

INDEX

DIVISION 15 MECHANICAL

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SECTION 15052 – COMMON WORK RESULTS FOR MECHANICAL

PART 1 - GENERAL

1.1 SUMMARY

- A. This Section includes the following:
 - 1. Piping materials and installation instructions common to most piping systems
 - 2. Escutcheons
 - 3. Electric motors
 - 4. Access Panels
 - 5. Equipment installation requirements common to equipment sections
 - 6. Painting and finishing
 - 7. Supports and anchorages

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 DRAWINGS AND SPECIFICATIONS

- A. The drawings are diagrammatic in character indicating design concept and do not indicate every required duct or piping offset, valve, fitting, etc.
- B. 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 Owner/Engineer for resolution.
- C. Unless otherwise indicated, all equipment and performance data listed is for job site conditions (elevation 5300 feet).
- D. Drawings are not to be scaled.

1.4 DEFINITIONS

- A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe chases, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.
- B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.
- D. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in chases.

- E. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.
- F. The following are industry abbreviations for plastic materials:
 - 1. ABS: Acrylonitrile-butadiene-styrene plastic.
 - 2. CPVC: Chlorinated polyvinyl chloride plastic.
 - 3. PE: Polyethylene plastic.
 - 4. PVC: Polyvinyl chloride plastic.
- G. The following are industry abbreviations for rubber materials:
 - 1. EPDM – Ethylene propylene diene terpolymer rubber.
 - 2. NBR – Acrylonitrile-butadiene rubber

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.
- B. Store plastic pipes protected from direct sunlight. Support to prevent sagging and bending.

1.6 COORDINATION

- A. Arrange for pipe spaces, chases, slots, and openings in building structure during progress of construction, to allow for plumbing installations.
- B. Coordinate requirements for access panels and doors for plumbing items requiring access that are concealed behind finished surfaces. Access panels and doors are specified in Division 8.
- C. Identification:
 - 1. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
 - 2. Coordinate installation of identifying devices with locations of access panels and doors.
 - 3. Install identifying devices before installing acoustical ceilings and similar concealment.
- D. Coordinate with all trades to maintain clearances to access panels, equipment, control and electrical panels. Intrusions into access space shall be brought to the attention of other trades. Notify Engineer of conflicts shown on drawings prior to installation.

PART 2 – PRODUCTS

2.1 MANUFACTURERS

- A. In other Part 2 articles where subparagraph titles below introduce lists, the following requirements apply for product selection:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the manufacturers specified.

2.2 PIPE, TUBE, AND FITTINGS

- A. Refer to individual Division 15 piping Sections for pipe, tube, and fitting materials and joining methods.
 - 1. Pipe Threads: ASME B1.20.1 for factory-threaded pipe and pipe fittings.

2.3 JOINING MATERIALS

- A. Refer to individual Division 15 piping Sections for special joining materials not listed below.
- B. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.
- C. Solder Filler Metals: ASTM B32, lead-free alloys. Include water-flushable flux according to ASTM B813.
- D. Solvent Cements for Joining Plastic Piping:
 - 1. CPVC Piping: ASTM F493.
 - 2. PVC Piping: ASTM D2564. Include primer according to ASTM F656.

2.4 TRANSITION FITTINGS

- A. Plastic-to-Metal Transition Fittings: CPVC and PVC one-piece fitting with manufacturer's Schedule 80 equivalent dimensions; one end with threaded brass insert, and one solvent-cement-joint end.
 - 1. Available Manufacturer: Eslon Thermoplastics
- B. Plastic-to-Metal Transition Adaptors: One-piece fitting with manufacturer's SDR 11 equivalent dimensions; one end with threaded brass insert, and one solvent-cement-joint end.
 - 1. Available Manufacturer: Thompson Plastics
- C. Plastic-to-Metal Transition Unions: MSS SP-107, CPVC and PVC four-part union. Include brass end, solvent-cement-joint end, rubber O-ring, and union nut.
 - 1. Available Manufacturers:
 - a. NIBCO Inc.
 - b. NIBCO, Inc.; Chemtrol Div.

2.5 ESCUTCHEONS

- A. Description: Manufactured wall and ceiling escutcheons and floor plates, with an ID to closely fit around pipe, tube, and insulation of insulated piping and an OD that completely covers opening.
 - 1. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with polished chrome-plated finish.
 - 2. One-Piece, Cast-Brass Type: With set screw or Split-Casting, Cast-Brass Type: With concealed hinge and set screw. Finish: Polished chrome plated
 - 3. Split-Casting, Cast-Brass Type: With concealed hinge and set screw. Finish: Polished chrome plated
 - 4. One-Piece, Floor-Plate Type: Cast-iron floor plate.
 - 5. Split-Casting, Floor-Plate Type: Cast brass with concealed hinge and set screw.

2.6 ELECTRIC MOTORS

- A. General Motor Characteristics: All motors (except as noted) shall conform to the following specifications:
1. Comply with requirements in this Section except when stricter requirements are specified in plumbing equipment schedules or sections.
 2. 1/2 hp and Smaller: Single-phase.
 3. Larger than 1/2 hp shall be three-phase, except where specifically noted otherwise.
 4. Comply with NEMA MG 1 unless otherwise indicated.
- B. Motor Characteristics:
1. Duty: Continuous duty at ambient temperature of 40°C and at site elevation.
 2. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.
- C. Polyphase Motors:
1. Description: General purpose NEMA MG 1, Design B, except "C" where required for high starting torque, medium induction motor.
 2. Efficiency: NEMA Premium Efficiency, as defined in NEMA MG 1 when available, otherwise energy efficient.
 3. Service Factor: 1.15.
 4. Multispeed Motors: Separate winding for each speed.
 5. Rotor: Random-wound, copper windings, squirrel cage.
 6. Bearings:
 - a. Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading, minimum 40,000 hour L10 life.
 - b. Sleeve type bearings are permitted for fractional horsepower and light-duty motors.
 7. Code Letter Designation:
 - a. Motors 15 hp and Larger: NEMA starting Code F or Code G.
 - b. Motors Smaller than 15 hp : Manufacturer's standard starting characteristic.
 8. Enclosure:
 - a. Material: Cast iron for motor frame sizes 324T and larger; rolled steel for motor frame sizes smaller than 324T.
 - b. Open drip-proof motors for indoor use where satisfactorily housed and properly ventilated during operation.
 - c. Weather protected Type I for outdoor use when enclosed or housed with adequate ventilation, or TEFC when exposed to weather or moist locations.
 - d. Special enclosures required for hazardous areas (explosion-proof, etc.) per equipment schedules. Explosion-proof motors shall be UL listed.
 9. Motor Selection Criteria:
 - a. 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.
 - b. Pump motors shall be "non-overloading"; i.e. shall not operate in service factor at any point on pump curve.

