposal for information purposes.
2. In addition to the information requested in #1 above, the Contractor must provide a statement(s) indicating that they meet the following minimum requirements:
   a. List a minimum of two projects completed in the last five years that were similar in size (or larger), complexity and type. For each project list:
      1) Name and location of project
      2) Name, address and phone number of the client/Owner and the Owner’s representative.
      3) Contract type (prime or subcontract) and contract value (or subcontract value).
      4) Year in which work was performed.
   b. The firm and its operating officers (above the level of project manager) shall have been involved in electrical contracting for at least five years.
   c. List project values (or subcontract values, if applicable) which total at least five times job value of electrical work in the last five years completed by the firm or its operating officers.

C. General Requirements:
1. The successful firm shall provide a project supervisor of proven experience, and be willing to leave him (or her) on the project for the duration of the project, unless acceptable alternative arrangements are made with the Owner.
2. The successful firm must have a business office which is staffed during normal working hours.
3. The project manager of the successful firm shall have paging capability during normal working hours.

D. Craftsman Regulations:
1. Contractors shall include no more than one indentured apprentice per journeyman electrician. Apprentices shall be under the direct supervision of a licensed electrician at all times.
2. Helpers may be assigned to the project as required to do laboring-type tasks, but may not do any installation type electrical work.
3. High voltage cable splicers must be certified by the Director of Facilities Management or his (her) Designated Representative, before either cable splicing or terminating begins. Certification must be satisfied by illustrating knowledge by a test demonstration of capabilities. The University of Colorado at Boulder (UCB) will provide cable for test splice, Contractor shall provide test splice kits per UCB Standard and perform splice for CU High Voltage Department. Upon completion of requirements, a certification card will be issued by the Department of Facilities Management.

1.7 WORK INCLUDED

A. Field lighting and power systems including lighting fixtures, lamps, ballasts, wiring devices, panelboards, transformers, feeders, and other items shown or required.
1. Provide new electrical service to the Norlin Library Building.
2. Secondary service and distribution systems.
3. Lighting fixtures, interior.
4. Trenching and backfilling for electrical work.
5. Certain equipment on this project is existing. When such is the case, description of these items shall be indicated on drawings or described herein. Unless otherwise noted, all labor, materials, and/or equipment for complete installation of electrical work shall be provided under this Division.
1.8 STANDARDS FOR MATERIALS

A. All materials shall conform to the current applicable industry standards. Workmanship and neat appearance shall be as important as electrical and mechanical operation. Defective or damaged materials shall be replaced or repaired prior to final acceptance in a manner meeting approval of Architect and/or Engineer and at no additional cost to Owner. The foregoing rules, standards, regulations, specifications, recommendations, and requirements shall not relieve the Contractor from furnishing and installing higher grades of materials and workmanship that are specified herein or indicated on drawings.

B. In addition to the latest federal and state regulations, the latest editions of the following standards are minimum requirements:
1. Underwriters' Laboratories, Inc. (UL)
2. National Electrical Manufacturer's Association (NEMA)
3. American National Standards Institute (ANSI)
4. Insulated Cable Engineer's Association (ICEA)
5. Institute of Electrical and Electronic Engineers (IEEE)
6. Association of Edison Illuminating Companies (AEIC)
7. National Electrical Code (NEC)
8. Certified Ballast Manufacturers (CBM)
9. Electrical Testing Laboratories (ETL)
10. Federal Specifications (Fed. Spec.)
11. Independent Testing Laboratories (ITL)
13. National Electrical Contractors Association (NECA)
14. National Fire Protection Association (NFPA)
15. Occupational Safety and Health Act (OSHA)

C. The work shall be done in conformance with these codes and standards. These codes and standards shall be considered as the minimum requirements for the Work. Items shown on the drawings or specified in these Specifications which exceed the minimum requirements of the code shall be installed as shown on the drawings or specified in these Specifications. Any known conflict between the specifications or the drawings and the codes or suspected error in the Specifications or the drawings shall be brought to the attention of the Architect/Engineer prior to the bid; otherwise, resolution of the error or code conflict shall be at the expense of the Contractor.

1.9 PRIOR APPROVAL OR SUBSTITUTION OF EQUIPMENT AND MATERIALS

A. Refer to Division 1.

B. Equipment of other manufacturers which is equal to or superior to that specified may be proposed in accordance with Division 1. Manufacturers and catalog numbers shown in these specifications or on the drawings followed by "OR EQUAL" are intended as a guide to quality. Substitute equipment of other manufacturers which is equivalent to or superior to that specified may be proposed; however, such prior approvals must be accepted in writing by the Architect/Engineer seven days prior to bidding. If prior approvals are not requested or granted, substitute materials and equipment may be submitted under the substitutions section of Division 1. The Engineer's decision regarding substitutions shall be final. It shall be the Contractor's responsibility under this division of the specifications to notify all related trades of the accepted substitutions and to assume full responsibility for all costs caused as a result of the substitution.
1.10 CODE COMPLIANCE

A. All work and materials shall comply with the latest rules, codes, and regulations, but not limited to the following. Code compliance is mandatory.
1. NFPA 70 - National Electrical Code (NEC)
2. IBC - International Building Code
4. OSHA, Occupational Safety and Health Act
5. All other applicable federal, state and local laws and regulations

B. Code compliance is mandatory. Nothing in these drawings and specifications permits work not conforming to these codes. Where work is shown to exceed minimum code requirements, comply with drawings and specifications.

C. No work shall be concealed until after inspection and approval by proper authorities. If work is concealed without inspection and approval, Contractor shall be responsible for all work required to be opened or exposed and restore the concealed areas in addition to all required modifications.

1.11 DRAWINGS AND SPECIFICATIONS

A. Refer to Supplementary Conditions for additional requirements.

B. Drawings are diagrammatic and indicate general arrangement of circuits and outlets, locations of switches, panelboards and other work. Drawings and specifications are complementary each to the other, and what is called for by one shall be binding as if called for by both. Data presented on drawings is as accurate as planning can determine, but accuracy is not guaranteed and field verification of all dimensions, locations, levels, etc. to suit field conditions is directed. Review all architectural and civil drawings, and adjust all work to conform to all conditions shown therein. Architectural drawings shall take precedence over all other drawings. Discrepancies between different drawings or between drawings and specifications or regulations and codes governing installation shall be brought to attention prior to bid.

C. Most direct routing of conduits and wiring is not assured. Exact requirements shall be governed by actual conditions of the job. Consult all other drawings in preparation of the bid. Extra lengths of wiring or addition of pull or junction boxes, etc., necessitated by such conditions shall be included in the bid. Check all information and report any apparent discrepancies before submitting bid.

