SECTION 15000
GENERAL MECHANICAL PROVISIONS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes general provisions applicable to Division 15 Mechanical.

REFERENCES

A. Manual Part 3, Project Planning and Design Guidelines and Standards

B. Drawing and General Provisions of Contract, including General and Supplementary
General Conditions and Division 1 section apply to work in Division 15.

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. UC Denver Philosophy:

1. The UC Denver is extremely conscious of maintenance costs. Give special
attention in the design process to provide for sufficient and safe access space for
maintenance of mechanical systems. Clearly indicate locations of ceiling and
wall access panels and other necessary access space. Provide easy access to
rooftop equipment.

2. Exterior mechanical installations must not only be designed for proper
functions, but must be considered in the aesthetics of building design. Locate
large and unsightly installations hidden from public view and enclose
appropriately.

3. Show mechanical installations on drawing elevations of structures including,
installations projecting above parapet walls.

4. Design systems to provide flexibility in the future. Provide systems that are
easily adaptable to new layouts or changes in use. Layout mechanical rooms
with space for future needs, expansion, or new equipment at the time the basic design is being formulated.

5. UC Denver is committed to sustainable, low energy use and environmentally
friendly buildings. Apply LEED and High Performance Buildings into design
and construction.

B. Utilities:

1. In general, utilities will be included in Division 2 and work in this Division will
only extend to 5 feet outside of Building or Structure excavation perimeter.

2. Specify the following where exceptions occur and Building Services extensions
and connections are made to public utilities:

a) Connection charges, membership fees, system development charges,
and the like, that in principle allow the right to obtain a services from a
Utility Company will be arranged and paid for by the UC Denver.
b) In the event that the serving Utility Company installs their own taps, service, meters, etc., all costs imposed by this action shall be the responsibility of the Contractor.

3. The Campus is a continuously operating facility. Construction of new and maintenance of existing utility systems, equipment and distribution requires capability of isolation of equipment, systems, and branches of the distribution system. It is therefore imperative that the design and installation of new and modified utility systems include sufficient isolation capability. All work involving the central utility systems (i.e., steam, natural gas, condensate, chilled water, hot water, domestic water, medical gases, and/or vacuum systems), whether upgrade of the system or tie-in to the central system must include provisions for system isolation. Location of isolation devices shall comply with the directives in Section 01040. An isolation plan shall be submitted to the UC Denver Project Manager as part of the Schematic Design and Construction Document phases of the project. The UC Denver Project Manager will be responsible for approval of the plan and coordination with the Design Team.

4. The UC Denver Project Manager will furnish information regarding the preferred locations of incoming utility services to the building and waste outlets. This will generally be furnished in the form of a site plan and pertinent elevations will be given. Piping in the building must be generally arranged and oriented to conform to these. Layouts should not be started until this information has been furnished.

5. All incoming utilities shall be metered. Meter domestic water per City of Aurora standards and meter chilled water, electricity and steam per UC Denver standards, which are available through the UC Denver Project Manager. Provide for isolation of meter, bypass around meter, and complete shutoff of meter and bypass.

6. All incoming utilities shall be provided with means of isolating the building from the utility distribution system inside the building at the point where the utility enters the building.

7. The UC Denver Project Manager will furnish the locations of all underground utilities prior to demolition and excavation.

C. Energy Conservation:

1. The UC Denver is dedicated to the principle of conserving energy and will scrutinize proposed construction for means of reducing not only initial cost, but also long range operating and maintenance costs. Buildings will be designed making the most efficient use of building materials and energy sources available. Compliance with the standards in ASHRAE Standard 90 is a minimum requirement.

2. Give consideration to building utilization by planning for conservation between summer and winter and for periods of minimum occupancy. Design systems that require 24 hours/day operation separate from those that may require only 8 hours/day operation. Systems serving spaces with special year-round cooling loads e.g., computer rooms, data centers, equipment rooms, shall be designed separate from the building HVAC system.

3. Conservation of energy should be a significant factor in specifying or selecting equipment, system, controls, and sequence of operation. The alternatives shall
be evaluated through life-cycle costing and presented to the UC Denver Project Manager for approval.

D. Air Handling Devices

1. Base calculations on methods and data from the most recent issues of ASHRAE, Fundamentals Handbook.

2. All AHUs and exhaust fans shall be AMCA certified for sound and air performance

3. Design air conditioning systems to conserve energy. Systems shall automatically adjust to actual space load conditions to reduce energy consumption at part loads. Where necessary, fan powered boxes are preferred over fan coil units.

4. Use the following design temperatures for heating and air conditioning systems:
   a. Winter:
      1) Outside air temperature: -10 degree F. outside air temperature. For 100 percent outside air systems use -20 degree F.
      2) Inside air temperature: 72 degree F.
      3) Wind velocity: 15 mph.
   b. Summer:
      1) Outside air temperature: 100 degree F. dry bulb, 59 Degree F. wet bulb for systems with OSA economizers or 100% OSA Systems, otherwise 95/63.
      2) Inside air temperature: 72 degree F dry bulb, 63 degree F wet bulb.
      3) Air cooled condensers and dry coolers: 105 degree F.
      4) Wind velocity: 8 mph.
   c. Discuss special room requirements with UC Denver Project Manager.


6. Pressurization: All specified pressure differentials are with respect to the adjacent corridor.

   | Ante Room (or lab without ante room) | Negative | 0.05 (In. H₂O) |
---|-------------------------------|----------|----------------|
   | Laboratory                   | Negative | 0.1 (In. H₂O) |
   | Office                        | Positive | 0.05 (In. H₂O) |
   | Classroom                     | Positive | 0.05 (In. H₂O) |
Others (specify)

Locate the supply, return, and/or exhaust in a given space so flow of air will be toward the most contaminated area of that space.

7. Do not provide humidity control except when specifically required by the program plan. When humidity control is necessary use plant steam to generate clean steam through a clean steam generator.

8. Use outside air for cooling whenever economical. Where practical design systems with economizer cycles that automatically allow the quantity of outside air supplied to the building to be modulated.

9. Equipment cooling with domestic water is prohibited. Cooling loads should be supplied chilled water from the campus district chilled water system. Requests for exemption shall be made to the UC Denver Project Manager.

10. Unless otherwise specified, isolate all rotating and reciprocating machines so that 90% of the disturbing frequency shall be eliminated.

11. The UC Denver utilizes a central Building Automation System (BAS) for control of HVAC functions. Coordinate HVAC tie-ins with the BAS.

12. Avoid small separate heating and cooling devices such as fan coil units and unit heaters except for energy conservation or to facilitate scheduling of air handlers. Where this equipment is used, it shall be controlled by the BAS.

13. Provide occupied-unoccupied programming of systems to initiate shut down of ventilation, exhaust, fan systems, and pumps wherever possible.

14. Use variable air volume supply and exhaust to compensate for diversities in loads and reduce equipment sizes.

15. Water-cooled or evaporative condensers are acceptable depending upon job requirements. Water-type cooling towers are preferred to conserve energy and should be considered on systems 80 tons and larger. On units below 80 tons, an economic evaluation, including cost of maintenance should be completed to determine whether air cooled or water cooled condensing is more economical. Cooling tower fan motor loads should not exceed 0.06 HP/ton of chiller capacity.

16. Specify electrical by-pass switch, external to the drive at critical locations, with appropriate safeties on variable speed controllers to allow use of the equipment if the variable speed controller fails.

17. Design systems utilizing campus district steam, chilled water, air, and oxygen. Limit the use of small chillers or air-cooled condensers to instances where winter operation of the chilled water systems can be decreased.

18. Hydraulically decouple the building pumped systems from Utility Company and/or campus district systems.

19. Design hydronic systems with two-way valves.
20. Chilled Water Systems: Design chilled water systems with a 14 degree temperature difference. Design buildings with variable flow pumping systems and control valve in the bridal assembly to maintain the design temperature difference.

21. Thermostat Locations: Locate thermostats central to the load and where possible near the door. Mount thermostats 60 inches above finished floor except mount adjustable thermostats in accordance with ADA requirements.

E. Animal Holding Areas Design Conditions:

1. Heat and ventilate animal laboratory and animal holding areas by an independent system and conform to the latest edition of "Guide for Care and Use of Laboratory Animals", No. 85-23, published by National Institute of Health (NIH). A copy of this document is available through the UC Denver Project Manager.

2. Additional guidelines and design criteria for animal holding areas may be applicable. The UC Denver Project Manager shall coordinate with the Director of The Animal Resource Center for additional guidelines.

3. Size strainers on floor drains to match the size of sewage material from the animal facilities. The UC Denver Project Manager shall coordinate with animal facility personnel.

F. Equipment Rooms:

1. Separate mechanical equipment rooms from electrical equipment rooms. Limit access to these rooms to authorized maintenance personnel only. House equipment requiring access by building or laboratory personnel separately.

2. Arrange access to equipment rooms so entry will not disturb the occupants or normal functions of the building. Outside access doors are preferable. Coordinate door sizes with the largest equipment size. Provide adequate heights for walking and moving equipment into and out of room.

3. Comply with ASHRAE standards and State of Colorado regulations for design and construction of mechanical refrigeration systems and related monitoring, ventilation, and storage of refrigerants.

4. Arrange and locate equipment rooms so that heat and sound will not be transmitted to other parts of the building. Insulation and ventilation are required where applicable per standard requirements. Where applicable size service elevators for equipment removal from basements and penthouses.

5. Locate equipment having parts which must be removed for maintenance (filter, coils, fan shafts, tube bundles, etc.) so that removal may be accomplished with adequate access and without interference with other functions of the building.

6. Surround the room with a 6 inch curb, a 2 inch cant, and waterproof the floor. Provide floor drains and slope floor to drains.

7. Provide high water detection alarms in all mechanical and equipment rooms at lowest point of floor. Provide a 3/4 inch conduit between high water alarm and the specified alarm panel for remote alarm.
8. Where possible lifting eyes should be permanently placed to aid in lifting and removal of mechanical equipment weighing over 100 pounds. Lifting eyes shall not be blocked by any device.

G. Pipe and Duct Spaces in Chases:
   1. Provide excess horizontal and vertical area in duct chases and pipe runs for future use where possible 25%, office buildings should have 10% excess.
   2. Provide full size doors for access at each floor of chase with steel floor grating for service and maintenance. Provide additional reduced size access doors where full size doors will not work to maintain and service devices and/or components within the duct.

H. Pipe and Duct Penetrations:
   1. Specify and detail the manner in which pipes pass through roofs, walls, floors, and ceilings. Fire ratings must be maintained for all penetrations. The Contractor responsible for cutting or drilling holes and flashing, sealing, or otherwise furnishing them must be clearly designated in the project documents.
   2. Design pipe, and duct penetrations so that minimum opening remains after installation. Seal openings to prevent passage of rodents, birds, bugs, fire and smoke. Materials used shall be sufficient to maintain fire rating of the wall, floor, ceiling and/or roofs.
   3. Provide for continuous insulation for pipes and ducts passing through openings.
   4. Provide tubing or pipe (not sheet metal) sleeves for all utility services passing through structural walls and slabs. All sleeves passing through slab floors shall project a minimum of 1 inch above the slab and be sealed water tight to the slab.
   5. Provide toe boards and handrails when floor grating is more than 4 feet above the walking surface below.

I. Access/Accessibility:
   1. Any device, equipment and/or component having a moving part or that requires maintenance and/or service shall be easily accessible. If it is located above solid ceiling, in a chase or other concealed areas, an access door shall be provided so that parts can be exchanged and work be done as required.
   2. Design and install utility distribution systems (i.e., conduit, piping, ductwork, etc.) in a layered configuration in the areas of renovation or new construction. Take into account the access to devices, equipment, and/or components.
   3. Locate access to equipment and valves outside critical areas, clean rooms, and red zones. Obtain a list of specific areas from the UC Denver Project Manager.
   4. Locate systems to provide access to devices and components that require access or maintenance. Design system hierarchy above ceilings as follows:
      a. Plumbing waste, vent piping and roof drain mains and leaders.
      b. Cable trays
c. Supply, return, and exhaust ductwork

d. Fire sprinkler mains and leaders.

e. Electrical conduit and duct banks.

f. Domestic hot and cold water, medical gas piping

g. Fire sprinkler branch piping and sprinkler run-outs.

5. Submit a system layering plan including electrical components to the UC Denver Project Manager for review and approval as part of the Schematic design phase of each project.

J. Acoustical Criteria:

1. Design systems to provide noise levels from equipment and ductwork not to exceed, ASHRAE NC-35 in class room, 40-45 in laboratories in all 8 octave bands.

2. Exceptions:
   a. Spaces within 15 foot radius from supply and return ducts from shafts: NC-40.
   b. Lobbies, Toilets, Commercial Areas: NC-45 – 50
   c. Kitchens: NC-45 to 50.
   d. Mechanical Rooms: NC-50 to 60.

K. Temporary Facilities:

1. Do not use permanent building equipment without written permission from the UC Denver Project Manager. If equipment is used for temporary heating or cooling, maintain equipment per manufacturer’s instructions and protect with filters, strainers, controls, reliefs, etc. Do not start the guarantee period until the equipment is turned over to the UC Denver for use.

L. Painting:

1. All piping, conduit and equipment in unfinished areas shall be painted as required for preservation and identification.

2. All exposed work in finished areas shall be painted for appearance as directed by the Architect.

3. Painters will cover or mask off equipment tags, nameplates, etc., before painting and then remove masking in such a way that it does not destroy the information on the tag or nameplate.

M. Process and Control Air:

1. Air supply for control of HVAC devices having electric or electronic components shall be dried through a refrigeration air dryer or desiccant dryer.
1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submittals shall be made in accordance with Section 01300 and as required by various Section of Division 15 the following provisions:

1. Submittals will be reviewed by the Engineer to determine that the materials, equipment, and installation methods are in accordance with the project design concepts. The Contractor shall be responsible for space requirements, configurations, performance, bases, supports, structural members and openings in structure, and other apparatus that may be affected by the material, equipment, or installation.

2. Include current, published catalog and specification sheets pertaining to proposed material and equipment.

3. Identify each item with identification symbols identical to those used on the drawings and/or in the specifications.

B. Operation and Maintenance Manual: Furnish operation and maintenance manuals for equipment and systems installed under Division 15 of the standards in accordance with Section 01730 and the following.

1. Submit one copy of the manual to the Engineer for preliminary review prior to production of the final manuals.

2. Following review of the preliminary manual by the Engineer prepare and submit final copies of the manual complying with the Engineer's comments noted on the preliminary manual.

3. Include the following information:

   a. Alphabetical list of all system components with the name, address, and 24-hour phone number of the company responsible for servicing each item during the first year of operation.

   b. Manufacturer's data that are applicable to the installed equipment such as the following:

      1) Shop drawings (reviewed and accepted)
      2) Product and performance data (reviewed and accepted)
      3) Installation instructions
      4) Lubrication instructions
      5) Wiring and temperature control diagrams (reviewed and accepted Shop Drawings)
      6) Parts lists
      7) Copies of warranties
8) A compilation of the manufacturer’s recommended maintenance schedule and routines for each piece of equipment

c. A simplified description of the operation of each system including the function of each piece of equipment within the system. Support descriptions with a schematic flow diagram when applicable.

d. Emergency procedures for equipment operation during a fire or following the failure of major equipment. Describe procedures for normal starting, operating, shutdown, and long-term shutdown.

e. Maintenance instruction including valves, valve tag, and other identified equipment lists, proper lubricants and lubricating instruction for each piece of equipment, and necessary cleaning, replacing, and adjusting schedules.

f. Assembly, installation, alignment and adjustment instructions.

g. System balancing report.

h. Temperature controls, cut sheets and record drawings.

i. Commissioning checklists and certification.

C. Record Documents: Furnish record documents for equipment and systems under Division 15 of the Standards in accordance with Section 01720 and the following:

1. Mark drawing prints to indicate revisions to piping and ductwork, size and location both exterior and interior; including locations of coils, dampers, and other control devices, filters, boxes, and similar units requiring periodic maintenance or repair; actual equipment locations, dimensioned from column lines; actual inverts and locations of underground piping; concealed equipment, dimensioned to column lines; mains and branches of piping systems, with valves and control devices located and numbered, concealed unions located. Note changes of ductwork or piping on the drawings if it has been relocated more than 1 foot from where shown on the drawings.

2. List all equipment parameters on the drawings in schedules whenever possible. Include room number where equipment is located.

3. At the completion of the project, mark all valve tag numbers on the drawings and turn these drawings over to the UC Denver Project Manager.


D. Spare Parts: Listed in individual sections.

1.6 QUALITY ASSURANCE

A. Installer Qualification:

1. Workmanship shall conform to the highest industry standard for each specific type of work.

2. Perform work in accordance with standard commercial practices.
B. Comply with Part 3 of this manual, state and federal codes, rules and regulations. As a minimum requirement, codes, rules and regulations take precedence over the drawings and specifications. Where the requirements of the drawings and specifications exceed those of applicable codes, rules and regulations, the drawings and specifications shall govern.

C. Chemical and physical properties, design, and performance characteristics of all materials and equipment, and methods of construction shall be in accordance with the following applicable codes, regulations and standards. Current editions in effect 30 days prior to receipt of bids will apply.