PART 3 – EXECUTION

3.1 PIPING SYSTEMS - COMMON REQUIREMENTS

- A. Install piping according to the following requirements.
- B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- C. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.
- D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- F. Install piping to permit valve servicing.
- G. Install piping at indicated slopes.
- H. Install piping free of sags and bends.
- I. Install fittings for changes in direction and branch connections.
- J. Install piping to allow application of insulation.
- K. Select system components with pressure rating equal to or greater than system operating pressure.
- L. Install escutcheons for penetrations of walls, ceilings, and floors according to the following:
 - 1. New Piping:
 - a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
 - b. Chrome-Plated Piping: One-piece, cast-brass type with polished chrome-plated finish.
 - c. Insulated Piping: Split, cast-brass type with spring clips.
 - d. Bare Piping at Wall, Floor, and Ceiling Penetrations in Finished Spaces, Unfinished Service Spaces, and Equipment Rooms: One-piece or split, cast-brass type with polished chrome-plated finish.
 - 2. Existing Piping: Use the following:
 - a. Chrome-Plated Piping: Split-casting, cast-brass type with chrome-plated finish.
 - b. Insulated Piping: Split, cast-brass type with spring clips.
 - c. Bare Piping at Wall, Floor, and Ceiling Penetrations in Finished Spaces, Unfinished Service Spaces, and Equipment Rooms: Split, cast-brass type with polished chrome-plated finish.

3.2 PIPING JOINT CONSTRUCTION

- A. Join pipe and fittings according to the following requirements and Division 22 15 Sections specifying piping systems.
- B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- D. Soldered Joints: Apply ASTM B813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B32.
- E. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8.
- F. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
 - 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- G. Plastic Piping Solvent-Cement Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:
 - 1. Comply with ASTM F402 for safe-handling practice of cleaners, primers, and solvent cements.
 - 2. CPVC Piping: Join according to ASTM D2846/D2846M Appendix.
- H. Plastic Pressure Piping Gasketed Joints: Join according to ASTM D3139.

3.3 ACCESS PANELS

- 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. Deliver all panels to General Contractor for installation. Provide instructions for their location in sufficient time so panels can be installed in the normal course of work.

3.4 ERECTION OF METAL SUPPORTS AND ANCHORAGES

- A. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor plumbing materials and equipment.
- B. Field Welding: Comply with AWS D1.1.

END OF SECTION 15052

SECTION 15062 – HANGERS AND SUPPORTS FOR PIPE

1.1 SUMMARY

- A. This Section includes the following hangers and supports for plumbing system piping and equipment:
 - 1. Steel pipe hangers and supports

1.2 SUBMITTALS

- A. Product Data: Provide submittal data for:
 - 1. Steel pipe hangers and supports
 - 2. Powder-actuated fastener systems

PART 2 – PRODUCTS

2.1 MANUFACTURERS

- A. Description: MSS SP-58, Types 1 through 58, factory-fabricated components. Refer to Part 3 "Hanger and Support Applications" Article for where to use specific hanger and support types.
- B. Manufacturers:
 - 1. B-Line Systems, Inc.; a division of Cooper Industries
 - 2. Grinnel
 - 3. ERICO/Michigan Hanger Co.; ERISTRUT Div.
 - 4. P.H.D.
 - 5. Tolco
- C. Galvanized, Metallic Coatings: Pregalvanized or hot dipped
- D. Nonmetallic Coatings: Plastic coating, jacket, or liner.

PART 3 – EXECUTION

3.1 HANGER AND SUPPORT APPLICATIONS

- A. Specific hanger and support requirements are specified in Sections specifying piping systems and equipment.
- B. Comply with MSS SP-69 for pipe hanger selections and applications that are not specified in piping system Sections.
- C. Use hangers and supports with galvanized, metallic coatings for piping and equipment that will not have field-applied finish.
- D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

- E. Not all hangers, attachments, and devices may be suitable for use as seismic restraints.

3.2 HANGER AND SUPPORT INSTALLATION

- A. Pipe Hanger and Support Installation: Comply with MSS SP-69 and MSS SP-89 for the installation of hangers, supports, clamps, and attachments to properly support piping from building structure.
- B. Hanger Spacing:
 - 1. Hanger spacing and sizing shall per MSS SP-69 or applicable 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. Maximum hanger spacing for plumbing piping shall be in accordance with Plumbing Code requirements.
 - 5. Hanger spacing must be reduced if thermal hanger shield insert cannot support full span.
- C. 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 is not exceeded.

END OF SECTION 15062

SECTION 15082 – PLUMBING INSULATION

PART 1 - GENERAL

1.1 SUMMARY

- A. This section includes the following insulation for plumbing systems.
 - 1. Insulation materials
 - 2. Mastics and adhesives

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 DEFINITIONS

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

1.4 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. HVAC makeup water piping

1.5 SUBMITTALS

- A. Product Data: For each type of product indicated. Include thermal conductivity, thickness, and jackets (both factory and field applied, if any).

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: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

PART 2 - PRODUCTS

2.1 PIPE INSULATION

- A. Manufacturers:
 - 1. Armstrong World Industries

2. Certainteed Crimpwrap
 3. Knauf Insulation; 1000 Pipe Insulation
 4. Manson Insulation Inc.; Alley-K
 5. Owens Corning; Fiberglas Pipe Insulation
 6. Johns Manville; Micro-Lok
- B. Preformed fiberglass conforming to ASHRAE 90.1-2004, ASTM C547, Class I or II, and ASTM C585 with "K" factor of 0.23 Btu-in./h-sf-°F maximum at 75°F mean temperature. See schedule for thickness.
- C. Jacket shall be factory-applied ASJ/SSL type, ASTM C921, or ASTM 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.

D. Pipe Insulation Thickness Schedule:

Piping System Type	Minimum Insulation Thickness for Pipe Sizes					
	From:	NPS 1	NPS 1-1/2	NPS 4	Greater than NPS 8	
	To less than:	NPS 1	NPS 1-1/2	NPS 4	NPS 8	
1. Domestic cold water, potable and non-potable		1/2"	3/4"	1"	1"	1"

Note: For piping exposed to outdoor ambient temperatures, increase thickness by 0.5 in.