D. Right is reserved to make reasonable change in location electrical equipment (10 feet in any direction) prior to work without increasing contract cost.

1.12 MINOR CHANGES AND DEVIATIONS

A. Furnish and install entire electrical installation as designed and in accordance with contract drawings and specifications. Minor deviations necessitated by field conditions or equipment being supplied may be made upon approval of Architect/Engineer. Changes in design and installation shall be done in manner as provided for in Division 1.

PART 2 – PRODUCTS

2.1 EQUIPMENT AND MATERIALS

A. Refer to related requirements in Division 1. Furnish and install all material, equipment, and devices which are new, first quality, of a type as listed and labeled by Underwriters Laboratories, Inc., in a manner
accepted by the Architect/Engineer, and pay for all equipment or materials damaged in the course of installation or test. Basic bid shall include manufacturers and catalog numbers as shown in these specifications or on the drawings with "NO EQUALS" unless specifically indicated. Specified materials, equipment, and devices shall be furnished and installed under the contract unless changed by mutual agreement between Contractor and Engineer. Where several manufacturers are indicated for material, equipment, or devices, Contractor shall have choice of manufacturers listed.

B. Equipment Requirements: The electrical requirements for equipment specified or indicated on the drawings are based on information available at the time of design. If equipment furnished for installation has electrical requirements other than indicated on the electrical drawings, the Contractor shall make all adjustments to wire and conduit size, controls, overcurrent protection, and installation as required to accommodate the equipment supplied, without additional expense to the Owner.

C. All similar materials and equipment shall be the product of the same manufacturer.

D. Materials and equipment shall be standard products of manufacturers regularly engaged in the production of such material and shall be the manufacturer's current and standard design.

E. All equipment and material shall be designed, constructed, and tested to operate successfully at 6,000 feet above sea level and -22°F to 104°F ambient temperature range unless otherwise specified, with the average relative humidity of 10% to 70% unless otherwise specified.

PART 3 – EXECUTION

3.1 CONDITIONS AT SITE

A. Prior to bidding, examine the site carefully and be fully familiar with existing conditions and be fully informed of all utility, state, and local requirements and regulations that will affect the electrical work.

B. Visit to site is required of all bidders prior to submission of bid. All will be held to have familiarized themselves with all discernible conditions, and no extra payment will be allowed for work required because of these conditions, whether specifically mentioned or not.

C. Existing conduits, pipes, utility lines, tanks, equipment, or other obstructions whether underground, concealed, or exposed are not indicated on drawings. Locate such obstructions prior to start of work so as to route and locate all new work to void these obstructions. Repair or replace, at no cost to Owner, existing installations where damaged during course of construction.

D. Refer to Division 1 for additional requirements.

3.2 LICENSE, FEES, AND PERMITS

A. Arrange for required inspections and pay all license, permit and inspection fees. Furnish a certificate of final inspections and approval from all local authorities having jurisdiction over electrical installation.

3.3 SERVICE INTERRUPTIONS

A. Any electrical work that will interfere with or interrupt the operation of buildings, or services, must be coordinated with the Owner and Contractor at least fourteen calendar days in advance for proper scheduling. The Contractor shall submit a request for the outage to the Owner detailing the reasons for the outage, areas affected, sequence of procedures to accomplish work, estimated maximum length of time, and the date and time of day the outage will occur. The Contractor shall obtain written authorization from the
Owner for all proposed outages. These connections may have to be done at any hour of any day at no increase in contract price. Outages shall be for minimum time periods. All preparation work shall be planned and executed prior to the actual outage. In all cases, all material shall be furnished by the Contractor. Submit written plan with time line for removal, installation and connection of generator sets. The Contractor will be responsible for any temporary power required.

B. Prior to disconnecting or re-energizing power equipment (transformers, primary switches, etc.), the Contractor shall identify and/or verify phase rotation of conductors.

3.4 RELATION WITH OTHER TRADES

A. Contractor shall coordinate work of this section with other trades to avoid conflict and to correct rough in and other connections for equipment furnished under other trades that required electrical connections. Inform contractors of other trades of required clearances of accesses for or around electrical equipment to maintain serviceability and code compliance.

B. Verify equipment dimensions and requirements with provisions specified under this section of work, and report any discrepancies to Architect/Engineer in ample time to prevent delays or unwarranted changes of work.

3.5 SHOP DRAWINGS AND MATERIALS LIST

A. In accordance with Division 1, and as required by individual sections of Division 16, submit to Architect/Engineer complete shop drawings, product information and materials lists as noted below, for review within 30 days after award of contract. All proposed deviations from specifications must be clearly listed under a prominent heading entitled "Deviations". Submittals required as follows:
2. Lighting Fixtures: Manufacturer's specifications sheets and ETL, ERL or ITL photometric data.
3. Switchboards: Shop fabrication details and technical data sheets.
4. Transformers and switchgear: Shop fabrication details and technical data sheets.

B. In addition to the above requirements, equipment wiring diagrams, including circuit arrangements, bussing, size, electrical ratings, equipment dimensions, weights, equipment arrangements, and NEMA ratings shall be provided for all cable and devices, low-voltage switchboards, and luminaries.

C. Prior to submitting shop drawings for review, the Contractor shall review same and signify by stamping and initializing, compliance with plans and specifications and for dimensional suitability for the application. If any deviation from the specified criteria for any item of material exists, such deviation shall be stated in writing and incorporated with the shop drawing submittal. Review of shop drawings by the Architect/Engineer shall not constitute agreement of any deviations from the plans and specifications unless such deviations are as specifically listed as required above, and such deviations accepted. Review of shop drawings by the Architect/Engineer shall not relieve the Contractor from responsibility for errors or omissions in same. Resubmittal costs beyond one are the expense of Contractor.

3.6 RECORD DRAWINGS AND INFORMATION

A. Refer to Division 1.

B. Maintain a contract set of electrical drawings at the site. Neatly mark all changes and deviations from the original drawings. Use a color that contrasts with the prints. This shall be a separate set of drawings, not used for construction purposes, and shall be kept up to date as the job progresses and shall be made available for inspection by the Architect/Engineer at all times. The Contractor will also be responsible for
updating the electronic drawing files. Upon completion of the contract this set of “as-builts” and updated CAD files shall be delivered to the Architect/Engineer.

C. In addition to the above required record drawings, maintain at all times at the project site the most current information on the following:
   1. Addenda
   2. Change orders
   3. Submittals
   4. Inspection reports
   5. Test results
   6. Outage information

3.7 DELIVERY AND STORAGE OF MATERIALS

A. Make provisions for the delivery and safe storage of all materials, including any materials furnished by others to be installed by this Contractor. Carefully mark and store all materials. Deliver materials to the job site in stages of the work that will expedite the work as a whole. Carefully check materials furnished to this Contractor for installation, and provide a receipt acknowledging acceptance of delivery and condition of the materials received. Thereafter, assume full responsibility for its safekeeping until the final installation has been reviewed and accepted.