Air Conditioning and Refrigeration Institute (ARI)
Air Movement and Control Association, Inc. (AMCA)
American Gas Association (AGA)
American National Standards Institute (ANSI)
(ASHRAE) American Society of Heating, Refrigerating and Air Conditioning Engineers
American Society of Mechanical Engineers (ASME)
American Standard Code for Pressure Piping (ASCPP)
American Society for Testing and Materials (ASTM)
American Water Works Association (AWWA)
Compressed Gas Association (CGA)
Environmental Protection Agency (EPA)

1.7 DELIVERY, STORAGE AND HANDLING

A. All mechanical equipment and materials shall be delivered, stored and handled in accordance with manufacturers instructions and the requirements of Section 01105.

WARRANTY

A. All mechanical equipment, materials and workmanship warranties shall be provided in accordance with the requirements of Section 01740 and the following:

1. Warranty all equipment, materials, workmanship, and proper operation of equipment and apparatus for a period of one year from date of final acceptance unless indicated otherwise in the individual sections. Extended warranty periods are identified in individual sections.

2. Compile and assemble the warranties specified in the individual sections into the operating and maintenance manuals.

3. Provide complete warranty information for each item to include date or beginning of warranty or bond; duration of warranty or bond; and names, addresses, and telephone numbers and procedures for filing a claim and obtaining warranty services.
PART 2 - PRODUCTS

2.1 MANUFACTURERS
   A. As specified in individual sections.

2.2 MATERIALS, GENERAL
   A. Products:
      1. Provide material and equipment new and free from defects.
      2. Install all material and equipment in accordance with the manufacturer's current published recommendations.
      3. Certain materials and equipment are specified by manufacturer and model or catalog number. Such specified items are the basis of design and establish a degree of quality, performance, and physical configuration.
      4. Equipment and materials manufactured by any one of the manufacturers listed on the drawings or in the specifications will be acceptable.
      5. Where no manufacturer is listed, provide a standard product meeting the requirements of the drawings and specifications, and manufactured by a firm regularly engaged in the manufacture of such products. All equipment, when possible, shall be:
         a. Manufactured and purchased in Colorado
         b. Manufactured and purchased in the USA.
      6. Requests prior to bid for approval of equipment or material not specified shall be done in accordance with the requirements of Section 01630.

PART 1 - EXECUTION

3.1 EXAMINATION
   K. Visit site and ascertain existing conditions prior to submitting bid. Include in bid all considerations necessary to accomplish the work under the existing conditions.
   L. Additional charges will not be authorized due to the contractor's failure to become familiar with the existing conditions.

3.2 INSTALLATION, GENERAL
   K. Permits and Inspections:
      1. Secure all required permits, UC Denver will pay for permit and inspection costs.
      2. Pay all applicable royalties, inspection fees, taxes, and licenses.
   L. Responsibility of Contractor:
1. The contractor is responsible for the complete installation and satisfactory operation of all work in accordance with requirements of the drawings and specifications.

2. The component parts of the installation shall function together as workable systems. Each system shall be left with all parts adjusted and in proper working order.

M. Coordination:

1. Coordinate project in accordance with Section 01040.

N. Scaffolding, Rigging, and Hoisting:

1. Provide all scaffolding, rigging, and hoisting necessary to safely accomplish the work following OSHA requirements.
   a. Remove from premises when no longer needed.

2. Provide necessary services to deliver, erect, place, and install all equipment and apparatus furnished.

O. Damaged Surfaces:

1. At completion of the work, all mechanical material and equipment furnished shall be inspected for damage.
   a. Repair damaged factory finishes to match adjacent, undamaged areas.
   b. Replace deformed metal cabinets, jackets, and enclosures with new items. Finish shall match similar undamaged items.

3.3 TESTING, CLEANING AND CERTIFICATION

A. Cleanup:

1. At completion of the work, check and thoroughly clean all equipment.
   Clean coils and plenums.
   Clean under, in, and around equipment.
   c. Clean exposed surfaces of piping, ducts, and hangers.
   d. Clean equipment cabinets and enclosures.
   e. Provide and install new filters for equipment.

B. Project Closeout:

1. Verify that all work has been completed prior to requesting final walkthrough, including Contractor’s preliminary review of mechanical systems start-up and acceptance checklists.

3.4 COMMISSIONING (DEMONSTRATION)
A. Training and Demonstration: Schedule instructional meetings for UC Denver’s Facilities Operations maintenance personnel on the proper operation and maintenance of mechanical systems. Provide the project manager a minimum of 5 days notice prior to any training, demonstration, or testing.

3.5 SCHEDULES

END OF SECTION
SECTION 15100
VALVES

PART 1 - GENERAL

1.1 SUMMARY
A. This section provides standards for valves used for isolation and balancing for hydronic, steam, and condensate systems.

1.2 REFERENCES
A. Section 15000 - General Mechanical Provisions
B. Section 15190 - Mechanical Identification

1.3 SYSTEM PERFORMANCE
A. General Information:
1. Show all valves on the drawings. Do not rely on a general note in the specifications or on the plans.
2. For applications up to 2”, specify full port ball valves. Butterfly valves are acceptable if pressure and leak risks are low.
3. Valves adjacent to equipment should have unions/flanges provided to allow for removal with minimal labor effort.

B. Isolation Valves:
1. Provide valves for isolating sections of piping systems. It should be possible to isolate; the entire building, separate floors, separate wings, toilet rooms, machinery rooms and other natural subdivisions of the buildings.
2. Provide valves for isolating equipment and fixtures. Place valves on both sides of backflow and check valves to permit inspection.
3. Do not use isolation valves for balancing and do not use balancing valves for isolation.
4. Isolation valves can be ball type (up to 2 inch), gate, or butterfly as deemed appropriate by designer for the type of service, pressure, and fluid.
5. Ball valves are acceptable as isolation valves for most hot water heating systems, domestic water systems, distilled or ionized water systems, blow-down valves, drain valves and other low hazard, low pressure systems.

6. Gate valves are required as isolation valves for steam supply and condensate return systems, chilled water supply, and condenser water systems and other high hazard, high pressure systems. Gate Valves installed on steam systems must have stainless steel gates and seats.

7. Butterfly valves are acceptable alternates as isolation valves for chilled water systems, and other low hazard, low pressure, systems where the entire system can be shut down if necessary to accommodate leaky isolation valves.
8. Valve Identifications: Identify all valves as specified in Section 15190.

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submit in accordance with Section 15000, Operation and Maintenance Manual:

1. Furnish valve schedule for each piping system, typewritten on 8-1/2-inch x 11-inch bond paper. In tabular format include valve identification number, piping system, system abbreviation (as shown on tag), location of valve (room number or space) function, normal position, and area served. Mark valves which are intended for emergency shut-off and similar special uses by special flags in margin of schedule.

1.6 QUALITY ASSURANCE

A. No additional requirements.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Hydronic Ball Valves: Stockham, Apollo, Crane, Jamesbury, Jenkins, Nibco, or Lunkenheimer

2. Hydronic Gate Valves (less than 2 inches): Stockham, Crane, Grinnell Corp, Nibco, or Jenkins

3. Hydronic Gate Valves (2 inches or larger): Crane, Jenkins, Lunkenheimer, Nibco, or Walworth

4. Hydronic Butterfly Valves: Dezurik, Crane, Jenkins, Stockham, Keystone, Centerline, or Nibco

5. Steam and Condensate Gate and Globe Valves: Stockham, Crane, Jenkins, Lunkenheimer or Walworth

6. Steam and Condensate Butterfly Valves: Jamesbury, Vanessa, or Keystone


8. Circuit Setters: FDI, Armstrong, Bell & Gossett, Tour Anderson


2.2 MATERIALS, GENERAL
A. Ball Valves:
   1. Blowout proof stems, full port type, brass or bronze body, chrome plated or stainless steel ball, Teflon seals and seat, vinyl-covered handle with memory stop. Pressure rating 150 psi SWP and 600 psi WOG.
   2. Ball valves shall be 2 inch or less. Larger pipe sizes shall require gate or butterfly valves.
B. Gate Valves: Solid wedge, rising stem type, except where clearance is a problem.
C. Globe Valves: Renewable disc, rising stem. Install where throttling may be necessary.
D. Butterfly Valves: Cast iron body, lug style, 150 psi pressure rating, aluminum bronze disc, 416 stainless steel stem, EPDM seat. Provide with cap screws instead of stud bolts to permit valve to remain in place with one flange removed.
E. Balancing or Throttling Valves:
   1. Use eccentric plug, globe or angle valves for balancing. Do not use gate valves.
   2. Butterfly valves equipped with memory stops may be used as balancing valves.
F. Safety Relief Valves: Brass or bronze body, designed, rated, and stamped in accordance with ASME. Steel and cast iron body valves may be used for steam service.
G. Gas Valves: Lubricated plug or AGA-approved ball valves.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. General Duty Valve Applications: The drawings indicate valve types to be used. Where specific valve types are not indicated, the following requirements apply:
   1. Shutoff duty: Use valve type as indicated on drawings and in this section.
   2. Throttling duty: Use globe (steam only) and plug (heating and chilled water).
B. Install shutoff duty valves at each branch connection to supply mains, at supply mains, at supply connection to each piece of equipment and elsewhere as indicated.
C. Install throttling duty valves at each branch connection to return mains, at return connections to each piece of equipment, elsewhere as indicated.
D. Install plug valves on the outlet of each heating or cooling element and elsewhere as required to facilitate system balancing.
E. Install drain valves at low points in mains, risers, branch lines, and elsewhere as required for system drainage. Provide 1/2-inch ball valves with chain end cap at all tops of risers to be used for venting.
F. Install check valves on each pump discharge and elsewhere as required to control flow direction.
G. Install pump discharge valves with stem in upward position; allow clearance above stem for check mechanism removal.

H. Install safety relief valves on hot water generators, and elsewhere as required by ASME Boiler and Pressure Vessel Code. Pipe discharge to floor without valves. Comply with ASME Boiler and Pressure Vessel Code Section VIII, Division 1 for installation requirements.

I. Install pressure reducing valves on hot water generators, and elsewhere as required to regulate system pressure.

J. Install valves with stems upright or 45 degree maximum, never inverted. When and if steam valves have to be mounted inverted they shall have a valve bonnet drain.

K. Mount all valves so operation is possible without interference from pipes, pipe hangers, walls, etc.

L. Valves (4 inches and larger) located more than 7 feet above floor in mechanical equipment rooms shall be chain operated.

M. Install valves easily accessible. Provide access panels when it becomes necessary to install valves above gypsum ceilings.

3.3 TESTING, CLEANING AND CERTIFICATION

3.4 COMMISSIONING (DEMONSTRATION)

3.5 SCHEDULES

END OF SECTION
SECTION 15110
PIPING

PART 1 - GENERAL

1.1 SUMMARY
A. This section provides standards for piping materials, basic piping installation and general testing instructions.

1.2 REFERENCES
A. Section 15000 - General Provisions
B. Section 15100 - Valves
C. Section 15120 - Piping Specialties
D. Section 15130 - Gauges
E. Section 15190 - Mechanical Identification
F. Section 15250 - Insulation
G. Section 15300 - Fire Protection
H. Section 15400 - Plumbing Systems
I. Section 15505 - Hydronic Systems

1.3 SYSTEM PERFORMANCE
A. Pipe Identifications: All piping shall be identified as to contents and direction of flow. Method and terminology shall be as specified in Section 15190.
B. Pipe Connections: Provide required straight sections for flow measurement stations.
C. Expansion Compensation:
   1. Piping and joints shall be designed to eliminate damage by expansion and contraction.
   2. Mechanical expansion devices are discouraged. Expansion loops are preferred. Where mechanical expansion devices are necessary, bellows type shall be specified. Other types with mechanical seals are not permitted.
   3. Devices shall be readily accessible for maintenance and repair per the manufacture’s recommendations.
D. Natural Gas Piping Systems:
   1. Provide shut-off cocks on all branch lines, and lab benches, and make cocks easily accessible for service and operation. Provide drip legs at all equipment connections. Use pipe dope on threaded pipe fittings, Teflon tape is prohibited.
E. Sanitary Sewer Piping Systems:
   1. Provide manholes at major junctions of exterior sewer lines, and provide cleanouts on all other junctions.
   2. Locate interior clean-out caps and plugs such that they can be removed without damaging the surfaces in which they are installed.
3. Do not discharge chemical waste, oils, antifreeze, and other wastes into the sanitary sewer without written approval of the UC Denver Project Manager. Coordinate the requirement of acid neutralizing systems and sand and oil interceptors with the UC Denver Project Manager.

4. Do not discharge domestic water used for cooling into the sanitary sewer except for emergency back up for critical systems and vacuum systems. Variance from this policy must be approved by the UC Denver CBO, through the UC Denver Project Manager.

F. Storm Drain Piping Systems:

1. At system low points where gravity drain is not possible provide duplex sump pump systems with high water alarms connected to Building Automation System. Provide gravity drainage piping downstream of pumps sized to accommodate the discharge of both pumps running at the same time and any additional load produced from normal gravity drainage.

2. Provide sump pump controls with a manual selectable, alternating relay to switch lead-lag operation.

3. Do not discharge sanitary waste into the storm sewer system. Do not discharge storm drain water into the sanitary waste system.

4. Provide all sump pumps with standby or emergency power.

G. Chemical and Acid Waste Systems:

1. Discuss the treatment and handling of chemical and acid wastes with the UC Denver Project Manager with HSD and operations. Typically, most wastes at the UC Denver are collected in containers and are disposed of through UC Denver HSC and the need for acid waste pipe is the exception. Acid wastes may be generated in deionized water systems and in these cases a neutralization system must be approved by the UC Denver Project Manager through HSD and Operations.

2. Where chemical and acid waste is required by specific circumstance and it is virtually inaccessible (i.e., concrete slab) polypropylene (acid waste) pipe should be used in these locations.

3. Lab waste lines including the dirty arm and all horizontal runs (to the vertical riser) shall be constructed from polypropylene pipe with mechanical joints.

H. Potable Water Piping System:

1. Lead pipe or lead solder is prohibited for all potable water piping systems.

2. Make domestic water piping joints with lead free solder.

3. Size domestic water piping to maintain maximum velocities of 8 feet per second for cold water and 5 feet per second on hot water and hot water circulation piping.

4. Provide main shutoff valve for potable water inside the building.
1.4 DEFINITIONS

1.5 SUBMITTALS
A. Submittals shall be made for the following in accordance with Section 15000.
   - Welding Certifications
   - Brazing Certifications

1.6 QUALITY ASSURANCE
A. Welders Qualifications: All welders shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications
B. Welding procedures and testing shall comply with the latest revisions of the applicable sections for B31, of the ANSI/ASME standard codes for pressure piping, noted as “B31.9 Building Services Piping”.
C. Before any welding is performed, the Contractor shall submit to the UC Denver Project Manager, a copy of the Manufacturer’s Record of Welder or Welding Operator Qualification Tests and his Welding Procedure Specifications together with the procedure Qualification Record as required by Section IX of the ASME Boiler and Pressure Vessel Code.
D. The types and extent of non-destructive examinations required for pipe welds are as shown in Table 136.4 of the ASME Code for Pressure Piping, ANSI/ASME B31.1 - Power Piping. If requirements for non-destructive examination are to be other than that stated above, the degree of examination, and basis for rejection shall be a matter of prior written agreement between the fabricator, of contractor and the purchaser.
E. Each manufacturer or contractor shall be responsible for the quality of welding done by his organization and shall repair or replace any work not in accordance with these standards.
G. Welding: All welding work shall be performed by welders certified to ASME or AWS standards within the last year for the type of material and application suited for the job. Contractors shall submit copies of qualification tests of the welders to the Project Manager prior to construction.
H. ASME B31.9 “Building Services Piping” for materials, products and installation. Safety valves and pressure vessels shall bear the appropriate ASME label.
I. Comply with Colorado cross connection control manual.
J. PDI Compliance: Comply with applicable PDI standards pertaining to products and installation of soil and waste systems

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY
PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Manufacturer’s Qualifications: Firms regularly engaged in manufacture of pipes and pipe fittings of types and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years

2. Grooved Piping:
   a. ITT Grinnell Corp.
   b. Victaulic Co. of America

3. Buried Piping:
   a. Perma – Piping/Ricwil
   b. Thermal Pipe System

4. Piping Connectors
   a. Fernco, Inc.
   b. Or equal

5. Pipe Thread Sealant
   a. The Rectorseal Corp.
   b. Or equal

6. Drainage Piping Specialties, including backwater valves, expansion joints, drains, cleanouts, flashing flange and vent flashing sleeve.
   a. JR Smith
   b. Zurn Industries
   c. Wade
   d. Josam

2.2 MATERIALS, GENERAL

A. Piping Materials: Provide pipe and tube of type, pressure and temperature ratings, capacities, joint type, grade, size and weight (wall thickness or Class) indicated for each service. Where type, grade or class in not indicated, provide proper selections determined by Installer for installation requirements, and comply with governing regulations and industry standards.
B. Pipe/Tube Fittings: Provide factory-fabricated fittings of type, materials, grade, class and pressure rating indicated for each service and pipe size. Provide sizes and types matching pipe, tube, and valve or equipment connection in each case. Where not otherwise indicated, comply with governing regulations and industry standards for selections, and with pipe manufacturer’s recommendations where applicable.