- E. 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.

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, the open space remaining between the sleeve and pipe shall be filled with fire-stop insulation.

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 (6300 mm) 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 15062, "Hangers and Supports for Plumbing Systems." 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.

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.

END OF SECTION 15082

SECTION 15083 – MECHANICAL INSULATION

PART 1 - GENERAL

1.1 SUMMARY

- A. This section includes the following insulation for HVAC systems.
 - 1. Insulation materials
 - 2. Mastics and adhesives
 - 3. Jacketing

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 DEFINITIONS

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

1.4 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. Ductwork:
 - a. Relief hoods.
 - 2. Acoustic Lagging: Provide where shown on the drawings.

1.5 SUBMITTALS

- A. Product Data: For each type of product indicated. Include thermal conductivity, thickness, and jackets (both factory and field applied, if any).
- B. Shop Drawings:
 - 1. Detail insulation application on ductwork and relief hoods.
- C. Field quality-control reports.

1.6 QUALITY ASSURANCE

- A. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing and inspecting agency.
 - 1. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

1.7 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: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

PART 2 - PRODUCTS

2.1 DUCT INSULATION

- A. Armatuff Plus II duct insulation.

2.2 DUCT LINER

- A. General:
 - 1. Shall comply with requirements of NFPA 90A and 90B, UL 181 Class 1, ASTM C1071, and the Materials Standard of the North American Insulation Manufacturer's Association (NAIMA); Type 200, Flame Spread 25 maximum and Smoke Development 50 maximum.
 - 2. Shall not absorb more than 1% moisture when tested per ASTM C553.
 - 3. Shall not cause corrosion of duct material (aluminum or galvanized steel) when tested per ASTM C665.
 - 4. Shall not breed or promote growth of fungi and/or bacteria when tested per ASTM C665, G-21, and G-22. Coating shall include an EPA-registered anti-microbial agent.
 - 5. Air-stream surface and transverse edge shall be factory-coated with a tough composite material to provide a maximum average velocity rating of 5,000 fpm or better at 250°F when tested per ASTM C1071.
 - 6. Shall have a nominal "K" value of 0.27 Btu-in./h-sf-°F or less (1-inch thickness, 1 lb/ft³) when tested per ASTM C518 at 75°F mean temperature.
 - 7. Shall have a sound absorption coefficient (1-inch thickness, 1 lb/ft³) of 0.72 or higher at 1,000 Hz when tested per ASTM C423, Type A mounting. Round duct liner shall have a Noise Reduction Coefficient (NRC) of 0.70 or better when tested per ASTM C423, Type A mounting.
- B. Rectangular Liner, Specification "L": Approved manufacturers are CertainTeed (ToughGard), Knauf type E-M, Owens-Corning (Aeroflex), and Schuller (Permacote Linacoustic).
 - 1. Duct sizes shown on drawings are outside dimensions and include liner.

PART 3 - EXECUTION

3.1 INSTALLERS

- A. Insulation shall be installed by workmen regularly engaged in this kind of work in strict accordance with the manufacturer's recommendations and recognized industry practices.

3.2 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. Duct Liner:

1. For velocities up to 2,000 fpm , duct liner shall be applied with 100% coverage of fire-retardant adhesive. Duct liner shall be cut to assure snug corner joints. The coated or most dense surface of the liner shall face the airstream. The liner shall be additionally secured with mechanical fasteners that shall compress the duct liner sufficiently to hold it firmly in place. They shall start within 3 inches of the leading edge of each duct section (and any line transverse joints within the duct section) and shall be spaced no more than 12-inch o.c. around the perimeter of the duct, except that they need to be no closer than 9 inches to a corner break. Elsewhere, they shall be a maximum of 18-inch o.c., except that they shall be placed not more than 6 inches from a cut edge, nor 12 inches from a corner break. All exposed edges and the leading edge of all cross joints of the liner shall be coated with the same adhesive used to secure the duct liner to the metal surface.

END OF SECTION 15083

SECTION 15145 – PLUMBING PIPING SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

- A. Section includes requirements for complete water and sanitary sewer.

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 SYSTEM DESCRIPTION

- A. Water Service: Existing building water distribution piping is to be utilized to serve the new plumbing system.
- B. Sanitary Sewer: Existing sanitary sewer is to be extended or modified to serve the new make-up water line.

1.4 SUBMITTALS

- A. Product Data: Provide submittals on all items furnished under this section excluding pipe and fittings.

PART 2 - PRODUCTS

2.1 DOMESTIC WATER PIPE, TUBE, FITTINGS, AND JOINTS

- A. Domestic Water Piping (Potable and Non-Potable):
 - 1. Copper Pipe:
 - a. Above Grade Pipe: ASTM B88, Type K drawn temper seamless copper tube.
 - b. Below Grade Pipe, NPS 3 and smaller: ASTM B88, Type K annealed temper, seamless copper tube.
 - c. Fittings: ASME B16.22 wrought copper or ASME B16.18 cast-copper alloy.
 - d. Flanges: ASME B16.24, Class 150 cast bronze flanges with solder joint ends.
 - e. 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.
 - f. Solder Filler: ASTM B 32, Alloy Sn95, Sn94 or E; lead free, NSF 61.
 - g. Brazing Filler Metal: AWS A5.8, BAg, silver classification (15% silver solder).

2.2 REDUCED-PRESSURE BACKFLOW PREVENTER

- A. Backflow preventer shall be provided with an upstream strainer.

2.3 TRAPS

- A. Provide traps for each plumbing fixture, floor drain, and other equipment requiring connection to the sanitary sewer system. Place each trap as near to the fixture outlet as practical. Trap material and type of connections shall be compatible with the connecting drainage system and be suitable for the intended application.

PART 3 - EXECUTION

3.1 PREPARATION

- A. General:
 - 1. Verify existing grades, inverts, utilities, obstacles, and topographical conditions prior to installation.
 - 2. Examine walls, floors, and plumbing chases for suitable conditions where piping and specialties are to be installed.
 - 3. Do not proceed until unsatisfactory conditions have been corrected.
- B. Domestic Water Service:
 - 1. Connect into the existing water piping as shown on the drawings. Coordinate with the Owner for shutdown of existing water service.
- C. Sanitary Sewer: Connect into the existing sanitary sewer as shown on the drawings. Coordinate with Owner for shutdown of existing water service.