B. Store materials and equipment indoors at the job site, or, if this is not possible, store on raised platforms and protect from the weather by means of waterproof covers. Use the staging area as shown on the drawings. Coverings shall permit circulation of air around materials to prevent condensation of moisture. Screen or cap openings in equipment to prevent the entry of vermin.

3.8 PROGRESS OF WORK

A. Order progress of electrical work so as to conform to progress of work of other trades, and complete entire installation as soon as conditions permit. Assume any cost resulting from defective or ill-timed work performed under this Division. The Contractor shall be liable for all additional costs associated with increased site visits by the Engineer.

3.9 CUTTING AND PATCHING

A. Refer to Division 1 for additional requirements. Provide all cutting, patching, channeling, core drilling, boring etc., necessary for electrical work. Locate holes to be drilled, light poles, etc., coordinate work with all other trades on the job, and make arrangements for necessary openings.

3.10 TRENCHING AND BACKFILLING

A. Perform all trenching and backfilling required by work performed under this Division as herein specified and under direct supervision of General Contractor. Refer to results of subsurface soil investigation for nature of materials to be excavated. Excavate trenches to depth required for utilities involved. Trench bottom shall be as specified, graded true and free from stones or soft spots. Repair any trenches where settlement occurs, and restore surface. Verify location of existing or new utilities and, if damaged, replace at the Contractor's expense.

3.11 EQUIPMENT PADS

A. The Contractor shall be responsible for providing housekeeping pads (concrete) for all grade or floor-mounted electrical equipment (i.e., pad-mounted transformers and switchgear). Concrete shall be in accordance with the concrete section of these specifications. Pads shall be at least 3-1/2 inches high (above
finished grade or finished floor) and shall be 2 inches larger, in all dimensions, than the equipment that will sit thereon.

3.12 REMODEL WORK

A. All electrical equipment in existing areas to be remodeled is to be preserved and reused unless indicated otherwise on plans.

3.13 MANUFACTURER'S INSTRUCTIONS

A. Where the specifications call for an installation to be made in accordance with manufacturer's recommendations, a copy of such recommendations shall at all times be kept in the job superintendent's office and shall be available to the Owner's representative.

B. Follow manufacturer's instructions where they cover points not specifically indicated on drawings and specifications. If they are in conflict with the drawings and specifications, obtain clarification from the Architect/Engineer before starting work.

3.14 OPERATING MANUAL, PARTS LIST, INDOCTRINATION OF OPERATING, AND MAINTENANCE PERSONNEL

A. Furnish service of a qualified representative or supplier of each item or system itemized below who shall instruct specific personnel, as designated by Owner, in operation and maintenance of that item or system. Instruction shall be made when the particular system is completed and at the time as requested by Owner.

B. Systems:
   1. Panelboards
   2. Transformers
   3. Transformers and switchgear

C. Refer to Division 1 for Operating Manuals and Instructions. Fully explain contents of such manuals as a part of indoctrination, and instruct Owner's personnel in correct procedure in obtaining service both during and after guarantee period. Operating manual and parts lists shall list complete information as to whom Owner shall contact for service and parts. Include address and phone number. Evidence shall be furnished that authorized service organization regularly carries a complete stock of repair parts for the above items or system, and that the organization is available for service. Service shall be furnished within 24 hours after request.

3.15 CLEANUP

A. Refer to Division 1.

B. Remove all materials, scrap, etc. relative to electrical installation, and leave premises in a clean, orderly condition. Any costs to Owner for cleanup of site will be charged to Contractor. At completion, all equipment, lighting fixtures, etc. shall be thoroughly cleaned and all residue removed from the inside and outside surfaces. Defaced finish shall be refinished.

3.16 GUARANTEE

A. Provide in accordance with the General Requirements and Division 1. Leave entire electrical system installed under this Division in proper working order. Replace, without additional charge, any work materials or equipment provided under this Division which develops defects within one year from date of
final acceptance of installation by Owner. Guarantee all materials and equipment against defects in composition, design or workmanship.

B. Furnish to the Owner a formal warranty covering the electrical system installed under this contract, to be free from defective materials and workmanship for a period of one year after date of acceptance of installation by Owner.

3.17 SAFETY AND INDEMNITY

A. The Contractor shall be solely and completely responsible for conditions of the job site, including safety of all persons and property during performance of the work. This requirement will apply continuously and not be limited to normal working hours. Refer also to General Requirements.

B. No act, service, drawing review or construction review by the Owner, the Architect, the Engineers or their Consultants is intended to include review of the adequacy of the Contractor's safety measures in, on, or near the construction site.

C. At all times during performance of this Contract, properly protect work from damage and protect the Owner's property from injury or loss. Make good any damage, injury, or loss, as may be directly due to errors in the Bidding Documents or caused by agents or employees of the Contractor.

3.18 PROJECT CLOSEOUT

A. Operating and Acceptance Tests:
   1. The Contractor shall hire an independent testing agency to conduct operating and acceptance tests on new electrical system components and all existing devices that are impacted by the project.
   2. The Testing Agency shall prepare written reports of values of all test readings and procedures. Reports shall include all breaker settings and modifications to one line and three line drawings.
   3. The Testing Agency shall furnish all equipment, instruments and personnel required to conduct tests.
   4. Tests will be defined in the individual section describing the equipment or system.

B. Punch Lists: Final payment will not be authorized until all items on the final punch list have been completed. Additional punch list completion verification visits beyond one by the Engineer shall be at the expense of the Contractor.

C. Cleaning and Painting: Clean all electrical equipment, such as switches, panelboards, luminaires, etc., of construction dirt, dust, paint smears, etc., and touch-up or repaint all scars, blemishes, rust spots, etc., to original state of finish.

D. Compile a complete list of product data and shop drawings, acceptance tests, warranties, certificates, and subcontractor and supplier information (i.e., name, address, phone number).

END OF SECTION 16010
SECTION 16050 - COMMON WORK RESULTS FOR ELECTRICAL

PART 1 – GENERAL

1.1 SUMMARY

A. This section includes requirements for basic electrical materials and methods for the following items:
   1. Raceways
   2. Conductors and cables
   3. Supporting devices for electrical components
   4. Electrical identification
   5. Concrete equipment bases
   6. Electrical demolition
   7. Cutting and patching for electrical construction
   8. Touch-up painting

1.2 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specifications, apply to this section.