C. Steel Pipes and Pipe Fittings:

1. Black Steel Pipe: ASTM A53, Grade B, Type E, electric resistance welded.
2. Galvanized Steel Pipe: ASTM A53, Grade B.
3. Seamless Steel Pipe: ASTM A53, Grade B, type S or A106 high temperature.
4. Stainless Steel Pipe: ASTM A312; Grade TP 304 (high temperature and corrosive service, 1/8-inch through 30-inch).
6. Cement-Mortar Protective Lining and Coating for Steel Pipe: AWWA.
7. Steel Water Pipe: AWWA for pipe 6-inch and larger.
8. Cast-Iron Flanged Fittings: ANSI B16.1, including bolting (class 125 and 250)
9. Cast-Iron Threaded Fittings: ANSI B16.4; plain or galvanized as indicated (Class 125 and 250)
10. Malleable-Iron Threaded Fittings: ANSI B16.3; plain or galvanized as indicated (Class 125 and 300)
11. Malleable-Iron Threaded Unions: ANSI B16.30, Class 150, 250 or 300; selected by Installer for proper piping fabrication and service requirements, including style, end connections, and metal-to-metal seats (iron, bronze or brass); plain or galvanized as indicated (Class 150, 250 and 300).
13. Steel Flanges/Fittings: ANSI B16.5, ASTM A234 (Fire Protection) including bolting and gasketing of the following material group, end connection and facing, except as otherwise indicated.
14. Corrosion-Resistant Cast Flanges/Fittings: MSS SP-51, including bolting and gasketing (threaded where pressure is not critical).
15. Forged-steel Socket-Welding and Threaded Fittings: ANSI B16.11, except MSS SP-79 for threaded reducer inserts; rated to match schedule of connected pipe up to 4 inch pipe size).
18. Forged Branch-Connection Fittings: Except as otherwise indicated, provide type as determined by Installer to comply with installation requirements.

19. Pipe Nipples: Fabricated from same pipe as used for connected pipe; except do not use less that Schedule 80 pipe where length remaining unthreaded is less that 1-1/2 inch and where pipe size is less than 1-1/2 inch, and do not thread nipples full length (no close nipples).

D. Copper Tube and Fittings:

1. Copper Tube: ASTM B 88; Type K or L as indicated for each service; hard-drawn, except as otherwise indicated.

2. DWV Copper Tube: ASTM B306

3. ACR Copper Tube: ASTM B280.


6. Cast-Copper Solder-Join Drainage Fittings: ANSI B16.23 (drainage and vent with DWV or tube).


8. Cast-Copper Flared Tube Fittings: ANSI B16.26

9. Bronze Pipe Flanges/Fittings: ANSI B16.24 (Class 150 and 300)

10. Copper-Tube Unions: Provide standard products recommended by manufacturer for use in service indicated.

E. Brass Pipe and Fittings:

1. Red Brass Pipe: ASTM B43 (boiler feed pipe, 1/8 inch through 12 inch, regular or extra strong weight)

2. Cast-Bronze Threaded Fittings: ANSI B16.15, Class 125 or 250.


F. Cast-Iron Soil Pipes and Pipe Fittings:


5. Neoprene Compression Gaskets: ASTM C564
G. Grooved Piping:

1. Coupling Housings: Malleable iron conforming to ASTM A47.

2. Coupling Housings: Ductile iron conforming to ASTM A536.

3. Coupling Housings Description: Grooved mechanical type, which engages grooved or shouldered pipe ends, encasing an elastomeric gasket which bridges pipe ends to create seal. Cast in two or more parts, secure together during assembly with nuts and bolts. Permit degree or contraction and expansions specified in manufacturer’s latest published literature.

4. Gaskets: Mechanical grooved coupling design, pressure responsive so that internal pressure serves to increase the seal’s tightness, constructed of elastomers having properties as designated by ASTM D2000.
   a. Water Services: EDPM Grade E, with green color-code identification.
   b. Other Services: As recommended by Manufacturer.


6. Branch Stub-ins: Upper housing with fill locating collar for rigid positioning engaging machine-cut hole in pipe, encasing elastomeric gasket conforming to pipe outside diameter around hole, and lower housing with positioning lugs, secured together during assembly with nuts and bolts.

7. Fittings: Grooved or shouldered end design to accept grooved mechanical couplings.
   a. Malleable Iron: ASTM A47
   b. Ductile Iron: ASTM A536
   c. Fabricated Steel: ASTM A53, carbon steel, Schedule 40, Type F, for 3/4 inch to 4 inch; Type E or S, Grade B for 5 inch to 20 inch.
   d. Steel: ASTM A234
   e. Wrought Copper and Bronze: ASTM B75 tube and ASTM B584 bronze castings.

8. Flanges: Conform to Class 125 cast iron and Class 150 steel bolt holes alignment.
9. Grooves: Conform to the following:
   b. Lightweight Steel: Roll grooved.

10. Buried Piping:
   a. Pipe Materials: Pipe and tube of type, pressure and temperature ratings, capacities, joint type, grade, size and weight indicated for each service.
   b. Pipe/Tube Fittings: Factory-fabricated fittings of type, materials, grade, class, and pressure rating indicated for each service and pipe size.
   c. Underground Steam Pipe: Pre-insulated piping system composed of Schedule 40 ASTM A53 or A106 Grade B carbon steel pipe, calcium silicate or mineral fiber insulation, FRP casing pipe.
   d. Underground Condensate Return Pipe: Pre-insulated piping composed of a filament wound epoxy resin FRP pipe conforming to Mil P28584 or steel pipe conforming to ASTM A53, Grade B, Schedule 80; polyurethane foam insulation; heavy duty PVC casing, minimum 150 mils thick. FRP fittings of compatible material adhesive bonded. Fittings for steel shall be welded steel.

H. Miscellaneous Piping Materials/Products:

1. Welding Materials: Except as otherwise indicated, provide welding materials as determined by Installer to comply with installation requirements.

2. Soldering Materials: Except as otherwise indicated, provide silver soldering materials.
   a) 95-5 Tin Antimony: ASTM B32, Grade 95TA.
   b) Silver-Tin-Copper Alloy: ASTM B32 (NSF)
   c) Approved Lead-free solder

3. Brazing Materials: Except as otherwise indicated, provide brazing materials to comply with installation requirements.
   a) Comply with AWS A5.8, Section II, ASME Boiler and Pressure Vessel Code for brazing filler metal materials.
      1) Copper phosphorus – Bcup
      2) Silver - BAg minimum 4% Silver content

4. Gaskets for Flanged Joints: ANSI B16.21; full-faced for cast-iron flanges; raised-face for steel flanges, unless otherwise indicated.
5. Piping Connectors for Dissimilar Non-Pressure Pipe: Elastomeric annular ring insert, or elastomeric flexible coupling secured at each end with stainless steel clamps, sized for exact fit to pipe ends and subject to approval by plumbing code. Not to be used on closed heating systems.

6. Pipe Thread Sealant Material: Except as otherwise indicated, provide all pipe threads with the sealant material as recommended by the manufacturer for the service.

I. Piping Systems:

1. Domestic Hot and Cold Water:
   a) Above Grade, Inside Buildings: Type L, hard drawn copper tube with wrought copper or bronze fittings, lead free solder joints or Schedule 40, galvanized steel pipe A53 grade B, ERW w/galvanized Grooved end fittings.
   
   b) Below Grade, Inside and Outside Buildings: Underground outside fittings shall comply with City of Aurora standards.
   
   1) 2 inches and Smaller: Type K, soft copper or Type K annealed copper tube with wrought copper fittings, silver brazed solder joints.
   
   2) 2.5 inches and Larger: Class 250, tar coated outside, cement lined, cast iron or ductile iron with mechanical or push on joints.

2. Equipment drain and overflows: Type “M” or “DWV” copper.

3. Sanitary Sewer and Vents:
   a. Above Grade: Service weight cast iron, no-hub type with neoprene gaskets; service weight cast iron, hub and spigot type with neoprene gaskets; or DWV copper with wrought copper or cast brass fittings.
   
   b. Below Grade: Sizes 2 inches to 20 inches, service weight cast iron, hub and spigot type with neoprene compression gaskets; or sizes 12 inches and larger ductile cast iron with neoprene gasket joints.
   
   c. Cleanout Openings: Two-way type, 1-1/4 inch nominal size minimum and located such that long lines can be entered from both ends. Lubricate plugs at installation.
   
   d. All sump pumps receiving floor drains located in boiler rooms will be non-submersible type. Pumps will be designed to handle hot water because boilers are flushed or emptied at intervals into floor sumps.

4. Storm Drain
   a. Above Grade:
1) Same as sanitary sewer. If no-hub is utilized, provide heavy duty coupling at the lowest two floors.

b. Below Grade: Sizes 2 inch to 20 inch, service weight cast iron, hub and spigot type or sizes 12 inch and larger ductile cast iron with neoprene gasket joints.

c. Roof drains or drains located in outside areaways, not subject to regular foot traffic, shall be of the beehive type to minimize clogging with leaves or other debris.

5. Natural Gas:

a. Within the Building: Schedule 40 black iron pipe, threaded for sizes 2 inches and smaller and welded for 2-1/2 inch and larger. All lines shall be accessible.

b. Flex lines to equipment and fixtures shall be stainless steel with epoxy coating on both sides, UL stamped. Other types are prohibited.

c. Pipe dope shall be Teflon based. Oil based is not permitted. Teflon tape prohibited.

6. Chemical and Acid Waste:

a. Acid resistant, flame retardant, schedule 40 polypropylene pipe and fittings with electrically-induced or mechanical joints.

b. Piping installed in return air plenums shall meet the 25/50 flame spread and smoke development requirements.

PART 3 - EXECUTION

3.3 EXAMINATION

A. Verify all dimensions by field measurements. Verify that all water distribution piping may be installed in accordance with pertinent codes and regulations, and original design, and the referenced standards.

B. Examine rough-in requirements for plumbing fixtures and other equipment having water connections to verify actual locations of piping connections prior to installation.

C. Do not proceed until unsatisfactory conditions have been corrected.

3.4 INSTALLATION, GENERAL

A. General: Install pipe and piped fittings in accordance with recognized industry practices which will achieve permanently leak-proof piping systems, capable of performing each indicated service without piping failure. Install each run with minimum joints and couplings, but with adequate and accessible unions for disassembly and maintenance/replacement of valves and equipment. Reduce sizes (where indicated) by use of reducing fittings. Align piping accurately at connections, within 1/16-inch misalignment tolerance.
1. Comply with ANSI B31 Code for Pressure Piping.

2. Electrical Equipment Spaces: Do not run piping through transformer vaults and other electrical or electronic equipment spaces and enclosures. Only piping serving this type of equipment shall be allowed.

3. Locations and arrangements: Drawings (plans, schematics, and diagrams) indicate the general location and arrangement of piping systems. Locations and arrangements of piping take into consideration pipe sizing and friction loss, expansion, pump sizing and other design considerations. So far as practical, install piping as indicated.

4. Use fittings for all changes in direction and all branch connections.

5. Install piping at right angles or parallel to building walls. Diagonal runs are not permitted, unless expressly indicated.

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. Provide space to permit insulation applications, with 1-inch clearance outside the insulation. Allow sufficient space above removable ceiling panels to allow for panel removal.

8. Locate groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

9. Install drainage piping with a minimum 1/8 inch per foot downward slope in the direction of the drain and a maximum slope of 1/4 inch per foot.

10. Install drains at all low points in mains, risers, and branch lines consisting of a tee fitting, 3/4-inch ball valve, and short 3/4-inch threaded nipple, hose connection, and cap.

11. Install piping free of sags or bends and with ample space between piping to permit proper insulation applications.

12. Fire and Smoke Wall Penetrations: Where pipes pass through fire and smoke rated walls, partitions, ceilings, and floors, maintain the fire and smoke rated integrity. Refer to Division 15, Section 15120 - Piping Specialties, for materials.

13. Exterior Wall Penetrations: Seal pipe penetrations through exterior walls using sleeves and mechanical sleeve seals (See Section 15120). Pipe Sleeves smaller than 6 inch shall be steel; pipe sleeves 6 inch and larger shall be sheet metal.

14. Anchor piping to ensure proper direction of expansion and contraction.

15. Coordinate foundation and all other structural penetrations with the structural engineer.

B. Piping System Joints:

1. General: Provide joints of type indicated in each piping system.
2. Thread pipe in accordance with ANSI B2.1; cut threads full and clean using sharp dies. Ream threaded ends to remove burrs and restore full inside diameter. Apply pipe joint compound, or pipe joint tape (Teflon) where recommended by pipe/fitting manufacturer, on male threads at each joint and tighten joint to leave not more than 3 threads exposed.


4. Solder copper tube-and-fitting joints with solder approved in Part 2.2, K, 3 of this section. Cut tube ends squarely, ream to full inside diameter, and clean outside of tube ends and inside of fittings. Apply solder flux to joint areas of both tubes and fittings. Insert tubes full depth into fitting, and solder in manner that will draw solder full depth and circumference of joint. Wipe excess solder from joint before it hardens.

5. Weld pipe joints in accordance with ASME Code for Pressure Piping, B31. Provide weld-o-let fittings for two pipe sizes less than main pipe size.

6. Weld pipe joints in accordance with recognized industry practice and as follows:
   a. Weld pipe joints only when ambient temperature is above 0 degrees F. (-18 degrees C)
   b. Bevel pipe ends at a 37.5-degree angle where possible, smooth rough cuts, and clean to remove slag, metal particles and dirt.
   c. Use pipe clamps or tack-weld joints with 1-inch long welds; 4 welds for pipe sizes to 10 inch, 8 welds for pipe sizes 12 inch to 20 inch.
   d. Build up welds with stringer-bead pass, followed by hot pass, followed by cover or filler pass. Eliminate valleys at center and edges of each weld. Weld by procedures, which will ensure elimination of unsound or un-fused metal, cracks, oxidation, blow-holes and non-metallic inclusions.
   e. Do not weld-out piping system imperfections by tack-welding procedures; re-fabricate to comply with requirements.

7. Weld pipe joints of steel water pipe in accordance with AWWA C206.

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


C. Pipe Fittings:

1. Place unions at all equipment, regulators, controls, etc., that require removal or replacement. Do not block removal with adjacent equipment or piping. Where necessary for removal of equipment, install unions on both sides of equipment. Unions are not required on flanged devices.
2. Use dielectric **waterway fittings** where dissimilar metals are connected. Isolate building distribution gas piping with dielectric unions from gas main for cathodic protection.

3. All unions shall be ground joints.

4. Make reductions in size with reducing fittings.

5. All screwed nipples from copper fittings shall be red brass.

D. **Pipe Connections:** Install pipe connections to pumps, compressors, etc., with adequate allowance for movement and vibration. Support connections so the equipment does not carry weight.

E. **Expansion Compensation:** Arrange pipes and equipment with due regard for the effects of thermal expansion.

F. **Hangers and Supports:**

1. Maintain uniform grading and pipe slope of piping system. Install supports between piping and building structure to prevent swaying and vibration. Install hangers to provide a minimum 1/2-inch clear space between finished covering and adjacent work. Use threaded rods with two lock nuts.

2. Do not support weight of piping from mechanical equipment, ductwork, pump flanges, coil connections, and related items.

3. Support hanger rods by coach screw rods, angle iron clips, or beam clamps. No drilling of structural members will be permitted without approval. Hanger rods shall be attached to the top of joist beams.

4. Do not bend hanger rods to provide alignment of piping offset from overhead supports.

5. Size hangers on insulated pipe to fit outside diameter of insulation.

6. Provide sway bracing every 40 feet on cast iron.

7. **Hanger Spacing:** Install adjustable hangers and support piping systems without sagging. Install hangers at locations not more than 3 feet from the end of each runout and not over 1 foot from each change in direction or offset and at the following maximum spacing:

<table>
<thead>
<tr>
<th>Pipe Type</th>
<th>Nominal Pipe Size-Inches</th>
<th>Maximum Span-Ft</th>
<th>Minimum Rod-_inches</th>
<th>Hanger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>½ through 1-1/4</td>
<td>7</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1-1/2 through 2</td>
<td>10</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2-1/2 through 3</td>
<td>12</td>
<td>1/2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 through 5</td>
<td>12</td>
<td>5/8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>12</td>
<td>¾</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 through 12</td>
<td>12</td>
<td>7/8</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>3/8 through ¾</td>
<td>5</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 through 1-1/2</td>
<td>6</td>
<td>3/8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 through 2-1/2</td>
<td>8</td>
<td>½</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 and above</td>
<td>10</td>
<td>½</td>
<td></td>
</tr>
</tbody>
</table>
### Piping

<table>
<thead>
<tr>
<th>Pipe Type</th>
<th>Nominal Pipe Size-Inches</th>
<th>Maximum Span-Ft</th>
<th>Minimum Hanger Rod-Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast Iron</td>
<td>2</td>
<td>1 each joint</td>
<td>3/8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1 each joint</td>
<td>½</td>
</tr>
<tr>
<td></td>
<td>4 through 5</td>
<td>1 each joint</td>
<td>5/8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1 each joint</td>
<td>¾</td>
</tr>
<tr>
<td></td>
<td>8 through 12</td>
<td>1 each joint</td>
<td>7/8</td>
</tr>
<tr>
<td>PVC</td>
<td>2 and smaller</td>
<td>4</td>
<td>3/8</td>
</tr>
<tr>
<td></td>
<td>2-1/2 through 3-1/2</td>
<td>4</td>
<td>½</td>
</tr>
<tr>
<td></td>
<td>4 through 5</td>
<td>4</td>
<td>5/8</td>
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<tr>
<td></td>
<td>6</td>
<td>4</td>
<td>¾</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>4</td>
<td>7/8</td>
</tr>
</tbody>
</table>

8. **Vertical Supports**

   a) **Cast Iron Pipe:** Support at each floor, not to exceed 15 feet between supports, and at pipe base.

   b) **Screwed Pipe:** Support at 8 foot on center for 1-1/2 inch and smaller pipe. Support at 10 foot on center for 2-inch and larger pipe.

   c) **Copper Pipe:** Support at 6 foot on center for 1-1/2 inch and smaller pipe. Support 8 foot on center for 2-inch and larger pipe.