3.2 INSTALLATION

- A. General:
 - 1. Examine walls, floors, and plumbing chases for suitable conditions where piping and specialties are to be installed.
 - 2. Piping shall be run true, plumb, and straight, with all restraints adjusted to carry their proportional load and locked to prevent pipe "wag," misalignment, movement, shear, or sagging.
 - 3. Use fittings for all changes in direction and all branch connections.
 - 4. Install exposed piping at right angles or parallel to building walls. Diagonal runs are not permitted unless expressly indicated.
 - 5. Install piping free of sags or bends and with ample space between piping to permit proper insulation applications. Piping hanger spacing and supports shall be per Code requirements (minimum), or per Section 15062, "Hangers and Supports for Plumbing Piping and Equipment," whichever is more stringent.
 - 6. Conceal all pipe installations in walls, pipe chases, utility spaces, above ceilings, below grade or floors unless indicated to be exposed to view.
 - 7. Install piping tight to slabs, beams, joists, columns, walls, and other permanent elements of the building. Allow sufficient space above removable ceiling panels to allow for panel removal.
 - 8. Fire Barrier Penetrations: Where pipes pass through fire-rated walls partitions, ceilings, and floors, maintain the fire-rated integrity. Use fire-stop caulking materials at all fire-rated wall penetrations.
 - 9. All copper tube and fitting shall be reamed and buffed prior to soldering or brazing.

10. The use of solder containing lead is prohibited.
11. Refer and conform to the "Copper Development Association" instructions for proper preparation and actual installation practice for all soldered and brazed joints.

B. Sanitary Waste and Vent Piping and Storm Drainage Piping:

1. Make changes in direction for drainage piping using appropriate 45-degree wyes, half-wyes, or long sweep quarter, sixth, eighth, or sixteenth bends. Sanitary tees or short quarter bends may be used on vertical stacks of drainage lines where the change in direction of flow is from horizontal to vertical, except use long-turn tees where two fixtures are installed back-to-back and have a common drain.

C. Cleanouts:

1. Provide cleanouts in locations required by Code and at locations shown on the drawings. Full size for pipe up to 4 inches at the base of all vertical stacks, ends of sewer mains, changes in direction of sewer mains, and in horizontal runs of piping not over 50 feet apart for interior sewers, and not over 100 feet apart for exterior sewers. Install cleanouts so they are accessible by extending them through walls or floors. Install floor and wall cleanout covers for concealed piping.

3.3 FIELD QUALITY CONTROL

A. General Testing Procedures:

1. All piping systems shall be tested and proven tight prior to concealment. The test shall be witnessed by the Owner's representative.
2. Insure that the test pressure that might damage fixtures or equipment does not reach such units by valving them off or otherwise isolating them during the test.

B. Domestic Water Pipe Testing:

1. Open and close all system valves at least once while system is pressurized to test valve packing. Tighten as required.
2. Test procedures shall be as follows:
 - a. Domestic Hot and Cold Water: 150 psig hydrostatic test. (200 psig on water service when serving a fire line.)
 - b. All hydrostatic tests shall be held for a minimum of eight hours without loss of pressure.

C. Drainage Systems Testing Procedure: Drainage systems (including sanitary sewers, sanitary vents, acid waste and vents): Test piping systems in accordance with the test procedures required by the applicable Plumbing Code.

END OF SECTION 15145

SECTION 15810 – HVAC DUCTS AND ACCESSORIES

PART 1 - GENERAL

1.1 SUMMARY

- A. Section Includes: This section covers general requirements for ducts and accessories including:
 1. Metal ducts
 2. Flexible duct
 3. Flexible connections
 4. Duct dampers and accessories
 5. Turning vanes

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 SUBMITTALS

- A. Product Data:
 1. Flexible duct and take-off fittings
 2. Duct sealant and fire-stop materials
 3. Duct access doors

1.4 MINIMUM DUCT CONSTRUCTION STANDARDS

- A. Duct construction and installation shall be in accordance with functional criteria requirements of the SMACNA HVAC Duct Construction Standards.
 1. All shop and field-fabricated ductwork, joints, seams, and reinforcement shall conform to SMACNA HVAC Duct Construction Standards for pressure classes specified.
 2. The proprietary TDC and TDF formed-on duct connector systems shall conform to SMACNA HVAC Duct Construction Standards for pressure classes specified.
 3. "Ductmate" or WDCI proprietary connector systems are acceptable provided the type of joint and the maximum joint spacing for various gauges and pressure classes conform to the SMACNA Duct Construction Standards Manual.
 4. All longitudinal seams shall be Pittsburgh Lock or better; "Snaplock" is not acceptable.
 5. The Contractor will be required to replace all ductwork not conforming to this specification.
- B. Duct sealing shall be per construction and installation standards published in the SMACNA HVAC Duct Construction Standards as follows:

DUCT SEALING REQUIREMENTS

Seal Class	Sealing Required
A	All transverse joints, longitudinal seams, and duct wall penetrations, 3-inch w.g. and up.
B	All traverse joints and longitudinal seams, 3-inch w.g. maximum
C	Transverse joints, 2-inch w.g. or less

- C. Rectangular ductwork shall be constructed standard to 1-inch w.g. w.g. pressure class and Seal Class B.

PART 2 - PRODUCTS

2.1 SHEET METAL DUCTWORK

- A. Shop- or field-fabricated ductwork shall comply with the SMACNA "HVAC Duct Construction Standards." See Part 1 of this specification for requirements.
 - 1. Sheet metal for all exposed ductwork shall be electro-galvanized.

2.2 FLEXIBLE DUCT AND TAKEOFF FITTINGS

- A. Approved Manufacturers: Atco, Cleveflex, Flexmaster, Genflex, Hart & Cooley, H.K. Porter, Omni-Air, Owens-Corning, Johns-Manville (Flex-Met), Thermaflex, and Wiremold.
- B. Flexible duct shall comply with requirements of NFPA Bulletin No. 90A and 90B, and UL 181 Standards as Class 1 Air Duct with a flame spread rating 25 or less and a smoke-developed rating not higher than 50.
 - 1. Low-pressure ducts shall have a minimum working pressure of 6-inch w.g. positive and 0.5-inch w.g. negative.
- C. Flexible ducts shall have a polyester inner liner supported by helical-wound, mechanically locked galvanized steel wire or flat strips, insulation, and an outer vapor barrier with fiberglass reinforcing.
- D. Flexible ducts shall be insulated with 1 inch or thicker, 3/4-pound/cf density fiberglass with a minimum "R" value of 4.0 sf-°F-h/Btu-in at 75°F. Dimensions shown on the plans are clear inside diameter.
- E. Takeoff fittings shall be conical type with quadrant damper equal to Hercules 9000 or lateral high-efficiency rectangular type equal to Hercules HTO 1095 Series with volume damper.