1.3 REFERENCES

A. The latest edition of the following standards and codes, standard publications of professional organizations, and the local authorities having jurisdiction are the minimum requirements for this work.
   1. American National Standards Institute (ANSI)
   3. Association of Edison Illuminating Companies (AEIC)
   5. Insulated Cable Engineer's Association (ICEA)
   6. Institute of Electrical and Electronic Engineers (IEEE)
   7. National Electrical Manufacturer's Association (NEMA)
   8. National Fire Protection Association (NFPA)
   9. NFPA 70, The National Electrical Code (NEC)
   10. Underwriters' Laboratories, Inc. (UL)
   11. State, City, and Local Authorities

1.4 DEFINITIONS

A. Instructions such as "Provide" shall mean the same as though the words "This Contractor shall" preceded each such instruction. "Provide" shall mean "Furnish and Install." Where the words "Accepted" or "Acceptable" are used, such "Accepted" or "Acceptable" action by the Engineer and/or Architect denotes that the work or equipment item is in conformance with the design concept of the project and, in general, complies with pertinent information given in the Contract Documents.

B. EMT: Electrical metallic tubing.

C. ENT: Electrical nonmetallic tubing.

D. FMC: Flexible metal conduit.

E. IMC: Intermediate metal conduit.
F. LFMC: Liquidtight flexible metal conduit.

G. LFNC: Liquidtight flexible nonmetallic conduit.

H. RMC: Rigid metallic conduit.

I. RNC: Rigid nonmetallic conduit.

1.5 SUBMITTALS

A. Product Data:
   1. Hangers and supports
   2. Electrical identification materials
   3. Raceways and fittings
   4. Conductors and Cable

B. Coordination Drawings: Plans, sections, and elevations drawn to scale and coordinating installation of equipment, where required by the contract drawings or where site physical conditions limit installation capabilities.

1.6 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. Comply with NFPA 70, the National Electrical Code.

C. All equipment and materials will be new and unused and shall be in conformance with the current applicable industry standards. Workmanship and neat appearance shall be as important as electrical and mechanical operation. Defective or damaged materials shall be replaced or repaired prior to final acceptance in a manner meeting approval of Architect and/or Engineer and at no additional cost to the Owner.

1.7 SEQUENCING

A. Coordinate chases, slots, inserts, sleeves, and openings with general construction work and arrange in building structure during progress of construction to facilitate the electrical installation.

B. Set inserts and sleeves in poured-in-place concrete, masonry work, and other structural components as they are constructed.

C. Sequence, coordinate, and integrate installing electrical materials and equipment for efficient flow of the Work. Coordinate installing large equipment requiring positioning before closing in the building.

D. No work shall be concealed until after inspection and approval by proper authorities. If work is concealed without inspection and approval, Contractor shall be responsible for all work that is required to expose and restore the concealed work in addition to all required modifications.

E. Where electrical identification devices are applied to field-finished surfaces, coordinate installation of identification devices with completion of finished surface.

F. Where electrical identification markings and devices will be concealed by acoustical ceilings and similar finishes, coordinate installation of these items before ceiling installation.
PART 2 - PRODUCTS

2.1 RACEWAYS

A. Metallic Conduit Systems:
   1. EMT: ANSI C80.3, zinc-coated steel. EMT shall be galvanized on the outside and coated on the inside with a hard smooth lacquer finish. EMT fittings shall be set-screw type. EMT shall comply with UL 797 and ANSI C80.3.
   2. FMC: Flexible metal conduit shall be galvanized steel with steel fittings and shall comply with UL 1.
   3. IMC: ANSI C80.6, zinc-coated steel, with threaded fittings. Intermediate steel conduit shall be hot-dipped galvanized.
   4. LFMC: Zinc-coated steel with sunlight-resistant and mineral-oil-resistant plastic jacket. Liquidtight Flexible Steel conduit shall comply with UL 514C. Liquid and moisture tight conduit shall be American Brass with Appleton “ST” connectors or approved equal.
   5. RMC: Rigid Steel Conduit shall be galvanized and shall comply with UL 6 and ANSI C80.1. Plastic-coated conduit shall be rigid galvanized steel conduit having a 0.030-inch minimum thickness. Plugs and connectors shall be plastic and shall be approved.

B. Nonmetallic Conduit Systems:
   1. ENT: NEMA TC 13
   2. RNC: NEMA TC 2, Schedule 40 or 80 PVC
   3. LFNC: UL 1660
   4. ENT and RNC fittings: NEMA TC 3, match to conduit or conduit/tubing type and material

C. Raceway Fittings: Specifically designed for the raceway type with which used.

2.2 CONDUCTORS AND CABLES

A. UL-listed building wires and cables with conductor material, insulation type, cable construction, and rating as specified in Part 3 "Wire and Insulation Applications."

B. Rubber Insulation Material: Comply with NEMA WC 3.

C. Thermoplastic Insulation Material: Comply with NEMA WC 5.

D. Cross-Linked Polyethylene Insulation Material: Comply with NEMA WC 7.

E. Ethylene Propylene Rubber Insulation Material: Comply with NEMA WC 8.

F. Conductor Material: Copper.

G. Conductors and Cables:
   1. All conductors shall be new, unless otherwise noted. All conductors #8 AWG and larger shall be stranded. Conductors #10 and smaller may be solid or stranded depending on their application.
   2. Secondary voltage conductors and cables shall be electrical grade, annealed copper, tinned if rubber insulated, and fabricated in accordance with ASTM and ICEA standards. The use of aluminum is prohibited except where shown on one-line or equipment schedules. Minimum size #12 for branch circuits; #14 for control wiring. Conductor types shall be as follows:
      a. In sizes #1/0 AWG and larger: Cross-linked polyethylene insulation type XHHW (75 to 90°C) or THWN/THHN.
b. In sizes #1 AWG and smaller: All conductors shall have heat/moisture resistant thermoplastic insulation type THW or THWN (75°C), except as follows:
   1) Where conduit temperature will exceed 100°F, use type THHN (90°C). Type XHHW (90°C) permissible in dry locations.
   2) Motor circuit conductors: 75° THWN or XHHW from disconnect to motor.
   3) In 120-volt incandescent fixtures, type AF (150°C).
   4) In wireways of fluorescent lighting fixtures types THWN/THHN/MTW (90°C).
   5) Handling cord drops and cord connections: Type "SO" cord.
   6) Conductors in 120 volt circuits longer than 100 feet or 277 volt circuits longer than 200 feet shall not be less than #10 AWG.
   c. All wiring for control circuits to contactors, pushbuttons, and the like, shall be #12 AWG, copper, stranded with THWN insulation.

H. Wire Connectors and Splices: Units of size, ampacity rating, material, type, and class suitable for service indicated.