9. **Trapeze Hangers:** Space for smallest pipe in-group. Provide additional hanger rod at mid span where trapeze length exceeds 4 feet. Secure pipe at each trapeze with standard pipe strap. Rest un-insulated copper pipe on neoprene sleeves.

**Pipe Joint Construction:**

1. **Soldered Joints:** Comply with the procedures contained in the AWS “Soldering Manual”.

2. **Brazed Joints:** Comply with the procedures contained in the AWS “Brazing Manual”.

   **CAUTION:** Remove stems, seats, and packing of valves and accessible internal parts at piping specialties before brazing.

3. Fill all medical gas and refrigerant pipe and fittings during brazing with an inert gas, i.e., nitrogen or carbon dioxide, to prevent formation of scale.


5. For all copper piping, ream and remove all burrs prior to making joints.

6. **Threaded Joints:** Conform to ANSI B1.20.1, tapered pipe threads for field cut threads. Join pipe fittings and valves as follows:

   a) Note the internal length of threads in fittings or valve ends and proximity of internal seat or wall, to determine how far pipe should be threaded into joint.

   b) Align threads at point of assembly.
c. Apply appropriate tape or thread compound to the external pipe threads (except where dry seal threading is specified).

d. Assemble joint wrench tight. Wrench on valve shall be on the valve end into which the pipe is being threaded.

7. Damaged Threads: Do not use pipe with threads that are corroded or damaged. If a weld opens during cutting or threading operations, that portion of pipe shall not be used.

8. Welded Joints: Comply with the requirement in ASME Code B31.9 “Building Services piping”.

9. Flanged Joints: Align flanges surfaces parallel. Assemble joints by sequencing bolt tightening to make initial contact of flanges and gaskets as flat and parallel as possible. Use suitable lubricants on bolt threads. Tighten bolts gradually and uniformly using torque wrench.

3.3 TESTING, CLEANING, AND CERTIFICATION

K. Test all piping systems in accordance with tests outlined in individual sections. Provide temporary equipment for testing, including pump and gages. Test each natural section of each piping system independently but do not use piping system valves to isolate sections where test pressure exceeds valve pressure rating. Test all new piping and parts of existing piping that have been altered extended or repaired. Submit report(s) on the results of each test.

L. Give a minimum of twenty-four hours notice to the Engineer for dates when acceptance test will be conducted. Conduct tests as specified for each system in presence of the UC Denver Project Manager or representative of agency having jurisdiction. Submit three (3) copies of successful tests to the Engineer for his review. Report shall state system tested and date of successful test.

M. Compressed air tests may be substituted for hydrostatic tests only when ambient conditions or existing building conditions prohibit safe use of hydrostatic testing and must be reviewed by the Engineer prior to any testing.

N. Remove equipment not able to withstand test procedure during test.

O. For piping, which is to be concealed, piping shall remain uncovered until tests have been completed.

P. Drain test water from piping systems after testing and repair work has been completed.

Q. Repair piping systems sections that fail testing, by disassembly and re-installation, using new materials to extent required to overcome leakage. Do not use chemicals, stop-leak compounds, mastics or other temporary repair methods.

R. Potable Water Piping System:

1. Cap domestic water piping and subject piping to static water pressure of 50 psig above operating pressures or 150 psig maximum without exceeding pressure rating of piping system materials. Allow the system to remain pressurized for 4 hours. Correct leaks and loss in pressure and retest system.
2. Disinfect all domestic hot and cold water systems upon completion of final piping installation. Following disinfection, flush water from system through its extremities. Continue flushing until samples show quality is comparable with public water supply and complies with requirements of public health authority.

S. Gas Pipe Testing:
1. Test with air, nitrogen, or carbon dioxide.
2. Test piping system with a pressure 1-1/2 times the proposed maximum working pressure, but not less than 3 psig. Test systems having a volume of 10 cubic feet or less for a period of not less than 10 minutes and larger systems for a period of not less than ½ hour for each 500 cubic foot of pipe volume or fraction thereof without showing any drop in pressure.
3. Fully purge gas piping after piping has been checked.

T. Sanitary Sewer Pipe Testing:
1. Test drain, waste, and vent piping on completion of rough in. Close openings in piping system and fill with water to point of overflow but not less than 10 feet of head. Water level must not drop from 15 minutes before inspection starts through completion of inspection. Correct leaks and retest system.

K. Adjusting and Cleaning:
1. General: Clean exterior surfaces of installed piping systems of superfluous materials, and prepare for application of specified coatings (if any). Flush piping systems with clean water. Inspect each run of each system for completion of joints, supports and accessory items.
2. Chemical Treatment: Provide a water analysis prepared by the chemical treatment supplier to determine the type and level of chemicals required for prevention of scale and corrosion. Perform initial treatment after completion of system testing.
3. Flush each new extension of existing systems, via hose connections prior to filling. Fill each new extension of existing systems with water that has the proper water treatment chemicals and in the proper quantity prior to connection, or opening valves to the main or existing system. Use chemicals that are compatible with the chemicals in the existing system. Flush each new system with the UC Denver representative present. Fill each new system with the proper chemicals, and with the UC Denver representative present.

3.4 COMMISSIONING (DEMONSTRATION)
1. Fill system and perform initial chemical treatment.
2. Check expansion tanks to determine that they are not air bound and that the system is completely full of water.
3.
4. Before operating the system, perform these steps:
5. Open valves to full open position. Close coil bypass valves.
6. Remove and clean strainers.
7. Check pump for proper rotation and proper wiring.
8. Set automatic fill valves for required system pressure.
9. Check air vents at high points of systems and determine if all are installed and operating freely (automatic type) or to bleed air completely (manual type).
10. Set temperature controls so all coils are calling for full flow.
11. Check operation of automatic bypass valve.
12. Check and set operating temperature of converters and chillers to design requirements.
13. Lubricate motors and bearings.

3.5 SCHEDULES

END OF SECTION
SECTION 15120
PIPING SPECIALTIES

PART 1 - GENERAL

1.1 SUMMARY

A. This section provides standards for piping specialties.

B. Types of piping specialties specified in this section include the following:

1. Air Vents
2. Escutcheons
3. Mechanical Sleeve Seal
4. Fire and Smoke Barrier Penetration Seal
5. Drip Pan
6. Pipe Sleeve
7. Combination Pressure and Temperature Relief Valves
8. Pressure Reducing Valves
9. Sleeve Seals
10. Expansion tanks
11. Air separators
12. Compression Tanks
13. Pump Suction Diffusers
14. Hydronic System Safety Relief Valves
15. Pressure Regulating Valves
16. Strainers
17. Natural Gas Meters
18. Domestic Water Meters
19. Vacuum Breakers

1.2 REFERENCES

A. Section 15000 - General Mechanical Provisions

B. Section 15110 - Valves

1.3 SYSTEM PERFORMANCE

A. Strainers:

1. Place strainers upstream of all regulators, pumps, chillers, boilers, control equipment or any other equipment, which could be damaged or rendered inoperative due to foreign matter in the piping. Provide adequate access for removal.

2. Provide parallel strainers with isolation valves on primary piping systems where operation is critical and is intended to continue during servicing. Strainers shall then be cleaned through removable caps.

3. For critical systems, provide pressure gauges to indicate loading. Consider clear see-through duplex strainers or filters for critical applications.
4. Provide single strainers with isolation valves on secondary piping systems where operation can be interrupted. Provide blowdown valves with caps on single strainers.

B. Hydronic Piping Specialties:

1. General: Provide factory fabricated piping specialties recommended by manufacturer for use in service indicated. Provide piping specialties of types and pressure ratings indicated for each service, or if not indicated, provide proper selection as determined by installer to comply with connections, within properly mate with pipe, tube, and equipment connections. Where more than one type is indicated, selection is Installer’s option.

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submittals shall be made in accordance with Section 15000.

1.6 QUALITY ASSURANCE

A. Codes and Standards:

1. FCI Compliance: Test and rate “Y” type strainers in accordance with FCI 73-1 “Pressure Rating Standard for “Y” Type Strainers”. Test and rate other type strainers in accordance with FCI 78-1 “Pressure Rating Standard for Pipeline Strainers other than “Y Type”.

2. ASME B31.9 “Building Services Piping” for materials, products, and installation.

3. Safety valves and pressure vessels shall bear the appropriate ASME label.

4. Fabricate and stamp air separators and compression tanks to comply with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.


1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2- PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Air Vents (manual)

   a. Armstrong Machine Works

   b. Bell & Gossett, ITT; Fluid Handling Div.
1. Piping Fittings, Flanges, and Sanitary Flanges:
   c. Producers Specialty & Mfg. Corp.
   e. Spirax Sarco

2. Pipe Escutcheons:
   c. Producers Specialty & Mfg. Corp.

3. Mechanical Sleeve Seal:
   a. Thunderline Corp.
   b. Or approved equal per Division 1 requirements.

4. Fire and Smoke Barrier Penetration Seal:
   a. Dow Corning
   b. Electrical Products Div./3M
   c. Flame Stop, Inc.

5. Expansion Tanks:
   a. Diaphragm Type Expansion Tanks
      (1) Amtrol, Inc.
      (2) Watts.
      (3) Bell and Gossett ITT; Fluid Handling Div.

6. Air Separators:
   a. Bell and Gossett ITT; Fluid Handling Div.
   b. Amtrol Inc.
   c. Armstrong Pumps, Inc.
   d. Spirax Sarco

7. Combination Pressure and Temperature Relief Valves:
   a. Amtrol, Inc.
   b. Bell and Gossett ITT; Fluid Handling Div.
   c. Watts Regulator Co
   d. Spirax Sarco
8. Low Pressure Strainers:
   a. Metraflex Co.
   b. Hoffman Specialty ITT; Fluid Handling Div.
   c. Watts Regulator Co.
   d. Spirax Sarco

9. Basket Strainers:
   a. R-P&C Valve
   b. Keckley.
   c. Metraflex

10. Pressure Reducing Valves (Water Application):
    a. Amtrol, Inc. Taco, Inc.
    b. Keckley
    c. Armstrong

11. Pump Suction Diffusers:
    a. Amtrol, Inc.
    b. Armstrong Pumps, Inc.
    c. Bell & Gossett ITT; Fluid Handling Div.

12. Diverting Fittings:
    a. Armstrong Pumps, Inc.
    b. Bell & Gossett ITT; Fluid Handling Div.
    c. Victaulic Company of America

13. Dielectric Waterway Fittings:
    a. America
    b. Epco Sales, Inc.
    c. Or approved equal per Division 1 requirements.

14. Hydronic System Safety Relief Valve:
    a. Kunkle Valve Co., Inc.
    b. Watts Regulator Co.
c. Bell & Gossett ITT; Fluid Handling Div.

15. Pressure Regulating Valves (Steam Application):
   a. Spence (preferred)
   b. Hoffman Specialty ITT; Fluid Div.
   c. Armstrong.

2.2 MATERIALS, GENERAL

A. Air Vents (Manual):
   1. Bronze body and nonferrous internal parts; 150 psig working pressure, 212 degree F operating temperature; screwdriver or coin operated type.
   2. Float Type: Brass or semi-steel body, copper float, stainless steel valve and valve seat; suitable for system operation temperature and pressure. With isolating valve.
   3. Washer Type: Brass with hydroscopic fiber discs, vent ports, adjustable cap for manual shut-off, and integral spring loaded ball check valve.
   4. Provide valve or gauge cock for isolation and repair.
   5. Pipe high point manual air vents to drain. Notify Project Manager in areas where the manual vents can not be piped to drain.

B. Pipe Escutcheons:
   1. General: Provide pipe escutcheons with inside diameter closely fitting pipe outside diameter, or outside of pipe insulation where pipe is insulated. Select outside diameter of escutcheon to completely cover pipe penetration hole in floors, walls, or ceilings; and pipe sleeve extension, if any. Furnish pipe escutcheons with nickel or chrome finish for occupied areas, prime paint finish for unoccupied areas.
   2. Pipe Escutcheons for Moist Areas: For waterproof floors, and areas where water and condensation can be expected to accumulate, provide cast brass or sheet brass escutcheons, solid or split hinged.
   3. Pipe Escutcheons for Oversized Holes: Provide sheet steel escutcheons, solid or split hinged.

C. Dielectric Protection:
   1. General: Provide standard products recommended by manufacturer for use in service indicated, which effectively isolate ferrous from non-ferrous piping (electrical conductance), prevent galvanic action, and stop corrosion.
   2. Use dielectric waterway fittings rather than dielectric unions
   3. Installing full-port brass valves, with half-unions at the inlet and outlet, to connect steel to copper pipe is acceptable.
4. Dielectric protection fittings shall be installed in equipment rooms only.

D. Sleeves:

1. Galvanized sheet steel with lock seam joints for sleeves passing through non-load bearing or non-fire rated walls and partitions. Minimum gauges as follows:
   a. Pipes 2-1/2 inch and smaller: 24 gauge.
   b. Pipes 3 inch to 6 inch: 22 gauge.
   c. Pipes over 6 inch: 20 gauge.

2. Schedule 40 galvanized steel pipe or cast iron pipe for sleeves passing through load bearing walls, concrete beams, fire-rated partitions, foundations, footings, and waterproof floors.

3. Insulated Pipe: Sleeves of sufficient internal diameter to install pipe and insulation and allow for free movement of pipe.

4. In finished areas where pipes are exposed, terminate sleeves flush with wall, partitions, and ceiling and extend 1 inch above finished floors.

5. Fire Protection Lines: Extend sleeves a minimum of 3 inches above finished floor.

E. Mechanical Sleeve Seals:

1. Modular mechanical type, consisting of interlocking synthetic rubber links shaped to continuously fill annular space between pipe and sleeve, connected with bolts and pressure plates which cause rubber sealing elements to expand when tightened, providing watertight seal and electrical insulation. Foundation walls only.

F. Fire and Smoke Barrier Penetration Seals:

1. Provide U.L. listed products for sealing all openings through fire or fire/smoke rated walls, floors, or ceilings used as passage for mechanical piping.

G. Fabricated Piping Specialties:

1. Drip Pans: Fabricated from corrosion resistant sheet metal with watertight joints, and with edges turned up 2-1/2 inch. Reinforce top, either by structural angles or by rolling top over 1/4-inch steel rod. Provide hole, gasket and flange at low point for watertight joint and 1-inch drain line connection.

H. Expansion Tanks:

1. Compression Tanks: Welded carbon steel rated for 125 psig working pressure, 375 degree F maximum operating temperatures. Provide with taps in bottom of tank for tank fittings and taps in end of tank for gauge glass. Tested and labeled in accordance with ASME Pressure Vessel Code.
a. Air Control Tank Fittings: Cast iron body, copper-plated tube, brass vent tube plug, and stainless steel ball check.

b. Tank Drain Fitting: Brass Body, nonferrous internal parts. Fitting to admit air into compression tank drain water, and close off the system.

2. Diaphragm Type Tanks: Welded steel, rated for 125 psig working pressure, 375 degree maximum operating temperature, flexible diaphragm sealed into tank. Provide taps for pressure gauge, air charging fitting, and drain fitting. Provide with steel legs or saddles. Tested and labeled in accordance with ASME Pressure Vessel Code.

I. Air Separators:

1. In-line air separators: Cast iron for sizes 1-1/2 inch and smaller, welded steel for sizes 2 inch and larger; tested and labeled for minimum 125 psig working pressure and 350 degree F operating temperature. ASME constructed and labeled

2. Air Elimination Valve: Bronze, float operated, for 125 psig operating pressure.

J. Pressure Reducing Valves:

1. Diaphragm operated, cast iron or brass body valve, with low inlet pressure check valve, inlet strainer removable without system shut-down and non-corrosive valve seat and stem. Factory set at operating pressure and field adjustable.

K. Hydronic System Safety Relief Valves:

1. Diaphragm operated, cast iron or brass body, Teflon seat, stainless steel stem and springs, with low inlet pressure check valve, inlet strainer removable without system shut-down, ASME certified and labeled. Select valve to suit actual system pressure and BTU capacity. Set valve to relieve at 10 psi above operating pressure.


M. Dielectric waterway fittings: Threaded end connections installed to isolate dissimilar metals, prevent galvanic action, and prevent corrosion.