2.3 DUCT SEALANT

- A. Approved Manufacturers: Chicago Mastic Corporation, Foster, Hardcast, SOLVseal, Tough Bond, and McGill Airflow.
- B. Duct joint and seam sealant options are:
 - 1. Tape System: Woven fiber, 2-inch tape impregnated with a gypsum mineral compound using an activator to form a hard, durable seal; Hardcast RTA-50, or approved equal. VOC content shall be 23 ounces/gallon maximum.
 - 2. Mastic: Water-based sealant with fiber-based resins, Hardcast DS-321 or approved equal. VOC content shall be 11 ounces/gallon maximum.
 - 3. Flanged Joint Gaskets: Butyl EPDM copolymer blend pressure sensitive gasket tape, Hardcast GT-1902, or approved equal. VOC content shall be 0 ounces/gallon.

2.4 TURNING VANES

- A. Turning vanes shall be single vane type, formed to assure that any point on one blade is equidistant from the same point on an adjacent blade. Construction shall be per SMACNA HVAC Duct Construction Standards.

2.5 FLEXIBLE CONNECTIONS

- A. Approved manufacturers are Ventfabrics, Inc. or Duro-Dyne.
- B. Provide flexible duct connections wherever ductwork connects to vibration isolated equipment.
- C. Ventfabrics Ventglas or equal by Duro-Dyne shall be used for flexible duct connections when not exposed to the weather (30 ounces/sq. yd.).
- D. Ventfabrics Ventlon or equal by Duro-Dyne shall be used for flexible duct connections exposed to the weather and/or fume hood connections (26 ounces/sq. yd.).

2.6 MANUAL VOLUME DAMPERS

- A. Approved Manufacturers: Air-stream, Air Balance, American Warming and Ventilating, Arrow, Cesco, Dowco, Duro-Dyne, Greenheck, Louvers & Dampers, Nailor, National Controlled Air, Pacific Air Balance, Penn, Ruskin, Vent Products, and Venco.
- B. Rectangular manual volume dampers for low velocities ((1,500 fpm) or less) shall be opposed or parallel blade type with concealed or exposed linkage and 3/8-inch-)square shaft with locking quadrant.
 - 1. Construction shall be of 16-gauge galvanized roll-formed channel or 0.125-inch aluminum frame with 16-gauge galvanized roll-formed blades. Maximum blade width is 8 inches, exception is single blade that is up to 12 inches. Blades 36 inches and longer and driven blade shall be furnished with reinforcing cone. Maximum blade length is 48 inches. Ruskin MD35 or equal.
 - 2. Round MVDs may be single blade to 20-inch diameter, multi-blade above 20 inches, 20-gauge blade and frame to 12-inch diameter diameter, 18-gauge blade above 12 inches diameter, Ruskin MDRS 25, Air Balance AC-112, or equal.
- C. Rectangular manual volume dampers for medium velocities (1,500 to 4,000 fpm) shall be airfoil opposed blade, low-pressure drop type, concealed linkage, 1/2-inch-diameter control shaft with locking quadrant. Construction shall be of 16-gauge galvanized steel channel or .125-inch aluminum frame with airfoil-shaped, double-skin steel or extruded aluminum blades. Maximum blade length shall be 60 inches. Ruskin CD 60, Air Balance AC-112 or equal.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Duct Construction and Installation:
 - 1. All ducts and plenums shall be constructed, reinforced, and sealed in accordance with SMACNA "HVAC Duct Construction Standards" and as scheduled in Part 1.

2. All ductwork shall be fabricated and installed so that no undue vibration or noise results. Joints per seal class shall be sealed airtight with additional taping and caulking provided if necessary.
 3. Hang ducts with strap iron attached to bottom of ducts spaced not over 5 feet center-to-center.
 4. Square elbows shall have single-thickness turning vanes.
 5. Provide all necessary manual dampers as required for proper adjustment and control of air distribution.
 - a. Provide a 45-degree entry fitting at all branches in rectangular ductwork, except where parallel flow branches are used.
 - b. Manual dampers shall have rigid bearings and locking quadrants that allow no rattling. Damper rods shall be marked to indicate the relative position of the damper blade with respect to the rod.
 6. Provide flexible and fabric connections at inlet and discharge duct connections to in-line fans, and on fan coil units and air handling equipment, except when fans are internally isolated. Flexible connections shall be securely fastened to the duct and equipment per SMACNA Duct Construction Standards. Allow at least 1 inch of slack.
 7. Transitions in ductwork, in changing shapes and sizes, shall be made with angles not exceeding 15 degrees (diverging) or 30 degrees (converging) (interior angle – both sides included) wherever possible.
 8. Flexible duct shall be used on supply diffuser runouts only, and only where indicated. Flexible ducts shall be installed using lengths not exceeding 6 feet (low-pressure) to make the connection. Where horizontal support is required, duct shall be suspended at intervals not exceeding 3 feet with a minimum 1-inch-wide, 22-gauge steel band. Maximum allowable sag is 1/2 inch per foot of spacing between supports. All connections shall be made with stainless steel duct clamp with worm gear fastener .
 9. Contractor shall not provide holes in the duct systems for the installation of hangers, conduits, etc., for other equipment. Work of all other trades shall be so coordinated as to render this unnecessary.
 10. At ends of ducts that are not connected to equipment, ductwork, or air distribution devices at time of ductwork installation, provide a temporary closure of plywood or corrugated cardboard backed polyethylene film or other covering that will prevent entrance of dust and debris and duct leakage until time connections are to be completed.
- B. Duct Penetrations through Wall and Floors:
1. Provide 1-inch angle collars for all exposed ducts passing through walls, ceilings, or floors. Anchor collars in position after installation is complete.
 2. Where vertical ducts pass through floors, supporting angles shall be rigidly attached to ducts and to the floor. Angles shall be galvanized and of approved sizes to properly support the ductwork. The supporting angles shall be placed on at least two sides of the duct.
 3. Where horizontal ducts pass through walls and vertical ducts pass through floors, opening shall be tightly sealed off so as to provide a tight seal between duct and opening. Refer to Part 2 of this section for approved fire stop materials to be used at all rated walls and floors.
- C. Sealing of Ducts:
1. All ducts shall be sealed as defined in Part 1 of this section. Metal surfaces to be joined must be clean, dry, grease-free. Apply a heavy brush coat of sealant to the interior metal surface of the duct slip joint, then interlock securely duct sections and position in place. Apply a finish heavy brush coat of sealant to the exterior metal surface duct joint or seam covering heads of

lock joint screws, making sure that all voids are completely filled to ensure a continuous air pressure sealant.