2.3 SUPPORTING DEVICES FOR ELECTRICAL COMPONENTS

A. Provide hangers and supports to support raceways, fixtures, cabinets, boxes, etc. as manufactured by B-Line, Unistrut, Binkley or Kindorf.
B. Material: Cold-formed steel, with corrosion-resistant coating acceptable to authorities having jurisdiction.
C. Metal Items for Use Outdoors or in Damp Locations: Steel, hot-dip galvanized after fabrication.
D. Slotted-Steel Channel Supports: Flange edges turned toward web, and 9/16-inch-diameter slotted holes at a maximum of 2 inches o.c., in webs.
E. Raceway and Cable Supports: Manufactured clevis hangers, riser clamps, straps, threaded C-clamps with retainers, ceiling trapeze hangers, wall brackets, and spring-steel clamps or click-type hangers.
F. Pipe Sleeves: ASTM A 53, Type E, Grade A, Schedule 40, galvanized steel, plain ends.
G. Expansion Anchors: Carbon-steel wedge or sleeve type.
H. Toggle Bolts: All-steel springhead type.

2.4 ELECTRICAL IDENTIFICATION

A. Identification Devices: A single type of identification product for each application category. Use colors prescribed by ANSI A13.1, NFPA 70, and these Specifications.
   1. As a minimum, identification means shall be installed on the following:
      a. Panelboards, switchboards, switchgear, etc.
      b. Transformers
      c. Junction boxes
      d. Disconnects
      e. Cables
   B. Colored Adhesive Marking Tape for Wires, and Cables: Self-adhesive vinyl tape, not less than 1 inch wide by 3 mils thick.
C. Underground Warning Tape: Permanent, bright-colored, continuous-printed, vinyl tape with the following features:
   1. Not less than 6 inches wide by 4 mils thick.
   2. Compounded for permanent direct-burial service.
   3. Embedded continuous metallic strip or core.
   4. Printed legend that indicates type of underground line.

D. Color-Coding Cable Ties: Type 6/6 nylon, self-locking type. Colors to suit coding scheme.

E. Engraved-Plastic Labels, Signs, and Instruction Plates: Engraving stock, melamine plastic laminate punched or drilled for mechanical fasteners 1/16-inch minimum thickness for signs up to 20 sq. in. and 1/8-inch minimum thickness for larger sizes. Engraved legend in black letters on white background.

F. Interior Warning and Caution Signs: Comply with 29 CFR, Chapter XVII, Part 1910.145. Preprinted, aluminum, baked-enamel-finish signs, punched or drilled for mechanical fasteners, with colors, legend, and size appropriate to the application.

G. Exterior Warning and Caution Signs: Comply with 29 CFR, Chapter XVII, Part 1910.145. Weather-resistant, nonfading, preprinted, cellulose-acetate butyrate signs with 0.0396-inch, galvanized steel backing, with colors, legend, and size appropriate to the application; 1/4-inch grommets in corners for mounting.

H. Fasteners for Nameplates and Signs: Self-tapping, stainless-steel screws or No. 10/32 stainless-steel machine screws with nuts and flat and lock washers.

2.5 CONCRETE EQUIPMENT BASES

A. Concrete: 3000-psi, 28-day compressive strength.

2.6 TOUCH-UP PAINT

A. Equipment: Equipment manufacturer's paint selected to match installed equipment finish.

B. Galvanized Surfaces: Zinc-rich paint recommended by item manufacturer.

PART 3 - EXECUTION

3.1 ELECTRICAL EQUIPMENT INSTALLATION

A. Headroom Maintenance: If mounting heights or other location criteria are not indicated, arrange and install components and equipment to provide the maximum possible headroom.

B. Materials and Components: Install level, plumb, and parallel and perpendicular to other building systems and components, unless otherwise indicated.

C. Equipment: Install to facilitate service, maintenance, and repair or replacement of components. Adhere to clearances required by the NEC, NFPA 70. Connect for ease of disconnecting, with minimum interference with other installations.

D. Right of Way: Give to raceways and piping systems installed at a required slope.
3.2 RACEWAY APPLICATION

A. Use the following raceways for outdoor installations:
   1. Exposed: IMC
   2. Concealed: IMC
   3. Underground, Single Run: RNC
   4. Underground, Grouped: RNC
   5. Connection to Vibrating Equipment: LFMC
   6. Boxes and Enclosures: NEMA 250, Type 3R or Type 4

B. Use the following raceways for indoor installations:
   1. Exposed: EMT
   2. Concealed: EMT
   3. Connection to Vibrating Equipment: FMC; except in wet or damp locations, use LFMC
   4. Damp or Wet Locations: IMC
   5. Embedded in concrete: IMC or RMC
   6. Boxes and Enclosures: NEMA 250, Type 1, unless otherwise indicated
   7. Damp or wet locations: NEMA 250, Type 4, nonmetallic

3.3 RACEWAY INSTALLATION

A. Conceal raceways, unless otherwise indicated, within finished walls, ceilings, and floors.

B. Install raceways at least 6 inches away from parallel runs of flues and steam or hot-water pipes. Locate horizontal raceway runs above water and steam piping.

C. Use temporary raceway caps to prevent foreign matter from entering.

D. Stub-up Connections: Extend conduits through concrete floor for connection to freestanding equipment. Install with an adjustable top or coupling threaded inside for plugs set flush with the finished floor. Extend conductors to equipment with rigid steel conduit; FMC may be used 6 inches above the floor. Install screwdriver-operated, threaded flush plugs flush with floor for future equipment connections. Arrange so that curved portion of bends is not visible above the finished slab.

E. Install raceways embedded in slabs in middle third of slab thickness where practical, and leave at least 1-inch concrete cover.
   1. Secure raceways to reinforcing rods to prevent sagging or shifting during concrete placement.
   2. Space raceways laterally to prevent voids in concrete.
   3. Install conduit larger than 1-inch trade size parallel to or at right angles to main reinforcement. Where conduit is at right angles to reinforcement, place conduit close to slab support.
   4. Transition from nonmetallic tubing to Schedule 80 nonmetallic conduit, rigid steel conduit, or IMC before rising above floor.
   5. Make bends in exposed parallel or banked runs from same centerline to make bends parallel. Use factory elbows only where elbows can be installed parallel; otherwise, provide field bends for exposed parallel raceways.

F. Make conduit bends and offsets so ID is not reduced. Keep legs of bends in the same plane and straight legs of offsets parallel, unless otherwise indicated.