N. Automatic Air Vent:

1. Designed to vent automatically with float principle; bronze body and nonferrous internal parts; 150 psig working pressure, 240 degree F operating temperature; and having 1/4 inch discharge connection and 1/2 inch inlet connection. B & G Model #87.

O. Pump Suction Diffusers:

1. Cast iron body, with threaded connections for 2 inch and smaller, flanged connections for 2-1/2 inch and larger; 175 psig working pressure, 300 degree F maximum operating temperature; and complete with the following features:
a. Inlet vanes with length 2-1/2 times pump suction diameter or greater.
b. Cylinder strainer with 3/16 inch diameter openings with total free area equal to or greater than 5 times cross-sectional area of pump suction, designed to withstand pressure differential equal to pump shutoff head.
c. Disposable fine mesh strainer to fit over cylinder strainer.
d. Permanent magnet located in flow stream, removable for cleaning.
e. Adjustable foot support designed to carry weight of suction piping.
f. Blowdown tapping in bottom; gauge tapping in side.

P. Diverting Fittings: Cast iron body with threaded ends or wrought copper with solder ends; 125 psig working pressure, 250 degree F maximum operating temperature. Indicate flow direction on fitting.

Q. Low Pressure Y-Pattern Strainers:

1. Line size strainer with ends matching piping system materials, 125 psig working pressure with Type 304 stainless steel screens with 3/64-inch perforations at 233 per square inch.

a. Threaded Ends, 2-Inch and Smaller: Cast iron body, screwed screen retainer with centered blowdown fitted with pipe plug.
b. Threaded or Flanged Ends, 2-1/2-inch and Larger: Cast iron body, bolted screen retainer with off-center blowdown fitted with pipe plug.
c. Butt Welded Ends, 2-1/2-inch and Larger: Schedule 40 cast carbon steel body, bolted screen retainer with off-center blowdown fitted with pipe plug.
d. Grooved Ends, 2-1/2-inch and Larger: Tee pattern, ductile-iron or malleable-iron body, and access end cap, access coupling with EDPM gasket.

R. High Pressure Pipeline Strainers:

1. Line size with ends matching piping system materials, 250 psig working pressure with Type 304 stainless steel screens with 3/64-inch perforations at 233 per square inch.

a. Threaded Ends, 2-Inch and Smaller: Cast iron body, screwed screen retainer with centered blowdown fitted with pipe plug.
b. Threaded or Flanged Ends, 2-1/2-inch and Larger: Cast iron body, bolted screen retainer with off-center blowdown fitted with pipe plug.
c. Butt Welded Ends, 2-1/2-inch and Larger: Schedule 40 cast carbon steel body, bolted screen retainer with off-center blowdown fitted with pipe plug.
d. -1/2-inch and Larger: Tee pattern, ductile-iron or malleable-iron body, and access end cap, access coupling with EDPM gasket.

S. Basket Strainers:

1. For 125 psig Systems or less and pipe sizes 16-inches or less: High-tensile ASTM A126B Class B cast iron, angle design, ductile iron clamped cover, flanged ends, stainless steel screen assembly, suitable gasket material, bottom threaded drain outlet.

2. For systems operating greater than 125 psig and pipe sizes greater than 16-inches: High-tensile ASTM A126 Class B cast iron, angle design, bolted cover, flanged ends, stainless steel screen assembly, suitable gasket material, bottom threaded drain outlet.

T. Gas Meter: General: A Natural Gas Meter with a pulse accumulator shall measure gas usage by reading total CCF.

U. Domestic Water Meter:

1. General: Install per City of Aurora Standards

V. Vacuum Breakers

1. Armstrong
2. Watts
3. Hoffman+
4. Spirax Sarco

W. Fire Pump Bypass Flow Measuring System

1. Victaulic Style 735 Fire Pump Test Meter
2. Equal or better

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. General:

1. Install specialties in accordance with manufacturer’s instructions to provide intended performance.

2. Support tanks inside building from building structure in accordance with manufacturer’s instructions.

3. Where large air quantities can accumulate, provide enlarged air collection standpipes.

4. For automatic air vents in ceiling spaces or other concealed locations, provide vent tubing to nearest drain.

5. Provide manual air vents at system high points and as indicated with ¼” X 2” minimum copper tube to direct flow of air and fluid.
6. Provide valved drain and hose connection on strainer blow down connection.

7. Support pump fittings with floor mounted pipe and flange supports.

8. Provide relief valves on pressure tanks, low pressure side or reducing valves, heat exchangers, and expansion tanks.

9. Select system relief valve capacity so that it is greater than make-up pressure reducing valve capacity.

10. Pipe relief valve outlet to nearest floor drain.

11. Where one line vents several relief valves, make cross sectional area equal to sum of individual vent areas.

12. Pipe Escutcheons: Install pipe escutcheons on each pipe penetration through floors, walls, partitions, and ceilings where penetration is exposed to view; and on exterior of building. Secure escutcheon to pipe or sleeve but not to insulation with set screws. Install escutcheon to cover penetration hole and flush with adjoining surface. Provide high cap type escutcheon to clear sleeve extension where sleeve extends above finished surface.

13. **Dielectric waterway fittings**: Install at each piping joint between ferrous and non-ferrous piping. Comply with manufacturer’s installation instructions.

14. Mechanical Sleeve Seals: at exterior foundation walls only
   a. Installed between sleeve and pipe.
   b. Loosely assemble rubber links around pipe with bolts and pressure plates located under each bolt head and nut. Push into sleeve and center. Tighten bolts until links have expanded to form watertight seal.

15. Fire or Fire/Smoke Barrier Penetration Seals: Where pipe penetration occurs in fire of fire/smoke rated walls, provide the following:
   a. Provide fire stopping material in accordance with manufacturer’s recommendations.

B. Hydronic Specialties Installation:

1. Install automatic air vents where noted.

2. Install in-line air separators in pump suction lines. Run piping to compression tank with 1/4 inch per foot (2%) upward slope towards tank. Install drain valve on units 2 inch and larger.

3. Install ball valve to isolate expansion tank for cleaning and blowdown. Install drain valve on tank for cleaning/blowdown.

4. Install separator in pump suction lines. Run piping to compression tank with 1/4 inch per foot (2%) upward slope towards tank. Install blowdown piping with ball valve, extend to nearest drain.

5. Provide sufficient number of pipe diameters to inlet of each pump as noted in detail or install pump suction diffusers on pump suction inlet, adjust foot support
to carry weight of suction piping. Install nipple and ball valve in blowdown connection.

6. Install gauge glass and cocks on end of compression tanks. Install tank fitting in tank bottom and charge tank. Use manual vent for initial fill to establish proper water level in tank.

7. Provide adequate support from structure to carry twice the weight of the tank, piping connections, fittings, and weight of water assuming a full tank of water. Do not overload building components and structural members. Coordinate concrete inserts with general contractor.

3.3 TESTING, CLEANING, AND CERTIFICATION

A. Testing shall be in accordance with Section 15110.

3.4 COMMISSIONING (DEMONSTRATION)

3.5 SCHEDULES

END OF SECTION
PART 1 – GENERAL

1.1 SUMMARY

A. This section provides standards for meters and gauges.

1. Temperature gauges and fittings:
   a. Glass thermometers
   b. Direct mount dial thermometers
   c. Remote reading dial thermometers
   d. Dial type insertion thermometers
   e. Thermometer wells
   f. Temperature gauge connector plugs

2. Pressure gauges and fittings:
   a. Pressure gauges
   b. Pressure gauge cocks
   c. Pressure gauge connector plugs

3. Flow measuring meters:
   a. Venturi flow measuring elements
   b. Calibrated balance valves
   c. Portable flow meters

1.2 REFERENCES

A. Section 15000 - General Mechanical Provisions

B. Meters and gauges furnished as part of factory-fabricated equipment, are specified as part of equipment assembly in other Division 15 sections.

1.3 SYSTEM PERFORMANCE

A. General Information:

1. Provide gauge cocks at all gauges for removal under operation.

2. Employ independent gauges with range twice the operating pressure across pumps, strainers, pressure reducing stations, etc.
3. Monitor all systems by the building automation system for On/Off, temperatures, and pressures.

B. Air Filters:

4. Provide pressure switches and magnehelic gauges across main building air filters.

C. Pressure Reducing Valves:

1. Provide single pressure gauge on upstream and downstream of pressure reducing valves to independently indicate high and low pressure.

D. Heating Water Systems:

1. Provide solar-powered digital thermometers in wells on hot water systems, domestic and heating, to indicate supply and return temperatures.

E. Air Systems:

1. Provide visual gauges on HVAC air distribution equipment to indicate temperatures at supply, return and mixed air points.

F. Pumps:

1. Provide separate pressure gauge in suction and discharge and temperature taps in pipes at each pump suction and discharge. Do not use pump housing ports for gauges.

G Chilled and Condenser Water Systems

1. Provide dial thermometers in wells to indicate supply and return temperatures

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submittals shall be made in accordance with Section 15000.

1.6 QUALITY ASSURANCE

A. Codes and Standards:

1. UL Compliance: Comply with applicable UL standards pertaining to meters and gauges.

2. ANSI and ISA Compliance: Comply with applicable portions of ANSI and Instrument Society of America (ISA) standards pertaining to construction and installation of meters and gauges.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS
2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by
the following:

1. Glass Thermometers:
   a. Marshalltown Instruments, Inc.
   b. U.S. Gage
   c. Mueller

2. Direct Mount Dial Thermometers:
   a. Marsh Instrument Co.; Unit of General Signal
   b. Trerice (H.O.) Co.
   c. Weiss Instruments, Inc.

3. Remote Reading Dial Thermometers:
   a. Ametek/U.S. Gauge
   b. Marsh Instrument Co.; Unit of General Signal
   c. Weiss Instruments, Inc.

4. Dual Type Insertion Thermometers and Wells:
   a. Marsh Instrument Co.; Unit of General Signal
   b. Taylor Instrument Co.
   c. Weiss Instruments, Inc.

5. Temperature Gauge Connector Plugs:
   a. Fairfax Company
   b. Peterson Equipment Co.
   c. Universal Lancaster

6. Pressure Gauges and Plugs:
   a. Ametek/U.S. Gauge
   b. Marsh Instrument Co.; Unit of General Signal
   c. Weiss Instruments, Inc.

7. Pressure Gauge Connector Plugs:
a. Fairfax Company
b. Peterson Equipment Co.
c. Universal Lancaster

8. Venturi Flow Measuring Elements:
   a. FDI (preferred)
   b. HCI
   c. Gerand

9. Calibrated Balancing Valves:
   a. FDI (preferred)
   b. HCI
   c. Gerand

10. Automatic Balancing Valves
    a. FDI (preferred)
    b. Griswold
    c. Approved equal

2.2 MATERIALS, GENERAL

A. Thermometers:

1. Case: Die cast aluminum, finished in baked epoxy enamel, glass front, spring secured, 9 inches long.

2. Adjustable Joint: Die cast aluminum, finished to match case, 180 degree adjustment in vertical plane, 360 degree adjustment in horizontal plane, with locking device.

3. Tube and Capillary: Spirit filled, magnifying lens, 1% scale range accuracy, shock mounted.

4. Scale: Satin faced, non-reflective aluminum, permanently etched markings.

5. Stem: Copper plated steel, or brass, for separable socket, length to suit installation.

6. Range: Conform to the following:
   a. Hot Water: 30 degree - 240 degree F with 2 degree F scale divisions.
   b. Chilled Water: 0 degree - 100 degree F with 2 degree F scale divisions.

B. Dial Type Insertion Thermometers:
1. Type: Bi-metal, stainless steel case and stem, 1 inch diameter dial, dust and leak proof, 1/8 inch diameter stem with nominal length of 5 inches.

2. Accuracy: 0.5% of dial range.

3. Range: Conform to the following:
   a. Hot Water: 0 degree - 240 degree F
   b. Chilled Water: 0 degree - 100 degree.

C. Thermometer Wells:
   1. Thermometer wells constructed of brass or stainless steel, pressure rated to match piping system design pressure. Provide 2 inch extension for insulated piping. Provide cap nut with chain fastened permanently to thermometer well.

D. Temperature Gauge Connector Plugs:
   1. Temperature gauge connector plugs pressure rated for 500 psi and 200 degree F (93 degree C). Construct of brass and finish in nickel-plate, equip with 1/2 inch NPS fitting, with self-sealing valve core type neoprene gasketed orifice suitable for inserting 1/8 inch OD probe assembly from dial type insertion thermometer. Equip orifice with gasketed screw cap and chain. Provide extension, length equal to insulation thickness, for insulated piping.

E. Pressure Gauges:
   1. Type: General use, 1% accuracy, ANSI B40.1 grade A, phosphor bronze bourdon type, bottom connection.
   2. Case: Drawn steel or brass, glass lens, 4-1/2 inch diameter.
   3. Connector: Brass with 1/4 inch male NPT. Provide protective siphon when used for steam service.
   4. Scale: White coated aluminum, with permanently etched markings.
   5. Range: Conform to the following:
      a. Vacuum: 30 inch Hg - 15 psi
      b. Water: 0 - 200 psi
      c. Steam: 0 - 150 psi. High pressure
         1) 0 - 25 psi. Low pressure
   6. Provide all steam pressure gauges with pigtail and shut-off valve suitable for temperature and pressure for specified service.

F. Pressure Gauge Cocks:
   1. Brass with 1/4 inch female NPT on each end and “T” handle brass plug.
2. **Siphon**: 1/4 inch straight coil constructed of brass tubing with 1/4 inch male NPT on each end. On steam pipe only.

3. **Snubber**: 1/4 inch brass bushing with corrosion resistant porous metal disc, through which pressure fluid is filtered. Select disc material for fluid served and pressure rating.

### G. Pressure Gauge Connector Plugs:

1. Provide pressure gauge connector plugs pressure rated for 500 psi and 200 degree F. Construct of brass and finish in nickel plate equipped with 1/2 inch NPS fitting, and self-sealing valve core type neoprene gasketed orifice suitable for inserting 1/8 inch OD probe assembly from dial type insertion pressure gauge. Equip orifice with gasketed screw cap and chain. Provide extension, length equal to insulation thickness, for insulated piping.

### H. 2-1/2 Inch and Larger Venturi Flow Measuring Elements:

1. Primary flow measuring elements consisting of solid brass or bronze venturi tubes. Tubes larger than 2 inches may be cast iron or steel. Steel tubes may be fabricated or cast with cadmium or zinc-plating. Line throats of cast iron tubes with bronze and plate cast iron portion with cadmium. Each station complete with safety shutoff valves, and quick coupling connections for use with a master portable meter set or individual permanently mounted meter. Tubes calibrated and tested by independent testing laboratory and performance data furnished with shop drawings.

2. Manufacturer shall certify venturi for actual piping configuration. Any necessary piping changes required for certification shall be provided without cost.

3. Provide venturi with throat diameter such that specified rate of flow will register scale reading of between 20% and 80% of full scale value.

4. Unrecovered head loss at maximum flow shall not exceed 10% for venturi used with permanently located meters and shall not exceed 12 inches w.g. when used with portable meters.

5. Provide each primary element with integral tab or metal tag on stainless steel wire extending outside pipe covering on which is stamped or clearly printed in plainly visible position the following information:
   
   a. Manufacturer’s name and address.
   
   b. Serial number of meter to which element is to be connected.
   
   c. Name, number or location of equipment served.
   
   d. Specified rate of flow.
   
   e. Multiplier (including unity, where applicable) to be applied to meter reading, including correction for operating temperatures and glycol solutions.

6. Provide taps with shutoff valves and quick connecting hose fittings for portable meters.
I. Inches and Smaller Calibrated Balance Valves:
   1. Calibrated balance valves equipped with readout valves to facilitate connecting of differential pressure meter to balance valves. Equip each readout valve with integral EPT check valve designed to minimize system fluid loss during monitoring process. Provide calibrated nameplate to indicated degree of closure of precision machined orifice. Construct balancing valve with internal EPT O-ring seals to prevent leakage around rotating element. Provide balance valves with preformed polyurethane insulation suitable for use on heating and cooling systems, and to protect balance valves during shipment.

J. Portable Flow Meters:
   1. Provide differential pressure gage and two 12-foot hoses in carrying case with equalizing manifold, check seals, and appurtenances. Plus or minus 2 percent accuracy between 20 to 80 percent of range. Provide master chart for conversion of meter readings to gallons per minute. Provide adapters as necessary.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. Temperature Gauges:
   1. General: Install temperature gauges in vertical upright position, and tilted so as to be easily read by observer standing on floor.
   2. Locations: Provide in the following locations and elsewhere as indicated:
      a. At inlet and outlet of each chiller.
      b. At inlet and outlet of each condenser.
      c. At inlet and outlet of each hydronic coil in air handling units and built-up central systems.
      d. At inlet and outlet of each hydronic heat exchanger or converter.
      e. At inlet and outlet of each hydronic heat recovery unit.
      f. At inlet and outlet of each thermal storage tank.
      g. At inlet and outlet of each pump.
      h. At each air handler to monitor Supply Air, Return Air, and Mixed Air temperatures.
   3. Thermometer Wells: Provide in piping tee where indicated, in vertical upright position. Fill well with oil or graphite, secure cap.
4. Temperature Gauge Connector Plugs: Provide in piping tee where indicated, located on pipe at most readable position. Secure cap.

5. 