2. In the event of possible excessive duct vibration or mechanical abuse, the exterior metal surface joint finish shall be applied as follows: Apply a heavy brush coat of sealant to the exterior metal surface joint or seam and lay into the wet film a reinforcing membrane of glass fabric approximately 2-inch-wide, making sure it is pressed firmly into the wet film. Immediately apply a heavy finish brush coat of sealant.

3.2 CLEANING

A. Duct Systems:

1. Clean ductwork internally of dust and debris as it is installed. Clean external surfaces of foreign substances that might cause corrosive deterioration of metal or, where ductwork is to be painted, might interfere with painting or cause paint deterioration.

END OF SECTION 15810

SECTION 15905 - INSTRUMENTATION AND CONTROLS

PART 1 - GENERAL

1.1 RELATED WORK SPECIFIED ELSEWHERE

- | | | |
|----|-----------------------------------|-------------------|
| A. | General Requirements | Divisions 0 and 1 |
| | Mechanical | Division 15 |
| | Sequence of Operation | Section 15985 |
| | 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 therein.
- C. All wiring required for proper operation of the automatic temperature control 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 DDC controls with electric components.

1.3 SPECIAL CONDITIONS

- A. The University uses only Andover Infinet II (i2) family of controllers 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 their 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 (xP 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 two approved Controls Contractors allowed to bid on projects utilizing Andover Controls products on the University of Colorado Boulder campus. They are Arkay Services and Westover Controls. These two companies competitively bid against each other for the entire Andover controls portion of the project; including design, programming, component purchasing, installation, graphics 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.

- F. All damper and valve actuators, including those for VAV control, smoke/fire or smoke dampers, shall be electric, unless specified otherwise. If field conditions appear to require a different type of actuator, the University Engineer shall be consulted for review and approval of a different type of actuator.

1.4 SCOPE

- A. The automatic control system shall be direct digital control (DDC) with electric components, unless noted otherwise.
- B. All digital and analog control loops shall be (DDC) controlled with electronic final control elements, 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. 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.
- F. 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.
- G. All automatic temperature control dampers shall be provided by the Controls Contractor for installation by the Mechanical Contractor under the Control Contractor's supervision, unless they are components of packaged equipment.
- 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. 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.

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. The University shall program the central workstations and the controller applications.
- 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 phrases "University Engineer" or "Owner's Representative" implies an engineer from the UCB Facilities Management Department.
- F. The term "UCB Controls Shop" or "CU Controls Shop" implies a representative of the control shop of the University of Colorado Boulder.
- G. 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 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, 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, and 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.
5. 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.
 6. 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 (per Section 01300) to the Architect/Engineer for review prior to ordering or fabrication of the equipment. The following information shall be included in these submittals:
1. 30 Days or Less After Notice to Proceed:
 - a. Control valve and damper schedules which include size, Cv (valves), closeoff pressure rating (valves), gpm or cfm, quantity of actuators (dampers), and actual pressure drop for each item.
 - b. Technical specification data sheets of each system component and device which includes all data needed to show compliance with this specification.
 2. 60 Days or Less After Notice to Proceed:
 - a. 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.
 - b. Sequence of operation for all controlled and monitored points for each system. Sequence shall be on same drawing as corresponding system schematic.
 - c. 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.
 - d. 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.
 - e. On control drawings show sensor, panel, and equipment locations by referring to room number.
 - f. DDC network configuration complete with interconnection diagrams for all peripheral devices, batteries, power supplies, etc.
 - g. 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.
 - h. 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.
 - i. 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.

3. 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 descriptions, 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.

1.10 DEMONSTRATION AND TRAINING

- A. This Contractor shall provide a minimum of two hours of system and control demonstration time at the job site for the Owner's personnel.
- B. The instructor(s) for the above sessions shall be employee(s) of the Control Contractor whose primary function is customer training and applications support.
- C. A minimum of two copies of the most current control drawings shall be provided to the CU Controls Shop before the training begins. These shall be in addition to the drawings to be provided under Paragraph 1.8, if the O&M Manuals have not been turned in to the Architect before the time of the training.

- D. 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 Paragraph 3.7 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. The training shall consist of an orientation session at the job site to familiarize the personnel with the location and type of controlled equipment and controls on the project, a discussion of the control sequences, and a review of the control drawings. 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 a 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 Paragraph 3.12, 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 ten (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 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.

2.3 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 $\pm 0.5^{\circ}\text{F}$ 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 $\pm 0.2^{\circ}\text{F}$ or 1% of span, whichever is less, and matched.
 - 1. Space (room) sensors shall be surface-mounted. Space sensors 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 $\frac{1}{2}$ -inch or $\frac{3}{4}$ -inch external NPT threads and shall provide for extension of sensor electrical junction box on insulated pipes.
- B. Humidity sensors shall be "Vaisala" capacitive type using thin film technology. Units shall have 2% accuracy from 0-90% RH at 25°C and 4-20 mA output. "HMD/W 20U" or Engineer-approved equal. Remote humidity sensors for outdoor application shall be protected from adverse weather conditions. Transmitters, if used, shall not be mounted outdoors.