G. Use raceway fittings compatible with raceways and cables and suitable for use and location.

H. Install pull wires in empty raceways. Use No. 14 AWG zinc-coated steel or monofilament plastic line with not less than 200-lb. tensile strength. Leave at least 12 inches of slack at each end of the pull wire.
I. Install telephone and signal system raceways, 2-inch trade size and smaller, in maximum lengths of 150 feet and with a maximum of two 90-degree bends or equivalent. Separate lengths with pull or junction boxes where necessary to comply with these requirements, in addition to requirements above.

J. Connect motors and equipment subject to vibration, noise transmission, or movement with a maximum of 72-inch flexible conduit. Install LFMC in wet or damp locations. Install separate ground conductor across flexible connections.

K. Set floor boxes level and trim after installation to fit flush to finished floor surface.

3.4 WIRING METHODS FOR POWER, LIGHTING, AND CONTROL CIRCUITS

A. Feeders: Type THHN/THWN insulated conductors in raceway.

B. Underground Feeders and Branch Circuits: Type THWN or single-wire, Type UF insulated conductors in raceway.

C. Branch Circuits: Type THHN/THWN insulated conductors in raceway.

D. Remote-Control Signaling and Power-Limited Circuits: Type THHN/THWN insulated conductors in raceway for Classes 1, 2, and 3, unless otherwise indicated.

3.5 WIRING INSTALLATION

A. Install splices and taps that are compatible with conductor material and that possess equivalent or better mechanical strength and insulation ratings than unspliced conductors.

3.6 ELECTRICAL SUPPORTING DEVICE APPLICATION

A. Damp Locations and Outdoors: Hot-dip galvanized materials or nonmetallic, U-channel system components.

B. Dry Locations: Steel materials

C. Support Clamps for PVC Raceways: Click-type clamp system

D. Selection of Supports: Comply with manufacturer's written instructions.

E. Strength of Supports: Adequate to carry present and future loads, times a safety factor of at least four; minimum of 200-lb. design load.

3.7 SUPPORT INSTALLATION

A. Install support devices to securely and permanently fasten and support electrical components.

B. Install individual and multiple raceway hangers and riser clamps to support raceways. Provide U-bolts, clamps, attachments, and other hardware necessary for hanger assemblies and for securing hanger rods and conduits.

C. Support parallel runs of horizontal raceways together on trapeze- or bracket-type hangers.

D. Size supports for multiple raceway installations so capacity can be increased by a 25 percent minimum in the future.
E. Support individual horizontal raceways with separate, malleable-iron pipe hangers or clamps.

F. Install 1/4-inch-diameter or larger threaded steel hanger rods, unless otherwise indicated.

G. Spring-steel fasteners specifically designed for supporting single conduits or tubing may be used instead of malleable-iron hangers for 1-1/2-inch and smaller raceways serving lighting and receptacle branch circuits above suspended ceilings and for fastening raceways to slotted channel and angle supports.

H. Arrange supports in vertical runs so the weight of raceways and enclosed conductors is carried entirely by raceway supports, with no weight load on raceway terminals.

I. Simultaneously install vertical conductor supports with conductors.

J. Separately support cast boxes that are threaded to raceways and used for fixture support. Support sheet-metal boxes directly from the building structure or by bar hangers. If bar hangers are used, attach bar to raceways on opposite sides of the box and support the raceway with an approved fastener not more than 24 inches from the box.

K. Install metal channel racks for mounting cabinets, panelboards, disconnect switches, control enclosures, pull and junction boxes, transformers, and other devices unless components are mounted directly to structural elements of adequate strength.

L. Install sleeves for cable and raceway penetrations of concrete slabs and walls unless core-drilled holes are used. Install sleeves for cable and raceway penetrations of masonry and fire-rated gypsum walls and of all other fire-rated floor and wall assemblies. Install sleeves during erection of concrete and masonry walls.

M. Securely fasten electrical items and their supports to the building structure, unless otherwise indicated. Perform fastening according to the following unless other fastening methods are indicated:
   1. Wood: Fasten with wood screws or screw-type nails.
   2. Masonry: Toggle bolts on hollow masonry units and expansion bolts on solid masonry units.
   3. New Concrete: Concrete inserts with machine screws and bolts.
   4. Existing Concrete: Expansion bolts.
   5. Threaded studs driven by a powder charge and provided with lock washers in existing concrete are not allowed unless approved by Architect.
   6. Steel: Welded threaded studs or spring-tension clamps on steel. Field welding shall comply with AWS D1.1.
   7. Welding to steel structure may be used only for threaded studs, not for conduits, pipe straps, or other items.
   8. Light Steel: Sheet-metal screws.
   9. Fasteners: Select so the load applied to each fastener does not exceed 25 percent of its proof-test load.

3.8 IDENTIFICATION MATERIALS AND DEVICES

A. All components of electrical system shall be neatly and accurately labeled to facilitate ready identification and service. Temporary type of markings, which are visible on equipment, will not be permitted. Repaint trims, housing, etc. where such markings cannot be readily removed. Defaced finish must be refinished. Provide labels as follows (or indicated elsewhere):
   1. Provide engraved composition nameplates having 3/8 inch minimum height, white letters engraved in a black face for each switch or circuit breaker in switchboards and subdistribution boards. Provide labeling of matching style designating all units as designated on drawings. Secure all laminoid nameplates with rivets or screws. Adhesives will not be allowed.
2. Use of Dymolabels for panels and circuit number identification on all disconnect switches in mechanical and equipment rooms is forbidden.

3. Provide engraved composition nameplates on all disconnect switches. Lettering shall be 3/8 inches minimum height for equipment. Labeling for equipment shall be in accordance with designations given on the associated drawings.

B. Coordinate names, abbreviations, colors, and other designations used for electrical identification with corresponding designations indicated in the Contract Documents or required by codes and standards. Install at locations for most convenient viewing without interference with operation and maintenance of equipment. Use consistent designations throughout Project.

1. Bands: Pretensioned, snap-around, colored plastic sleeves or colored adhesive marking tape. Make each color band 2 inches wide, completely encircling conduit, and place adjacent bands of two-color markings in contact, side by side.

2. Band Locations: At changes in direction, at penetrations of walls and floors, at 50-foot maximum intervals in straight runs, and at 25-foot maximum intervals in congested areas.

3. Colors:
   a. Fire Alarm System: Red
   b. Security System: Blue and yellow
   c. Telecommunication System: Green and yellow

C. Tag and label each feeder conductor (having an operating voltage of 600 volts or less) in pullboxes with an engraved, non-metallic tag, having 3/16-inch minimum height letters. Tag shall be a minimum of one inch diameter or square. State circuit number and phase (A, B, C).

D. Install continuous underground plastic markers during trench backfilling, for exterior underground power, control, signal, and communication lines located directly above power and communication lines. Locate 6 to 8 inches below finished grade. If width of multiple lines installed in a common trench or concrete envelope does not exceed 16 inches, overall, use a single line marker.