B. Pressure Gauges:

1. General: Provide pressure gauges in piping tee with pressure gauge cock, located on pipe at most readable position.

2. Locations: Provide in the following locations and elsewhere as indicated:
   a. At suction and discharge of each pump.
   b. At inlet and discharge of each pressure reducing valve.
   c. At water service outlet.
   d. At inlet and outlet of water cooled condensers and refrigerant cooled chillers.
   e. At steam source heating equipment including but not limited to converters and hot water generators.

3. Pressure Gauge Cocks: Provide in piping tee with snubber. Install siphons for steam pressure gauges.

4. Pressure Gauge Connector Plugs: Provide in piping tee where indicated, located on pipe at most readable position. Secure cap.

C. Flow Measuring Devices:

1. General: Provide flow measuring devices on piping systems located in accessible locations at most readable position.

2. Arrange piping in accordance with manufacturer’s published literature. In horizontal pipes, place connections slightly above horizontal centerline of pipe.

3. Install so connections for attachment to portable flow meter hoses is readily accessible

4. Locations: Provide in the following locations and elsewhere as indicated:
   a. At discharge of each pump.
   b. At inlet of each hydronic coil in built-up central systems.

5. Calibrated Balance Valves: Provide on piping with readout valves in vertical upright position. Maintain minimum length of straight unrestricted piping equivalent to 5 pipe diameters upstream and downstream of valve and/or fittings.

3.3 TESTING, CLEANING AND CERTIFICATION

A. Adjusting: Adjust faces of meters and gauges to proper angle for best visibility.
B. Cleaning: Clean windows to meters and gauges and factory-finished surfaces. Replace cracked or broken windows, repair any scratched or marred surfaces with manufacturer’s touch-up paint.

C. Certification: Provide meters and gauges whose accuracy’s, under specified operating conditions, are certified by manufacturer.

3.4 COMMISSIONING (DEMONSTRATION)

3.5 SCHEDULES

END OF SECTION
SECTION 15160
PUMPS

PART 1 - GENERAL

1.1 SUMMARY

A. This section provides standards for pumps.

1.2 REFERENCES

A. Section 15000 – General Mechanical Provisions
B. Section 15190 – Mechanical Identification
C. Section 15990 – Adjusting and Balancing
D. Section 15480 – Special Piping Systems

1.3 SYSTEM PERFORMANCE

A. Pumping System Design

1. Primary-secondary pumping systems are required where applicable. Provide standby pumps for primary pumps and pumps serving critical areas.

2. Design pumping systems so that the available positive head at the pump intake will be larger than the required net positive suction head at the highest possible water temperature at the pump intake.

3. The pump curve representing flow-head relationship shall intersect the system curve at design operating point.

4. Select pumps to operate at optimum efficiency.

5. Pump motor shall be non-overloading over the entire pump curve shown by the manufacturer.

6. Specify pumps with separate pump and motor shafts and replaceable couplings for all but cartridge pumps.

7. Provide mechanical shaft seals. Gland seals are not acceptable.

8. Provide duplex pumping units for sewage ejectors and for sump pumps in critical areas. Include lead/lag selector and automatic switchover in the event of failure.

9. Pumps for Softened or DI water shall have Stainless Steel Impellers

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submit the following in accordance with Section 15000 and the following.
1. Product Data: Submit pump characteristic performance curves with selection points clearly indicated.

1.6 QUALITY ASSURANCE

A. Regulatory Requirements:

1. HI Compliance: Design, manufacture and install HVAC pumps in accordance with HI "Hydraulic Institute Standards".

2. UL Compliance: Design, manufacture and install HVAC pumps in accordance with UL 778 "Motor Operated Water Pumps".

3. UL and NEMA Compliance: Provide electric motors and components, which are listed and labeled by Underwriters Laboratories, and comply with NEMA standards.

4. SSPMA Compliance: Test and rate sump and sewage pumps in accordance with Sump and Sewage Pump Manufacturers Association (SSPMA) and provide certified rating seal.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. In-line Circulator Pumps:
   a. Armstrong Pumps, Inc.
   c. Aurora

2. Vertical In-line Pumps:
   a. Armstrong Pumps, Inc.
   b. Bell and Gossett ITT: Fluid Handung Div.
   c. Aurora

3. Base-Mounted End Suction Pumps:
   a. Armstrong Pumps, Inc.
   b. Bell and Gossett ITT: Fluid Handung Div.
   c. Aurora
4. In-line Circulation Pumps:
   a. Armstrong Pumps, Inc.
   b. Bell and Gossett ITT: Fluid Handling Div.
   c. Aurora

5. Positive Displacement Pumps:
   a. Viking
   b. Blackman
   c. Roper

6. Vertical Suspended Sump Pumps and Sewage Ejector:
   a. Armstrong Pumps, Inc
   b. Peerless Pump
   c. Wek Pumps Co.

2.2 MATERIALS, GENERAL

A. Provide factory-tested pumps, thoroughly cleaned and painted with one coat of machinery enamel prior to shipment. Type, size and capacity of each pump is listed in the pump schedule. Provide pumps of same type by same manufacturer.

B. In-line Circulator Pumps:

1. General: Provide in-line circulator pumps where indicated and of capacities as scheduled. All pumps shall be bronze fitted.

2. Type: Horizontal, in-line, oil lubricated, designed for 125 psi working pressure and 225 degree F (107 degree C) continuous water temperature.

3. Body: Cast iron with suction and discharge gauge tappings.


5. Bearings: Oil lubricated bronze journal bearings.

6. Seal: Mechanical with carbon seal ring and ceramic seat.

7. Motor: Non-overloading at any point on pump curve, open, drip-proof, oil lubricated journal bearings, resilient mounted construction, built-in thermal overload protection on single phase motors.


9. Impeller: Bronze, enclosed type, hydraulically and dynamically balanced and keyed to shaft.
C. Vertical In-Line Pumps:

1. General: Provide vertical in-line pumps where indicated and of capacities as scheduled. All pumps shall be bronze fitted.

2. Type: Vertical mount, in-line, close-coupled, single-stage, designed for 175 psi working pressure.

3. Body: Cast iron, 125 psi ANSI flanges of equal size, tappings for gauge and drain fittings.

4. Shaft: Steel with replaceable shaft sleeve.

5. Seal: Mechanical seal with ceramic seal seat.

6. Motor: Non-overloading at any point on pump curve, open, drip-proof, ball bearings, 15,000 hours bearing life, with lifting lug on top of motor.

7. Impeller: Bronze enclosed type, hydraulically and dynamically balanced, keyed to shaft and secured with locking screw.

D. Base Mounted End Suction Pump:

1. General: Provide base-mounted end suction pumps where indicated and of capacities and having characteristics as scheduled. All pumps shall be bronze fitted.

2. Type: Horizontal mount, single-stage, flexible coupling, base mounted, designed for 175 psi working pressure.

3. Casing: Cast iron, 125 psi ANSI flanges, tappings for gauge and drain connections.

4. Shaft: Steel with replaceable shaft sleeve.

5. Bearings: Regreasable ball bearings.

6. Seal: Mechanical, with carbon seal ring and ceramic seat.


8. Impeller: Bronze enclosed type, hydraulically and dynamically balanced, keyed to shaft and secured with locking screw.


10. Coupling: Flexible, capable of absorbing torsional vibration, equipped with coupling guard.

E. In-Line Recirculation Pumps:

1. General: Provide in-line recirculation pumps where indicated and of capacities as scheduled.
2. Type: Horizontal, oil lubricated, designed for 125 psi working pressure, 225 degree F (107 degree C) continuous water temperature and specifically designed for quiet operation.

3. Impeller: Bronze.

4. Body: Bronze or stainless steel construction.

5. Shaft: Steel, ground and polished, integral thrust collar.

6. Bearings: Two horizontal sleeve bearings designed to circulate oil.

7. Seal: Mechanical, with carbon seal face rotating against ceramic seat.

8. Motor: Non-overloading at any point on pump curve, open, drip-proof, sleeve bearings, quiet operating, rubber mounted construction, built-in thermal overload protection.


F. Positive Displacement Pump:

1. Type: Single stage, rotary gear.

2. Pumps: Cast iron casing hardened shaft with stainless steel sleeves and mechanical seal, seal-lubricating bronze bearings and integral by-pass type adjustable relief valve.

3. Drive: flexible couplings.

4. Base: Cast iron common mounting for pump and motor with drop rim and drain tapping.

G. Vertical Suspended Sump Pump and Sewage Ejector:

1. General: Provide above pit sump pumps as indicated, of size and capacity as scheduled.

2. Pump: Cast iron shell, stainless steel impeller for sewage ejector; bronze impeller for sump pump, stainless steel shaft, two factory sealed heavy duty grease lubricated sleeve bearings, elevated thrust bearing, ceramic mechanical seal, and perforated steel strainer.

3. Provide extended tubing for grease bearing service above basin cover.

4. Provide basin cover and pump support with access/inspection cover.

5. Controls:

   a. Wall mounted sump/sewage electrical control in a self containing NEMA 12 enclosure, two door type fabricated from not less than 14 gauge steel. Neoprene sponge door gasket seals sufficient to protect interior components from weather and dust. Electrical panel doors constructed from 12 gauge steel with integral latches.
b. All external operating devices shall be dust and weather proof. Provide operating handle for main power disconnects on the front of the panel. Mount internal components of the enclosures on removable back panels. Mounting screws for components shall not be tapped in the panel enclosure. Internal wiring within and interconnecting between, the panels shall be complete and no field wiring within the panels shall be required. Self contained wiring troughs and cable raceways within the enclosures. External cable traps or wiring troughs are not permitted.

c. Do not install pressure gauges, pressure switches, water activated devices or water lines of any sort in any electrical control panel. Panel shall include the following:

1) Low voltage control power transformer
2) Transformer primary and secondary shall be fused.
3) Nameplates shall identify the piece of equipment and respective function.
4) All pilot lights shall be of the push to test type.
5) Lamps shall be of the filament type and shall include 3-phase calibrated, adjustable class 10 overload relay including ambient compensated thermal overloads. They shall provide differential single-phasing protection.
6) H.O.A. for each pump.
7) Make termination of wires and cables at designated terminal blocks only. Identify control wiring as well as terminal blocks by abbreviated legends, clearly designating the equipment with which the wiring and terminal blocks are associated. Identify all wiring with heat shrink labels.
8) All panel wiring shall be type XHHW, stranded copper. Minimum control wire size shall be #14 AWG.

6. The pump and alarm controller shall provide full range differential control of two pumps, plus a high and low level alarm in response to an electronic, level-proportional signal. Provide automatic switchover in the event one pump fails.

7. The controller will have the capabilities of observing the level and making adjustments of the control form the face of the controller. The level will be displayed on a 40 segment LED bar graph. Level adjustments will be by means of plug-in programming pins.

8. An alarm silence push-button on the face of the controller with four LEDs across the top of the controller shall indicate the ON/OFF state of each pump and alarm control circuits.

9. Locate manual override switch on the face of the unit. This switch will allow the input level signal to be overridden to confirm the performance of the controlled equipment. The switch shall be a spring-return-to-center type with raise-auto-lower positions.
10. The controller shall measure 36 inch high by 45 inch wide by 10 inch deep. All job connections to be a clamp type barrier terminal.

11. One (1) Model A-100 submersible transducer constructed of PVC/Buna N, supported by wall or cover clamps. Transducer will start and stop pumps and give alarm function of high/low level alarm and water in wet well depth. Mercury and/or magnet type float will not be used. Alarm levels and pump start/stop settings will be field adjusted via the plug in programming pin on the control panel.

12. Provide field wiring of pumps, level transducer, moisture temperature sensor, remote alarm, and incoming power.

H. Spare Parts: Furnish one mechanical seal for each pump. Label seal with pump designation number.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions under which pumps are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to installer.

3.2 INSTALLATION, GENERAL

A. General: Install pumps where indicated, in accordance with manufacturer’s published installation instructions.

B. Pipe drain from bases and stuffing boxes to floor drains.

C. Discharge increasers shall be concentric and located at pump discharge nozzle. Suction piping reducers shall be eccentric (flat on top) and located at pump suction nozzle. Do not use horizontal elbows at pump suction.

E. Support pumps and piping separately so that piping is not supported by pumps. Provide support under elbows on pump suction and discharge line sizes 4 inches and over.

E. Access: Arrange pumps to provide access for periodic maintenance, including removal of motors, impellers, couplings, and accessories.

F. Install base-mounted pumps on minimum of 6 inch high concrete housekeeping pad equal or greater than 3 times total weight of pump and motor with anchor bolts poured in place. Set and level pump, grout under pump base with non-shrink grout.

G. Install in-line pumps using continuous-thread hanger rod and vibration isolation hangers of sufficient size to support pump weight independent of piping system.

H. Electrical Wiring: Install electrical devices furnished by manufacturer but not specified to be factory-mounted. Furnish copy of manufacturer’s wiring diagram submittal to electrical installer.

I. Verify that electrical wiring installation is in accordance with manufacturer’s submittal and installation requirements of Division 16 sections. Do not proceed with equipment start-up until wiring installation is acceptable to equipment installer.
J. Install line size isolation valves on both sides of pumps. The valve on the discharge side shall be a balancing type with “Memory Stop”.

U. Install flexible connections on suction and discharge sides of base-mounted pumps between pump casing and valves, unless grooved pipe and fittings are used.

3.3 TESTING, CLEANING, AND CERTIFICATION

A. Test, adjust, and balance pumps as specified in Section 15990.

B. Alignment: Check alignment and where necessary realign shafts of motors and pumps within recommended tolerances by manufacturer and in presence of manufacturer’s service representative.

C. Lubricate pumps before start-up. Start-up in accordance with manufacturer’s instructions.

F. Cleaning: Clean factory-finished surfaces. Repair any marred or scratched surfaces with manufacturer’s touch-up paint.

E. Qualified millwright shall check, align and certify base-mounted pumps prior to start-up.

F. Balance all base-mounted pumps to 1 mil P-to-P.

G. Certification, Pump Performance: Provide pumps whose performances, under specified operating conditions, are certified by manufacturer.

COMMISSIONING (DEMONSTRATION)

A. Training: Provide 2 hours of instruction to UC Denver representative for each pumping system provided.

3.5 SCHEDULES

END OF SECTION
SECTION 15170
MOTORS AND DRIVES

PART 1 - GENERAL

1.1 SUMMARY

A. This section provides standards for motors, drives and variable frequency drives for HVAC and mechanical equipment.

1.2 REFERENCES

Section 15000 - General Mechanical Provisions

B. Division 16, Sections as applicable

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. Provide mechanical/electrical coordination schedule on the drawings and coordination section in the specifications to clarify power and control wiring.

B. Altitude Deration: Motors shall operate within nameplate horsepower at 5000 feet elevation. Do not operate on service factor.

C. Energy Efficiency: Select and specify energy efficient motors with nominal efficiency equal to or greater than that stated in NEMA MG 1, for motor type and rating. Motors specifically manufactured for a particular piece of equipment with a lower efficiency shall be brought to the attention of the Project Manager.

D. On variable frequency drives (VFD) applications Provide motors rated for inverter-duty with attached steel nameplate indicating “Inverter-Duty Motor”

E. Use VFD’s to drive motors 1-1/2 horsepower or larger on variable flow systems

F. Starters: Starters shall be specified in Division 16. Consult with Electrical Engineer and ensure starters are scheduled and provided.

G. Motor drive sheaves shall be a minimum of one size smaller than the driven pulleys

H. Motor Control Centers:

1. Where a large group of starters can be centrally located, it will be beneficial to have these assembled in a motor control center (MCC) and specified in Division 16.

2. Where starters are specified in a MCC in Division 16, close coordination is required with the Electrical Engineer to make sure starters match specific motor requirements for part winding start, auto transformer type starting, wye/star-delta closed transition type or where two speed motors have been specified.

3. Provide adequate space in design for installation of field panels to contain relays and point cards for remote start-stop and status indication.

I. Manual Control:
1. Specify maintained-contact push buttons with pilot lights for single-speed or multi-speed operation.

J. Automatic Control:

1. Specify magnetic starters for motors 1/2 horsepower and larger and for smaller motors with interlock or automatic operation.

2. Specify auxiliary contacts if needed. Provide space for future.


4. Specify trip-free thermal overload relays for each phase. Size for 125 percent of rated load.

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submittals for the following shall be in accordance with Section 15000 and the following.

1. Submit motor literature showing nominal efficiency rating for each motor at rated load and voltage at an ambient temperature of 40 degree C.

1.6 QUALITY ASSURANCE

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

A. Provide option for an extended warranty package on variable frequency drive package including motor matched to drive.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Motors
   a. Baldor
   b. Magneteck
   c. Toshiba

2. Variable Frequency Drives: Purchase VFD and motor from one distributor. Drive manufacturers shall submit a list of acceptable motors for use with the proposed drive.
   a. Toshiba
   b. Siemens
   c. ABB
2.2 MATERIALS, GENERAL

A. Motor Frames and Mounts: Equip motor frames with two axis adjustments, namely slotted frame ends for adjusting in shaft direction and two adjusting screws for belt tensioning.

1. Motor sizes shall be large enough so that the driven load will not require the motor to operate in the service factor range.