2.4 TRANSMITTERS - SOLID-STATE

- A. Transmitters shall have sensing elements suitable for the application.
- B. Transmitters shall have direct-acting, linear output signal compatible with controller, with full-scale accuracy of $\pm 1\%$ or better. Zero and span shall be field-adjustable.
 - 1. Transmitter range (span) shall be suitable for application, typically as follows:
 - a. Water Static Pressure: 0 to 100 psig
 - b. Steam: 0 to 30 or 0 to 100 psig
 - 2. Transmitter sensing elements shall withstand continuous operating conditions plus or minus 50% greater than calibrated span without damage. Air pressure transmitters shall have a minimum overpressure rating of 10-inch w.c.
 - 3. Water, Compressed Air, Steam, etc.: Pressure transmitters shall have stainless steel diaphragm construction, proof pressure of 200% proof pressure minimum, accuracy shall be $\pm 0.1\%$ of full scale. Transmitter shall be complete with 4-20 mA output, required mounting brackets, and block and bleed valves. Mount in location accessible for service. Kele PTX1 Series with pigtail (steam) or approved equal. Low-pressure steam shall be 0-30 psi, high-pressure steam shall be 0-300 psi.
 - 4. Low differential pressure air: Dwyer Magnehelic series 605, Air Monitor or Engineer approved equal

2.5 FIELD-MOUNTED ELECTRIC AND SOLID-STATE DEVICES

- A. Current-sensing-type switches shall be used to prove equipment operation. 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. Manufacturers are Neilsen-Kuljian or SD100, or approved equal.
- B. Damper end-switches shall be UL-listed, line voltage SPDT snap-acting, pilot duty rated (125 VA minimum) NEMA 1 enclosure, with roller-type actuating arm suitable for damper position application. Manufacturer: Allen Bradley, Kele TS-470, or approved equal.
- C. 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.
- D. 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.
- E. 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.
- F. Solid-State Sensing Devices:

1. Humidity Sensors:
 - a. Wall-mounted, manufacturer: Vaisala Model HMW-20U
 - b. Duct-mounted, manufacturer: Vaisala Model HMD-20U
 2. Dew point transmitter:
 - a. Manufacturer: Kahn Transmet
- G. Air Differential Static Pressure Transmitters:
 1. Manufacturers: Dwyer Magnehelic Series 605, Air Monitor, or approved equal.
- H. Temperature RTD:
 1. 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. Standard Nomenclature for Valve and Damper Position Description:
 1. Set up the conversion table for each valve or damper control output so that 100% OPEN = open and 0% OPEN = closed.
 2. For mixed-air dampers, 100% OPEN = fully open outside air damper and closed return damper.

3. For face and bypass dampers, 100% OPEN = face damper fully open and bypass damper closed. This would apply to both a face and bypass damper for a heating coil, which is normally open to the coil; and to a face and bypass damper for a evaporative cooling pad, which is normally closed to the pad.
- H. 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.
- I. Setup of Inputs:
 1. 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.
 - a. Temperature (Space, OAT, MAT, DAT, RAT, etc.) .1°F
 - b. Space Static Pressure 0.01"W.C.
 - c. Duct Static Pressure 0.2W.C.
 - d. Relative Humidity (Space, OAT, MAT, DAT, RAT, etc.) 1%
- J. Provide thermal-conducting compound for all sensors in thermowells.
- K. Protect all points where 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.
- L. Seal all penetrations into ductwork or air-handling units with duct sealant or other means to make the installation airtight.
- M. 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.
- N. Install sensor tubing to both the high and low pressure side of a fan when installing DP switches.
- O. Averaging type sensing elements shall be firmly supported in ductwork or air handling units using 1/2" EMT or other auxiliary support.
- P. 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.)
- Q. 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.

- R. 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.
- S. Layout of Points on Controllers. The points on controllers shall be arranged by the controls contractor 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. Room thermostats and sensors shall be mounted 5'-0" above finished floor unless otherwise noted on drawings.
- B. Outdoor temperature sensing bulbs and sensors shall be located generally on a northern exposure, in a shaded location, preferably in a place where there is a continuous stream of outside air over the sensor, unless shown otherwise. Provide sun shield for temperature sensors. All locations shall be pre-approved by the Owner's Representative.
- C. Provide wind dampening "weatherhead", with insect screen on outdoor-atmospheric-pressure sensing point and mount at least 3 ft above the highest roof structure to minimize false readings due to wind direction and/or eddies.
- D. Remote control devices not in local panels shall be accessible for adjustment and service below 6 ft above finished floor whenever possible.
- E. Locate all control devices wired by the Electrical Contractor under Division 16.
- F. Outdoor-relative-humidity-sensing elements shall be located generally on a northern exposure, in a shaded location, preferably in a place where there is a continuous stream of outside air over the sensor, unless shown otherwise. Provide a sun shield. If there is an existing or new dry-bulb temperature sensor, mount the humidity sensor next to the temperature sensor. All locations shall be pre-approved by the Owner's Representative.

3.3 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 1 (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 ½ 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 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 by 3 inches.

3.4 INSTALLATION PROCEDURES

A. Control Cabinets:

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

3.5 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 UCB designated terminals.
5. Only two pair of communication wires shall be connected to the communication terminal on the controller.
6. All controllers shall have display screens.

3.6 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.
- 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.

3.7 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.

3.8 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.

3.9 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 and scheduled with the Owner's Representative.

- D. Control loops shall maintain setpoint within the following tolerances:

Air Pressure +0.5-inch w.g. range 0-6-inch w.g. +0.01-inch w.g. range -0.1 to 0.1-inch w.g.

Airflow ± 100 cfm

Humidity $\pm 5\%$ RH

Temperature $\pm 1.0^\circ\text{F}$

Fluid Pressure +2.0 psi range 1-150 psi +2.0-inch w.g. range 0-50-inch differential pressure

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

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

3.10 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.

3.11 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.

3.12 FIBER OPTICS - NETWORKING

- A. The temperature controls contractor shall be responsible for coordinating new system alarms with CU Controls Shop.

3.13 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.

3.14 CONTROL PANEL REPLACEMENT DATA SHEETS AND POINT LAYOUT (I/O) SUMMARIES AND ELECTRICAL PANEL INFORMATION

A. Provided on the following pages.

END OF SECTION 15905

SECTION 15990 – TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

- A. This Section includes testing, adjusting, and balancing (TAB) to produce design objectives for the following:
 - 1. Air Systems:
 - a. Constant volume air systems

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 SUBMITTALS

- A. Quality Assurance/Control Submittals: Qualifications - Within 30 days after contract award, submit the name(s) of the professional engineer and/or the NEBB or AABC certified supervisor who will be supervising this work. Submit the name(s) of the TAB technician(s) who will be performing the work.
- B. Closeout Submittals:
 - 1. TAB Report: After all balancing is complete, and all coordination with the the Owner or his representative is complete, the balancing firm shall furnish four bound reports that shall contain the following information:
 - a. Belt and drive sheave information (as installed and as changed), fan nameplate information, motor nameplate information, and amperage and voltage to all motors (in various operating modes where applicable). Also, maximum and minimum rpm settings on VFD units.
 - b. Static pressure drops across all components of the air systems. Static pressure profile for each air handling unit system.
 - c. 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.