E. Color-code 208/120V system secondary service, feeder, and branch-circuit conductors throughout the secondary electrical system as follows:
   1. Phase A: Black
   2. Phase B: Red
   3. Phase C: Blue
   4. Neutral: White
   5. Ground: Green

F. Color-code 480/277V system secondary service, feeder, and branch-circuit conductors throughout the secondary electrical system as follows:
   1. Phase A: Brown
   2. Phase B: Orange
   3. Phase C: Yellow
   4. Neutral: White with a colored stripe or gray
   5. Ground: Green

G. Install warning, caution, and instruction signs where required to comply with 29 CFR, Chapter XVII, Part 1910.145, and where needed to ensure safe operation and maintenance of electrical systems and of items to which they connect. Install engraved plastic-laminated instruction signs with approved legend where instructions are needed for system or equipment operation. Install metal-backed butyrate signs for outdoor items.
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3.9 FIRESTOPPING
A. Apply firestopping to cable and raceway penetrations of fire-rated floor and wall assemblies to achieve fire-resistance rating of the assembly.

3.10 CONCRETE BASES
A. Construct concrete bases of dimensions indicated, but not less than 4 inches larger, in both directions, than supported unit. Follow supported equipment manufacturer's anchorage recommendations and setting templates for anchor-bolt and tie locations, unless otherwise indicated.

3.11 DEMOLITION
A. Protect existing electrical equipment and installations indicated to remain. If damaged or disturbed in the course of the Work, remove damaged portions and install new products of equal capacity, quality, and functionality.
B. Accessible Work: Remove exposed electrical equipment and installations, indicated to be demolished, in their entirety.
C. Abandoned Work: Cut and remove buried raceway and wiring, indicated to be abandoned in place, 2 inches below the surface of adjacent construction. Cap raceways and patch surface to match existing finish.
D. Remove demolished material from Project site. Coordinate with Owner for any materials to be salvaged.
E. Remove, store, clean, reinstall, reconnect, and make operational components indicated for relocation.

3.12 CUTTING AND PATCHING
A. Cut, channel, chase, and drill floors, walls, partitions, ceilings, and other surfaces required to permit electrical installations. Perform cutting by skilled mechanics of trades involved.
B. Repair and refinish disturbed finish materials and other surfaces to match adjacent undisturbed surfaces. Install new fireproofing where existing firestopping has been disturbed. Repair and refinish materials and other surfaces by skilled mechanics of trades involved.

3.13 FIELD QUALITY CONTROL
A. Inspect installed components for damage and faulty work, including the following:
   1. Raceways
   2. Conductors and cables
   3. Supporting devices for electrical components
   4. Electrical identification
   5. Concrete equipment bases
   6. Electrical demolition
   7. Cutting and patching for electrical construction
   8. Touch-up painting

3.14 REFINISHING AND TOUCH-UP PAINTING
A. Refinish and touch-up paint as required.
   1. Clean damaged and disturbed areas and apply primer, intermediate, and finish coats to suit the degree of damage at each location.
2. Follow paint manufacturer's written instructions for surface preparation and for timing and application of successive coats.
3. Repair damage to galvanized finishes with zinc-rich paint recommended by manufacturer.
4. Repair damage to PVC or paint finishes with matching touch-up coating recommended by manufacturer.

3.15 CLEANING AND PROTECTION

A. On completion of installation, including outlets, fittings, and devices, inspect exposed finish. Remove burrs, dirt, paint spots, and construction debris.

B. Protect equipment and installations and maintain conditions to ensure that coatings, finishes, and cabinets are without damage or deterioration at time of Substantial Completion.

END OF SECTION 16050
SECTION 16120 – WIRE AND CABLE

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specifications, apply to this Section.

1.2 SUMMARY

A. This Section includes wire and cable and associated connectors, splices, and terminations for wiring systems rated 600V and less.

1.3 SUBMITTALS

A. Field Test Reports: Indicate and interpret test results for compliance with performance requirements.

1.4 QUALITY ASSURANCE

A. Listing and Labeling: Provide wires and cables specified in this Section that are listed and labeled.
   1. The Terms "Listed" and "Labeled": As defined in NFPA 70, Article 100.

B. Comply with NFPA 70 (National Electrical Code).

1.5 DELIVERY, STORAGE, AND HANDLING

A. Deliver wire and cable according to NEMA WC 26.

1.6 COORDINATION

A. Coordinate layout and installation of cable with other installations.

B. Revise locations and elevations from those indicated, as required to suit field conditions and as approved by the Architect/Engineer.

PART 2 – PRODUCTS

2.1 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   1. Wire and Cable:
      b. BICC Brand-Rex Company
      c. Carol Cable Co., Inc.
      d. Senator Wire & Cable Company
      e. Southwire Company
2. Connectors for Wires and Cables:
   a. AMP Incorporated
   b. General Signal; O-Z/Gedney Unit
   c. Monogram Co.; AFC
   d. Square D Co.; Anderson
   e. 3M Company; Electrical Products Division

2.2 BUILDING WIRE AND CABLE

A. UL-listed building wire and cable with conductor material, insulation type, cable construction, and rating as specified in Part 3 "Wire and Insulation Applications" Article.

B. Rubber Insulation Material: Comply with NEMA WC 3.
   1. Type RH, RHW, RHH, XHHW; rating 600V.

C. Thermoplastic Insulation Material: Comply with NEMA WC 5.
   1. Types THW, THHN, THWN; rating 600V.

D. Conductor Material: Copper.

E. Stranding: Solid conductor for No. 12 AWG and smaller; stranded conductor for larger than No. 12 AWG.

2.3 CONNECTORS AND SPLICES

A. UL-listed, factory-fabricated wiring connectors of size, ampacity rating, material, type, and class for application and service indicated. Comply with Project's installation requirements and as specified in Part 3 "Connections" Article.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Examine raceways and building finishes to receive wires and cables for compliance with requirements for installation tolerances and other conditions affecting performance of wires and cables. Do not proceed with installation until unsatisfactory conditions have been corrected.

3.2 WIRE AND INSULATION APPLICATIONS

A. Feeders: Type THHN/THWN, in raceway.

B. Branch Circuits: Type THHN/THWN, in raceway. Minimum wire size #12 for power and lighting circuits. For 20 ampere 120V circuits longer than 75 feet, #10 AWG minimum. For 20 ampere 277V circuits longer than 150 feet, #10 AWG minimum. For circuit amperes other than 20 ampere and for distances greater than listed above, calculate voltage drop and size conductors for maximum 3% voltage drop.