2. Motors shall be capable of starting the driven equipment while operating at 90 percent rated terminal voltage.

3. Service Factor: 1.15 for poly-phase motors and 1.35 for single phase motors.


5. Provide inverter-duty motors specifically designed for variable speed operation with high efficiency at part load conditions an constructed with Class F insulation for equipment specified to operate with variable frequency drives.

6. Phases and Current characteristics: Unless indicated otherwise, provide squirrel-cage induction poly-phase motors for 3/4 hp and larger, and provide capacitor-start single-phase motors for 1/2 hp and smaller, except 1/6 hp and smaller may be split-phase type.

7. Provide motors for operation at 5000 foot elevation or higher.

8. Motors 1/2 hp and smaller to be single-phase. Motors larger than 1/2 hp to be 3-phase.

9. Motors 1-1/2 HP and larger shall be inverter-duty, high efficiency type with a minimum efficiency of 92% or higher in accordance with NEMA Standard MG1-12.55.

10. Match motor electrically to the drive (a package unit).

11. Motors for pulse-width modulating (PWM) drives will have both motor bearings isolated.

12. Motors, 5hp and lager, must be driven by PWM drives and have end bell brush type shaft grounding kits installed.

13. Bearings:

   a. Ball or roller bearings with inner and outer seals on sizes up to 1.5”. Ball or roller bearings with inner and outer shields on sizes greater than 1.5” shaft dia.

   b. Regreasable except permanently sealed where motor is normally inaccessible for regular maintenance.

   c. Sleeve type for light-duty, fractional horsepower equipment.

B. Drives:
1. Rated capacity of V-Belt drives shall not be less than 150 percent of motor nameplate horsepower.

2. Fixed pitch sheaves, including single groove fan sheaves shall be of the bushed type. No fixed pitch sheave shall be smaller than 3” dia.

3. Variable pitch sheaves are not allowed.

4. Provide OSHA approved belt guard with tachometer holes.

5. For equipment serving hazardous or critical systems such as fume hoods, and bio-hazards, provide fans with a minimum of two-groove sheaves and fan belts.

C. Variable Frequency Drives:

1. Drive shall convert constant frequency AC line voltage to a variable frequency, variable voltage AC output suitable for control of variable frequency, NEMA design B induction motor, with full-load amp rating between 10 percent and 110 percent of the drive full load current capability, without requiring modifications to the motor or drive.

2. VFD for motors shall have the following features.

   a. One motor per drive. No sharing of drive by two motors.

   b. Pulse width modulation.

   c. Enclosure type - NEMA 1. Provide bypass power and controls in separate enclosure.

   d. AC line fused disconnect or circuit breaker. Provide door interlock disconnect.

   e. AC line reactors in drive cabinet for protection against line notching and surges without requirement for an input isolation transformer. Minimum impedance of line reactors shall be 2.5 percent. Maximum total harmonic distortion shall not exceed 3 percent per IEEE. Input isolation transformers are not permitted.

   f. Metal oxide varistors on incoming line for transient protection.

   g. Manual speed potentiometer, HAND-OFF-AUTO switch and 4-20 milli-amp signal follower, fully isolated and suitable for grounded or ungrounded input signal.

   h. RS485 communication port and protocol capable of full communication with the Siemens FLN. The drive control should act as an application and allow monitoring and manipulation of points from the Siemens front-end software.

   i. Current Rating: A minimum continuous current rating of the VFD shall be a continuous ampere rating suitable for operation of a premium efficiency motor, VFD continuous amps shall not be less than the amps specified in NEC Table 430-150 for the specified horsepower motor.
Additionally, provide VFD to operate at 125 percent of design motor load. Overcurrent rating shall be 110 percent for one minute minimum.

j. Instantaneous overcurrent shutdown with indicator lamp when current exceeds 200% of nameplate values.

k. Inverse characteristic time-overcurrent overload protection for the motor sized in accordance with NEC requirements.

l. Drive shall be capable of withstanding random application of an output short circuit without damage to drive components or fuses.

m. Input phase loss and under voltage protection.

n. Torque/current limit control which will slow the motor without tripping when the motor is subjected to an overload, or slow the acceleration ramp when accelerating a high inertia load.

o. Automatic restart circuitry to restart motor after a momentary or sustained power failure, phase loss, or non-damaging fault trip. No more than 5 restart attempts should be allowed before lockout. Auto restart feature shall be switch defeatable. For fan applications, the VFD shall be capable of restarting into a spinning load.

p. Cabinet ground lug in VFD enclosure.

q. Troubleshooting diagnostic features of diagnostic fault display to show reason for trip. Display shall differentiate between: input under voltage, input phase loss or blown fuse, instantaneous overcurrent, sustained motor overload, heat sink over-temperature, over voltage, etc. Diagnostic test unit may be of the plug-in type, with one test unit provided for several VFDs. If plug-in type unit is provided, provide minimum of one for each building.

r. LED indicators, for all normal operation functions, including on-off status of all power SCRs or transistors, and bypass LED indication when the drive is in bypass.

s. Test mode switch to allow operation and setup of control electronics with power circuitry disabled.

t. Availability of critical speed avoidance option which could be added to VFD in the field at a future date.

u. UL listed.

v. Rated and sized for 5000 foot elevation operating condition.

w. Automatic soft start feature to start motor at lowest speed and ramp slowly up to required speed on start-up and for any abrupt increases in required speed.

x. Factory test of each unit for a minimum of 2 hours of burning at elevated temperatures of 122-176 degree F prior to shipping.
Bypass device (automatic and manual) to allow for total isolation of drive unit for service, while providing for temporary operation of motor. This shall include:

1) A main disconnect switch in the bypass enclosure with a door interlock handle which provides positive shutdown of all power to both bypass circuitry and VFD. The by-pass shall be in a separate enclosure from the VFD.

2) VFD output contactor and a constant speed contactor.

3) Three pole motor overload relay with heaters connected to shut down the motor in both VFD and bypass modes.

4) Timing relay adjustable 5-30 seconds to prevent rapid switching from bypass to VFD modes.

5) A control relay and terminal blocks which allows two-wire, start-stop control of motor from a single remote contact in both VFD and bypass (auto) modes.

6) Control relay and terminal blocks to allow connection of remote interlock shutdown contacts such as freeze stats, smoke detectors, etc. When this interlock loop is opened, operation of the motor shall be disabled in both VFD and bypass modes.

7) Four position oil-tight selector switch for VFD-OFF-BYPASS(AUTO)-BYPASS (MANUAL). Indicator lights on face of bypass panel with long life neon or transformer type incandescent bulbs to indicate "POWER ON", "MOTOR ON VFD", "MOTOR ON BYPASS CONTROL", "MOTOR OVERLOAD", "INTERLOCK SHUTDOWN".

8) 120 volt control power transformer with fused secondary and primary.

9) Bypass mode operation shall be independent of VFD control power.

10) Output contactor shall be wired to allow a controlled VFD deceleration ramp to stop.

11) Panel shall be arranged to allow power-off maintenance of VFD while motor is operating on bypass. Bypass circuitry in same compartment as VFD is not permitted.

Locate test switches, LED readouts or digital readouts on outside of panel.

Correction for long-lead length as pertains to over voltage problems at the motor will be the responsibility of the installer. Electrical correction will be implemented as required to achieve and maintain safe and smooth motor operation. Leads shall not be longer than 50 ft.
bb. Provide current transformers with adjustable, internal, current sensitive, normally open and normally closed contacts (one each), for Bypass, Drive, and motor contactor conductors (for status).

c
cc. At least two pre-set speed-control modes in drive circuitry.

dd. Disconnect at motor shall have auxiliary contact so that when disconnect is opened, the control circuitry to the drive will be interrupted.

e
ee. VFDs shall not be located inside the cabinets of controlled equipment.

3. Spare Parts: Provide one complete set of spare fuses for each VFD supplied.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. Motor Frames and Mounts:
   1. Check installations for "soft foot" conditions and shim appropriately.
   2. Mounts for adjustment of belt tension shall be of the two-pull variety.

B. Variable Frequency Drives: Install floor mounted variable frequency drives on 4-inch high concrete housekeeping pad.

C. Correction for long-lead length at the motor will be the responsibility of the installer. Electrical correction will be implemented as required to achieve and maintain safe and smooth motor operation.

D. Disconnect at the motor shall have auxiliary contact so that when disconnect is opened the control circuitry to the drive will be interrupted. Provided by Division 16.

3.3 TESTING, CLEANING, AND CERTIFICATION

A. Factory test variable frequency drives under simulated operation. Provide certification of factory test.

B. Testing: Test and start VFD’s and bypass under actual conditions by factory trained personnel. Operate VFD’s through its full range to determine resonant speeds, and program VFD’s to skip those speeds.

3.4 COMMISSIONING (DEMONSTRATION)

Start-up of variable frequency drive equipment shall be performed by factory authorized representative. Provide checklist certifying equipment startup and operation.

B. Training: Provide owner’s representative 2 hours of training by factory authorized representative for each variable frequency drive installed. Training includes startup, shutdown, emergency operation, maintenance and servicing.

3.5 SCHEDULES
END OF SECTION
SECTION 15190
MECHANICAL IDENTIFICATION

PART 1 - GENERAL

1.1 SUMMARY

A. This section provides standards for identification of mechanical products installed under Division 15.

1.2 REFERENCES

Section 15000 – General Mechanical Provisions

1.3 SYSTEM PERFORMANCE REQUIREMENTS

Assignment of equipment identification numbers will be made during the design phase in accordance with Manual Part 1.6.

1.4 DEFINITIONS

1.5 SUBMITTALS

1.6 QUALITY ASSURANCE

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Identification Devices:
   a. Seton Name Plate Company
   b. Marking Services, Inc.
   c. National Marker Co.

2. Paint:
   a. Benjamin Moore
   b. Devoe
   c. Glidden
2.2 MATERIALS, GENERAL

A. Plastic Pipe Markers
   1. Pipe labels that adhere to pipe or insulation surface with directional arrows.

B. Tags:
   1. Engraved anodized aluminum or engraved plastic, 2-inch diameter. Pre-punched and provided with brass chain.

C. Labels and Nameplates:
   1. Laminated three-layer plastic with black engraved letters on light contrasting background color, drilled for mounting with two sheet metal or brass screws. Pressure-sensitive embossed labels are not acceptable.

D. Paint Stencils:

   Use metal stencils only. No cardboard stencils are allowed.

   2. Size of Legend and Letters for Stencils:

<table>
<thead>
<tr>
<th>Insulation or Pipe Diameter</th>
<th>Length of Color Field</th>
<th>Size of Letters</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot; to 1-1/4&quot;</td>
<td>8&quot;</td>
<td>½&quot;</td>
</tr>
<tr>
<td>1-1/2&quot; to 2&quot;</td>
<td>8&quot;</td>
<td>¾&quot;</td>
</tr>
<tr>
<td>2-1/2&quot; to 6&quot;</td>
<td>12&quot;</td>
<td>1-1/4&quot;</td>
</tr>
<tr>
<td>Ductwork &amp; Equipment</td>
<td>N/A</td>
<td>2-1/2&quot;</td>
</tr>
</tbody>
</table>

E. Paint:

   Paint shall be the best quality grade regularly manufactured for the application.


F. Underground Plastic Line Markers:

   1. Multi-ply tape consisting of solid aluminum foil core between 2 layers of plastic tape, not less than 6-inches wide x 4 mils thick.

G. Valve Schedule Frames:

   1. Provide frames of finished hardwood or extruded aluminum, with non-glare glass.

H. Mount with screws for option to relocate if necessary.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL
A. Provide pipe identification, valve tags, stencils, or engraved name plates to clearly identify all mechanical equipment, including motors, piping and controls of the various mechanical systems and direction of flow in piping.

Tags:

Stamp tags with letter prefixes to indicate service, followed by a number for location in system.

C. Labels and Nameplates:

1. Attach nameplates with brass screws.

Labels and nameplates shall bear the same identifying legend as defined under paragraph 3.5 of this Section.

D. Painted Stencils:

Wipe pipes and equipment to be stenciled clean of dirt, dust, rust, grease and moisture.

Prepare surfaces and apply paint in accordance with paint manufacturer’s instructions.

3. Paint pipes and equipment with required color code. Paint on a smooth hard surface in the area the stencil is to be applied.

4. Perform stenciled markings neatly with no overspray, drips, or other imperfections.

E. Plastic Pipe Markers

1. On bare pipe when surface temperature exceeds 180 degree F provide a 1-inch thick insulation band under marker for protection from the hot pipe.

F. Piping, Ducts, and Equipment Identification:

1. Piping:

   a. Identify all piping accessible for maintenance in crawl spaces, tunnels, above ceilings, and access spaces as well as exposed to view utilizing stenciled markings according to the following procedures:

      1) Use an arrow marker for each pipe-content legend. The arrow shall always point away from the pipe legend and in the direction of flow. Color and height of arrow to be same as content legend lettering.

      2) If flow can be in both directions, use a double-headed arrow indication.

      3) Apply pipe legend and arrow indication at every point of pipe entry or exit where line goes through wall or ceiling cut.

      4) Apply pipe legend and arrow indication within 3 inch of each valve to show proper identification of pipe contents and direction of flow.
5) Apply legend to the pipe so that lettering is in the most legible position. For overhead piping, apply legend on the lower half of the pipe where view is unobstructed, so that legend can be read at a glance from floor level.


7) Legend on steam piping, condensate return, compressed air, gas, and vacuum systems: Include working pressure or vacuum.

2. Valves:
   a. System service valves located inside the building: Tag and identify as to type of service.
   b. Valves or cocks controlling branch mains or risers to various portions of the building: Tag and identified as to service and location.

3. Controls:
   a. Magnetic starters and relays: Install nameplates or stencil to identify connecting or controlled equipment.
   b. Manual operating switches, fused disconnect switches and thermal over-load switches which have not been specified as furnished with indexed face plates: Install nameplates or be stencil as to controlled equipment.
   c. Automatic controls, control panels, zone valves, pressure electric, electric pressure switches, relays, and starters: Clearly identified with unit served and function.
   d. Identify all starters, disconnect switches, and manually operated controls, except integral equipment switches with nomenclature corresponding to operating instructions in the "Operation and Maintenance Manual". Coordinate with UC Denver Facilities Operations personnel through the UC Denver Project Manager.

4. Fans:
   a. Label exhaust fans, air handling units and connecting ductwork supplying one or more areas from an equipment room or isolated crawl or furred space. Install nameplate or stencil as to plan code number, service and areas or zones served.

5. Pumps:
   a. Identify as to service and zones served.
   b. Install nameplate or stencil system served on base mounted pumps.
   c. Install brass tags secured by tie wires on small in-line pumps.
6. Storage Tanks, Water Treatment Equipment and Heaters:
   a. Stencil service on tanks and heaters
   b. Label connecting pipes and indicate the service temperature entering and leaving the tank or heater.

7. Air Conditioning Equipment:
   a. Equipment such as chillers, pumps, condensers, or rooftop equipment: Identified by stencils, or system nameplates. Labels of remote equipment shall also indicate the space(s) being served and the location of their electrical breaker (Panel ID, Room No. And Circuit).
   b. Identify locations of air handling devices which have filters and are above accessible ceilings by a blue circular dot or tack at least 3/4 inch in diameter, or embossed tape, adhered to the nearest T-bar.

8. Access Doors:
   a. Provide engraved nameplates or painted stencils to identify concealed valves, controls, dampers or other similar concealed mechanical equipment.
   b. Identify the locations of fire dampers above accessible ceilings with a red circular dot at least 3/4 inch in diameter, or embossed tape, adhered to the nearest T-bar. Access door shall be painted red.
   c. Obtain UC Denver Project Manager’s approval before installation on all access doors in finished areas.

9. Lift-Out Ceilings:
   a. Provide engraved nameplates on ceiling tee stem (screwed or riveted, adhesive not allowed) to identify concealed valves, filters, fire/smoke dampers or similar concealed mechanical equipment that is directly above nameplate in ceiling space.
   b. Obtain UC Denver Project Manager’s approval before installation.

10. Terminal Units:
   a. Identify all units with unique numbers corresponding to the drawings, and indicate the space being served.
   b. Use engraved plastic laminate labels affixed to each box by screws or rivets.