1.4 QUALITY ASSURANCE

A. Qualifications:

1. Pre-qualified TAB firms for this project are:
 - a. Checkpoint Balance, LLC 303-670-3650
 - b. Finn & Associates 303-353-8210
 - c. JPG Engineering 303-688-9044
2. Other qualified firms desiring to furnish services for this project shall submit for written approval, during bid time, a brochure listing the qualifications of personnel in the organization, instruments available to be used, an outline of system balancing procedures that is intended to be followed, and a list of projects successfully balanced within the last two years. Information regarding additional qualifications listed below must be in the office of the Engineer at least 10 calendar days prior to the date set for receiving bids.
3. 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.
4. TAB firm shall:
 - a. Have had previous experience with at least one project of similar type and size in the State of Colorado. Provide the project(s) name, owner, general contractor, mechanical contractor, and references with phone numbers for each.
 - b. Have a permanent place of business and phone number within a 200-mile radius of the job site.
 - c. Have been actively engaged in balancing work within the State of Colorado for at least three of the past five years. Provide at least three project references with phone numbers.
 - d. Have a minimum of two permanent employees who have been actively engaged in balancing work for a minimum of three (3) years. Provide names, certifications, and experience resumes.
5. 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 15053, "Common Work Results for HVAC," 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.
3. Applicable sections and paragraphs as published in ASHRAE 1995 Applications Handbook, Chapter 34, Testing, Adjusting, and Balancing, and Standard 111-1988.

1.5 SCHEDULING

- A. Coordinate scheduling of work with the General Contractor, the appropriate subcontractors.
 1. Schedule TAB work to coincide with testing and verification of control systems where practical.
 2. Coordinate system startup and performance verification with the Commissioning Contractor as TAB work is in progress.
- B. Provide written notification (within 24 hours) to General Contractor, Engineer, and Owner or his representative of any component and/or system deficiencies.

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. Calibration histories for each instrument shall be available for examination.
- C. When DDC terminal unit controls are used, appropriate application software and hardware shall be obtained from the Temperature Control Systems Contractor for proper interface to the terminal unit DDC controls.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Air balancing shall not begin until the system to be tested has been cleaned and flushed, and is in full working order.
- 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 that proper access is provided.

- 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 air balance work is done, the system shall be checked for:
 - 1. Excessive duct leakage
 - 2. Dirt and debris in ducts and/or AHUs
 - 3. Filters are installed (and changed if they are dirty)
 - 4. Correct motor rotation
 - 5. Excessive vibration
 - 6. Equipment lubrication
 - 7. Proper operation of automatic control and smoke dampers
 - 8. Manual control dampers, fire dampers, and air outlet dampers are wide open

3.2 REQUIREMENTS OF WORK

- A. Adjust air handling systems to the following tolerances:
 - 1. Fume hood face velocities shall be adjusted to average 0% to +10% of design values.
- B. Air Balance:
 - 1. Air supply, return, and exhaust systems with air quantities for each air device.
 - a. Air handling units including supply, return, mixed, and outside air temperatures
 - b. Fan data including cfm, static pressure, fan rpm, motor running amperage; (and full load amperage) before and after final balance.
 - 2. Air diffuser patterns shall be set to minimize objectionable drafts and noise.
 - 3. The supply, return, and exhaust fan static pressures shall be set by the balancing firm (and the Controls Contractor if the systems have fan volume control).
 - a. The pitot tube traverse method for determining main duct cfm shall be used and recorded wherever possible; flow hood measurements at registers and diffusers may be totaled for branch duct quantities.
 - b. The supply air system shall be tested in all operating modes (full return air, full outside air, full cooling with the design diversity, and full cooling with no diversity).
 - c. After balancing is completed, check fan motor amperage with the filters clean.
 - d. System static pressure profiles and fan motor amperages shall be recorded in all modes.
 - e. The lowest fan speed resulting in satisfactory system performance shall be determined at full design delivery. Any inlet or outlet fan volume (balancing) dampers shall be in the wide-open position and one path presenting the greatest resistance to flow shall be fully open and unobstructed.
 - f. After balancing, all adjustable speed sheaves 7-1/2 hp and larger shall be replaced with fixed-speed sheaves by the TAB Contractor.
 - 4. Provide system static pressure profiles that identify pressure differences across all components of air handling units and built-up systems. Pressure drops shall be individually measured and recorded for intake and exhaust vents, hoods, louvers, manual and auto control dampers, filters, coils, evap. coolers, fans, terminal units, etc.
 - a. On systems with OSA economizers, pressure drop values shall be recorded for both minimum and 100% OSA modes.

5. Building static pressure adjacent to entries shall be measured and recorded. Adjust systems to maintain a positive pressure of 0.05-inch w.c. when possible. Note any discrepancies.
6. Final adjustments shall include but not be limited to the following:
 - a. Fans:
 - 1) Belt Drive: RPM - Include sheave and belt exchange as required to deliver airflow within limits of installed motor horsepower and mechanical stress limits of the fan. Determine the limiting fan tip speed before increasing rpm. Final fan speed setting shall allow for predicted filter loading and shall provide proper duct pressures for operation of zone cfm regulators where used.
Note: Fan rpm shall not be increased more than 10% from the factory setting without prior authorization by the Engineer.
 - 2) VFD Drive: Coordinate VFD startup with the applicable Division 15 vendor. Adjust maximum and minimum rpm settings as necessary to obtain design cfm. Verify that ramp-up and down adjustments are made as necessary to prevent overshoot and "hunting."
 - 3) Direct Drive:
 - a) RPM with Speed Taps: Set fan speed on tap that most closely approaches design cfm. Report tap setting on equipment data sheet.
 - b) RPM with Speed Control Rheostat: Set output of fan to design cfm by adjusting the SCR. After adjustment, check fan's ability to restart after powering down. Increase SCR setting if required for proper starting.
 - c) CFM with Variable Pitch Blades: Variable fixed pitch fan blades and variable in-motion pitch fan blades shall be adjusted initially by the manufacturer at pitch required to provide design output. Check and readjust if necessary to obtain design cfm. Pitch angle adjustment shall not exceed recommended maximum to prevent "stall."
7. When air balancing is done and manual dampers are set, all test holes shall be plugged and all manual damper positions shall be marked. The following information shall be recorded in the final report: Design inlet or outlet size, actual inlet or outlet size, and design cfm (velocity) through the orifice for each terminal in the system.

3.3 FIELD QUALITY CONTROL

- A. Upon request of the 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