C. Where harmonic currents exist on circuits supplying electric discharge lighting, data processing or similar equipment, a full sized neutral shall be provided for each single phase circuit, and an oversized neutral may be required for each multi-wire circuit.

D. Class 1 or 2 Control Circuits: Type THHN/THWN, in raceway, #14 AWG minimum.
3.3 INSTALLATION

A. Install wires and cables as indicated, according to manufacturer's written instructions and NECA's "Standard of Installation."

B. Conduit fill: Regardless of the type of wire insulation used, for power circuits and feeders, size conduits according to Table 3C of the National Electrical Code. Lighting circuit conduits shall be sized in accordance with Table 3B.

C. Remove existing wires from raceway before pulling in new wires and cables.

D. Pull Conductors: Use manufacturer-approved, UL listed pulling compound or lubricant where necessary; compound used must not deteriorate conductor or insulation. Do not exceed manufacturer's recommended maximum pulling tensions and sidewall pressure values. All conductors shall be pulled into conduit at the same time.

E. Use pulling means, including fish tape, cable, rope, and basket-weave wire/cable grips that will not damage cables or raceway.

F. Install exposed cables, parallel and perpendicular to surfaces of exposed structural members, and follow surface contours where possible.

G. Identify wires and cables according to Division 16, Section "Electrical Identification."

H. Provide a separate green insulated grounding conductor in all branch circuit and feeder raceways.

3.4 CONNECTIONS

A. Conductor Splices: Keep to minimum. Conductors shall be spliced or tapped only in accessible junction boxes or wireways.

B. Install splices and tapes that possess equivalent or better mechanical strength and insulation ratings than conductors being spliced. Steel split-bolt connectors or butt-splices shall be used for splices and taps in conductors #8 AWG and larger. Connections shall be taped to 150% of insulation value with UL listed electrical tape.

C. Use splice and tap connectors compatible with conductor material. Splices and taps shall carry full ampacity of conductors without perceptible temperature rise.

D. Wiring at Outlets: Install conductor at each outlet, with at least 6 inches of slack. Provide pigtail at all device locations, and connect devices using pigtailed.

E. Connect outlets and components to wiring and to ground as indicated and instructed by manufacturer.

F. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A.

3.5 FIELD QUALITY CONTROL

A. Independent Testing Agency: Provide services of an independent electrical testing agency according to the requirements of Division 1 Section "Quality Requirements" to perform tests on installations made under this Section.
B. Testing: Ground resistance testing shall be performed in the presence of a representative of the Department of Facilities Management. Provide at least two weeks’ notice prior to testing.

C. Testing: On installation of wires and cables and before electrical circuitry has been energized, demonstrate product capability and compliance with requirements.
   1. Procedures: Perform each visual and mechanical inspection and electrical test stated in NETA ATS, Section 7.3.1. Certify compliance with test parameters.

D. Correct malfunctioning conductors and cables at Project site, where possible, and retest to demonstrate compliance; otherwise, remove and replace with new units and retest.

END OF SECTION 16120
SECTION 16480 – MOTOR CONTROL

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   3. Combination magnetic motor starters.

B. Related Sections:
   1. Individual motor starters shall be provided by Division 16 in full compliance with these requirements.

1.2 REFERENCES

A. Specify Underwriters Laboratories (UL) listed equipment, assemblies and materials.

B. Where appropriate, refer to current ANSI and NEMA Standards for material ratings.


PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Motor Starters:
   1. General Electric CR306 series starters
   2. Westinghouse Class A200/Cutler Hammer Type AN16 series starters
   3. Furnas Class 14 starters
   4. Cutler Hammer File A-10 series starters
   5. Allen-Bradley
   6. Square-D
   7. Sprecher and Schuh (shall have an “S” designation next to the contactor size, i.e. CA3-23S...)

2.2 MATERIALS

A. Manual Motor Starters: (NEMA.1CS 2)
   1. AC general purpose Class A manually operated full-voltage controller for induction motors rated in horsepower, with Class 10 overload relay, red pilot light and toggle operator. Number of poles as required. Enclosure rating as required. Housing finished in manufacturer’s standard enamel.

B. Magnetic Motor Starters: (NEMA.1CS 2)
   1. AC general purpose Class A magnetic controller for induction motors rated in horsepower. Coil operating voltage 120V. Provide control power transformer if necessary. Melting alloy Class 10 overload relay. Push-button operators in front cover with operation indicating lights. Number of poles as required. Housing finished in manufacturer’s standard enamel. Provide an HOA switch for all motors with automatic operation.
2. Combination Motor Starter:
   a. AC general purpose Class A magnetic controller in the same enclosure with motor circuit protector.

3. Operation Configurations:
   a. Full voltage starting
   b. Where soft starting is required use Cutler Hammer sof starter, or University approved equal. Do not use reduced voltage or two speed starters.

4. Auxiliary Contacts:
   Two normally open and two normally closed contacts in addition to seal-in contact.

5. All starters shall be UL listed and rated in accordance with the requirements of NEMA Standards Publication ICS-2.

C. Controller Overcurrent Protection and Disconnecting Means:
   1. Motor Circuit Protector:
      a. Circuit breakers with integral instantaneous magnetic trip in each pole.
   2. Fusible Switch Assemblies:
      a. Quick-make, quick-break, load interrupter enclosed knife switch with externally operable handle. Provide interlock to prevent opening front cover with switch in “on” position. Handle lockable in “off” position.

D. Motor Control Center:
   1. Class I or II as required by controls. Main overcurrent protection, molded case circuit breaker, fusible switch or main lugs as required. Voltage rating 120/208V or 480V, 1Ø or 3Ø, 60 Hz as required. Horizontal bussing, copper with continuous current rating as required. Provide with continuous copper ground bus entire horizontal length of control center. Vertical bussing copper. Integrated short circuit rating as required by available fault current. Enclosure rating as required with manufacturer’s standard enamel finish.

E. Fuses:
   1. Dual element current limiting one time fuses.

F. IEC style starters are prohibited, NEMA style starters shall be specified and utilized. Starters shall be capable of starting a range of motors with no degradation of starter life.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Provide a neatly typed label inside each motor starter enclosure identifying motor served, nameplate horsepower, full load amperes, code letter and service factor.

B. Locate controllers in acceptable environments not subject to temperature extremes beyond UL listing criteria. Provide appropriate enclosure rating for environments in which installed.

C. Contractor to size heater elements in starters in accordance with manufacturer’s recommendations for motor type.

3.2 ADJUSTING AND CLEANING

A. Require the Following:
   1. Touch up scratched or marred surfaces to match original finish.
2. Verification that control sequences, time delay and adjustments are as indicated on documents.

END OF SECTION 16480