3.3 TESTING, CLEANING AND CERTIFICATION
3.4 COMMISSIONING (DEMONSTRATION)
3.5 SCHEDULES
A. Piping Identification:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Color of Field</th>
<th>The Campus Letters</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials Inherently Hazardous:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flammable or Explosive:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Yellow</td>
<td>Black</td>
<td>NG</td>
</tr>
<tr>
<td>Lab Waste</td>
<td>Yellow</td>
<td>Black</td>
<td>AW</td>
</tr>
<tr>
<td>Extreme Temperatures or Pressures:</td>
<td>Yellow</td>
<td>Black</td>
<td></td>
</tr>
<tr>
<td>Domestic Hot Water</td>
<td>Yellow</td>
<td>Black</td>
<td>Dom HW</td>
</tr>
<tr>
<td>Domestic Hot Water, Circulating</td>
<td>Yellow</td>
<td>Black</td>
<td>Dom HWC</td>
</tr>
<tr>
<td>Heating Water Supply</td>
<td>Yellow</td>
<td>Black</td>
<td>HWS</td>
</tr>
<tr>
<td>Heating Water Return</td>
<td>Yellow</td>
<td>Black</td>
<td>HWR</td>
</tr>
<tr>
<td>Low Pressure Steam</td>
<td>Yellow</td>
<td>Black</td>
<td>LPS</td>
</tr>
<tr>
<td>Low Pressure Steam Condensate</td>
<td>Yellow</td>
<td>Black</td>
<td>LPSC</td>
</tr>
<tr>
<td>High Pressure Steam</td>
<td>Yellow</td>
<td>Black</td>
<td>HPS</td>
</tr>
<tr>
<td>High Pressure Steam Condensate</td>
<td>Yellow</td>
<td>Black</td>
<td>HPSC</td>
</tr>
<tr>
<td>Boiler Feed Water</td>
<td>Yellow</td>
<td>Black</td>
<td>BFW</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>Yellow</td>
<td>Black</td>
<td>REF</td>
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<tr>
<td>High Pressure Compressed Air (over 90 psig)</td>
<td>Yellow</td>
<td>Black</td>
<td>CA</td>
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<tr>
<td>Materials of Inherently Low Hazard:</td>
<td></td>
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<td></td>
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<tr>
<td>Liquid or Liquid Admixture:</td>
<td>Green</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td>Distilled Water</td>
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<td>V</td>
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<td>White</td>
<td>CWS</td>
</tr>
<tr>
<td>Chilled Water Return</td>
<td>Green</td>
<td>White</td>
<td>CWR</td>
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<td>Condenser Water Supply</td>
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<tr>
<td>Condenser Water Return</td>
<td>Green</td>
<td>White</td>
<td>CR</td>
</tr>
<tr>
<td>Gas or Gaseous Admixture:</td>
<td>Blue</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td>Medium Pressure Compressed Air (30 to 90 psig)</td>
<td>Blue</td>
<td>White</td>
<td>CA</td>
</tr>
<tr>
<td>Low Pressure Compressed Air (less than 30 psig)</td>
<td>Blue</td>
<td>White</td>
<td>CA</td>
</tr>
<tr>
<td>Vacuum</td>
<td>White</td>
<td>Black</td>
<td>VAC</td>
</tr>
<tr>
<td>Fire Quenching Materials:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire Lines</td>
<td>Red</td>
<td>White</td>
<td>FL</td>
</tr>
</tbody>
</table>

B. Mechanical Equipment Naming Strategy:

1. Equipment identification numbers may be up to 32 characters. Equipment naming strategy is:

   System – Bld – Number
   
   ###-#####-##-###

2. The first three placeholders are reserved for the system designation (alpha characters)

3. The fourth character is a hyphen
4. The fifth through ninth placeholders are reserved for the building designation (alpha and/or numeric)

5. The tenth character is a hyphen

6. The eleventh through sixteenth placeholders are a “smart number.” It is composed of a two-digit, alpha or numeric, floor location designator followed by a hyphen and a three digit numeric sequential indicator.

7. The seventeenth character is a hyphen

8. In some instances the point name will be followed by a hyphen and a sub-point name

9. All device and point names will be assigned by the Facilities Operations, Building Operations Department.

10. All references to equipment and devices in drawings, labels, equipment tags, BAS system, etc., must use this naming convention.

11. Equipment designation, for prints may exclude the building designator.

END OF SECTION
SECTION 15250
INSULATION

PART 1 – GENERAL

1.1 SUMMARY
A. This section provides standards for insulation for mechanical piping, ductwork, and related equipment.

1.2 REFERENCES
A. Section 15000 - General Mechanical Provisions
   Section 15110 - Piping
   Section 15880 - Air Distribution

1.3 SYSTEM PERFORMANCE REQUIREMENTS
A. Provide minimum insulation thickness as suggested in ASHRAE Standard 90A.
B. If more than one type of insulation material is available for satisfying technical requirements, then price-performance should be evaluated and maximized in actual selection.
C. Weigh need to insulate unions, flanges, valves, control devices and similar items where maintenance access is needed. Give consideration to:
   - Energy conservation.
   - Where heat gain to space or ductwork is objectionable.
   - Where condensation must be prevented.
D. Provide removable insulation for chilled water pumps and specialty valves and fittings.

1.4 DEFINITIONS
A. Concealed: As used in this Section refers to insulation in ceiling plenums, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, unexcavated areas, and crawl spaces.
B. Exposed: As used in this Section refers to insulation that is not concealed.

1.5 SUBMITTALS
A. Submittals shall be made in accordance with Section 15000.

1.6 QUALITY ASSURANCE
A. Composite insulation, including jackets, coverings, sealers, mastics, and wet or dry adhesives shall have a flame spread rating of 25 or less and smoke-developed rating of 50 or less, as tested by ASTM E84.
B. Elastomeric foam with a smoke-developed rating of 150 or less may be used, except in ducts, plenums, and concealed spaces that are part of the air distribution system.

C. PVC fitting covers shall have a maximum flame spread of 25 or less and are exempted from the smoke spread criteria.

D. Duct liner shall comply with NAIMA Fibrous Glass Duct Liner Standard.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Insulation: Identification and/or type of material from a manufacturer is as shown under each heading of 2.2 Materials, General.
   a. Manville Products
   b. CertainTeed
   c. Rubatex
   d. Knauf
   e. Pittsburgh Corning

2. Adhesives, Coatings, and Sealants:
   a. Foster
   b. Childers Product Company
   c. Hardcast

2.2 MATERIALS, GENERAL

A. Pipe Insulation:

1. Glass Fiber:
   a. Rigid, molded, noncombustible, conforming to ASTM C547
   b. Thermal Conductivity (k value): 0.23 at 75 degrees F
   c. Maximum Service Temperature: 850 degrees F
   d. Vapor Retarder Jacket: Pressure sensitive, self-sealing tape lap system of white kraft paper reinforced with glass fiber yarn and bonded to aluminum foil.
e. Manville Micro-Lok, AP-T Plus, or equal.

f. Use high density insulation when insulating steam lines.

2. Hydrous Calcium Silicate:
   a. Rigid, molded block, conforming to ASTM C533.
   b. Asbestos-free, color-coded throughout material. Coding shall remain stable throughout rated temperature range.
   c. Thermal Conductivity (k Value): 0.40 at 300 degrees F.
   d. Maximum Service Temperature: 1,200 degrees F.
   e. Compressive Strength: Minimum of 160 PSI to produce 5% compression at 1-1/2 inch thickness.
   f. Tie wires: 16 gauge stainless steel.
   g. Manville Thermo 12/Gold, or equal.

3. Elastomeric Foam:
   a. Flexible, cellular, molded or sheet, conforming to ASTM C534.
   b. Thermal Conductivity (k value): 0.27 at 75 degrees F.
   c. Maximum Service Temperature: 220 degrees F.
   d. BBX, K-Flex acceptable for high temp applications to 300 deg F.
   e. Connection Adhesive: Waterproof, vapor retarding, Rubatex R-373, equal or better.
   f. UV protective coating: Water-based latex enamel paint. Rubatex 374, equal or better.
   g. Insulation Tape: Elastomeric thermal insulation tape with closed-cell structure.
   h. Rubatex R-180-FS/R-1800-FS, or equal.

4. Cellular Glass:
   a. Waterproof, closed cell, rigid insulating material composed of sealed glass cells conforming to ASTM C552.
   b. Thermal Conductivity (k value): 0.35 at 75 degrees F.
   c. Density: 8 pounds per cubic foot.
   d. Water-vapor Permeability: 0.005 perm-inch.
   e. Pittsburgh Corning Foamglass, or equal.

B. Field Applied Pipe and Fitting Jacketing:
1. PVC Plastic: One-piece, UV-resistant, 20-mil thick, molded type, gloss white finish with fiberglass insulation insert for fittings.
   a. Manville Zeston 2000 (indoors), or equal.
   b. Manville Zeston 300 (outdoors), or equal.

2. Aluminum:
   a. 0.016-inch thick sheet with smooth or embossed finish, longitudinal slip-joints with 2-inch laps.
   c. Fitting covers: Die shaped with factory attached protective liner.

3. Canvas:
   a. Plain weave cotton treated with fire-retardant lagging adhesive.
   b. Weight: 6 ounces per square yard.
   c. UL listed fabric.

4. Stainless Steel:
   a. 0.010-inch thick, type 304 stainless steel with smooth or corrugated finish.

C. Duct Insulation:

1. Flexible Fiberglass Blanket:
   a. ASTM C553, Type 1, Class B-3.
   b. Thermal Conductivity (k value): 0.25 at 75 degrees F.
   c. Density: 1.0 pounds per cubic foot.
   d. Vapor barrier jacket: Aluminum foil reinforced with fiber-glass yarn and laminated to fire-resistant Kraft (Foil Scrim Kraft).
   e. Manville Microlite, or equal.

2. Rigid Fiberglass Board: Not allowed.

3. Interior duct lining allowed only for sound attenuation at ventilation system terminal units. Insulation shall be installed only on the leaving side of the terminal box, and in quantities of less than six lineal feet.

D. Duct Jacketing:

1. Canvas:
b. Plain weave cotton treated with fire-retardant lagging adhesive.

c. Weight: 6 ounces per square yard.

d. UL listed fabric.

2. Outdoor Duct Jacketing:

a. Aluminum: 0.016-inch thick sheet with smooth or embossed finish, longitudinal slip joints with 2-inch laps.

b. Non water-vapor retarder: Non-burning, weatherproof coating, Manville Insulkote ET.

c. PVC plastic: 30mil thickness, UV resistant, Manville Zeston, 300 Series, or equal.

E. Duct Liner (allowed for sound attenuation only, 6 lineal feet, at leaving side of terminal units. Duct liner is not allowed in lab air supply):

1. Round Duct Liner:

a. Rigid material, conforming to ASTM C427.

b. Thermal Conductivity (k value): 0.23 at 75 degrees F.

c. Noise Reduction Coefficient: ASTM C423, minimum of 0.70 based on type-A mounting.

d. Velocity rating: Minimum of 4,000 feet per minute.

e. Manville Spiracoustic, or equal.

F. Equipment Insulation:

1. Flexible Fiberglass Blanket:

a. ASTM C612, Class 1.

b. Thermal Conductivity (k value): 0.24 at 75 degrees F.

c. Maximum Service Temperature: 450 degrees F.

d. Density: 1.5 pounds per cubic foot.

e. Vapor Retarder Jacket: Aluminum foil reinforced with fiber glass yarn and laminated to fire-resistant kraft paper.

f. Manville 812 Spin-Glas, or equal.

2. Rigid Fiberglass Board:

a. ASTM C612, Class 1 or Class 2.

b. Thermal Conductivity (k value): 0.23 at 75 degrees F.

c. Maximum Service Temperature: 450 degrees F.
d. Density: 3 pounds per cubic foot.

e. Vapor Retarder jacket: Aluminum foil reinforced with fiberglass yarn and laminated to fire-resistant kraft paper.

f. Facing: 1-inch galvanized hexagonal wire mesh stitched on one face of insulation.

g. Manville 814 Spin-Glas, or equal.

3. Rigid Fiberglass Board (High Temp):
   b. Thermal Conductivity (k value): 0.23 at 75 degrees F.
   c. Maximum Service Temperature: 850 degrees F.
   d. Density: 3 pounds per cubic foot.
   e. Facing: 1-inch galvanized hexagonal wire mesh stitched on one face of insulation.
   f. Manville 1000 Spin-Glas, or equal.

4. Cellular Glass:
   a. ASTM C552.
   b. Thermal Conductivity (k value): 0.35 at 75 degrees F.
   c. Density: 8 pounds per cubic foot.

5. Hydrous Calcium Silicate:
   a. Rigid, molded block, conforming to ASTM C533.
   b. Asbestos-free color-coded throughout material. Coding shall remain stable throughout rated temperature range.
   c. Thermal Conductivity (k value): 0.40 at 300 degrees F.
   d. Maximum Service Temperature: 1200 degrees F.
   e. Compressive strength: Minimum of 160 PSI to produce 5% compression based on 1-1/2 inch thickness.
   f. Manville Thermo-12/Gold, or equal.

G. Tank Insulation:
   1. Flexible Fiberglass Board:
      a. Thermal Conductivity (k value): 0.35 at 200 degrees F.
b. Maximum Service Temperature: 650 degrees F.
c. Density: 3 pounds per cubic foot.
d. Vapor Retarder Jacket: Pressure sensitive, self-sealing tape lap system of white kraft paper reinforced with glass fiber yarn and bonded to aluminum foil.
e. Manville Pipe and Tank Insulation, or equal.

H. Steam Valve Insulation:

1. Material:
   a. Insulation: 2-inch thick fiberglass with density of 6 pounds per cubic foot.
   b. Inner jacketing: Teflon coated Nomex cloth, equal or better.
   c. Gussets: Teflon coated Nomex cloth, equal or better.
   d. Outer jacketing: Teflon coated Nomex cloth, equal or better.
   e. Sewing Thread: Stainless steel using lock stitch with seven stitches per inch.
   f. Seam Fasteners: Teflon belts with stainless steel double D-rings and Velcro tabs.
   g. Terminal Ends: Teflon coated Nomex cloth flaps with Teflon coated Nomex cloth drawcord.
   h. Hardware: 304 stainless steel.
   i. Maximum Service Temperature: 500 degree F, wet or dry environment.
   j. Secure insulation within the jacketing with stainless steel quilt pins. Secure covers with cinch belts. Teflon belts with two stainless steel D-ring fasteners.
   k. Belts secured to cover with Velcro hook-and-loop fasteners.
   l. Advance Thermal Corporation, or equal.

I. Fire-stop Insulation:

1. Flexible blanket, amorphous wool:
   a. Thermal Conductivity (k value): 0.85 at 1000 degrees F and 1.70 at 1800 degrees F
   b. Continuous use-temperature rating: 1834 degrees F
   c. Melting point: 2327 degrees F
   d. Thickness: 1/2 inch or 2 inches.
e. Density: 6 pounds per cubic foot.

f. Thermal Ceramics SF607, or equal.

J. Fixed and Removable Valve Insulation:

1. Insulate valves, strainers and other equipment on steam, condensate, and hot water lines.

2. Steam and Hot Water Valves:
   a. 3 inch and larger: Insulate with removable insulation jacket.
   b. 2-1/2 inch and smaller: Do not insulate unless removable type is shown to be cost effective or effect of heat loss is shown to be detrimental.

3. Removable Insulation Jackets:
   a. 1 inch thick fiberglass insulation.
   c. Maximum Service Temperature: 1000 degree F.
   d. Secure with stainless steel quilting pins.
   e. Inner and Outer Jacket: Silicone coated fiberglass, 34 oz. per sq. yard, chemical resistant, suitable for temperatures to 500 degree F.
   f. Seam Closure: Teflon coated fiberglass threads suitable for temperatures to 600-degree F. of type 20 lb. Tensile strength.
   g. Fastening System: Type 304 stainless steel double D-rings with silicone coated fiberglass belts with Velcro on ends. 1-inch wide belt sewn to adjacent insulation, flanges, etc. Stainless steel wire cords, minimum 1/4 inch diameter and Teflon coated.
   a. Identification: Furnish type 304 stainless steel or aluminum I.D. tag riveted to jacket with item description, location and factory number.

K. Utility Vault Pipe Insulation

I. Steam and condensate line insulation
   a. Closed-cell fiberglass
   b. Required insulation thickness

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Insulation Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 8”</td>
<td>1-1/2”</td>
</tr>
<tr>
<td>10”+</td>
<td>2”</td>
</tr>
</tbody>
</table>

c. All insulation surfaces shall be protected by metal jacketing

2. Chilled water supply and return insulation
   a. Closed-cell fiberglass
   b. Required insulation thickness
### INSULATION

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Insulation Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;14”</td>
<td>1”</td>
</tr>
<tr>
<td>14”+</td>
<td>1-1/2”</td>
</tr>
</tbody>
</table>

### PART 3 – EXECUTION

#### 3.1 EXAMINATION

#### 3.2 INSTALLATION, GENERAL:

**A. Overview:**

1. Maintain highest level of workmanship. The appearance of the completed work is of equal importance to its technical performance.

2. Install insulation tightly over clean, dry surfaces free of foreign materials. Butt all edges firmly together.

3. Install insulation only after piping, ducts, and equipment have been tested and approved by the Project Manager, and after all other tests and certifications which are required by the specifications have been satisfactorily completed.

4. Continue insulation vapor barriers through penetrations except where prohibited by code.

5. Install pipe and duct insulation continuous through wall and floor openings except where the penetrated surfaces or assemblies are fire-resistance rated. Provide fire-stop insulation at penetrations of fire-rated surfaces and assemblies. Maintain fire-resistance ratings of penetrated surfaces and assemblies.

6. Install insulation on cold surfaces with a continuous, unbroken vapor seal. Insulate and vapor seal supports and anchors, which are directly secured to cold surfaces.

7. Seal all exposed raw edges of insulation with vapor retarder or finishing cement.

8. Do not use staples on vapor barrier jackets. Where staples must be used, thoroughly seal the vapor barrier penetrations with a white vapor-barrier finish. The Engineer prior to installation must approve use of staples.

9. Do not weld insulation support pins to pressure vessels.

10. Leave all insulation surfaces dry and clean, and ready for subsequent work.

**B. Installation of Piping Insulation:**

1. Install insulation and covers with seams in the least visible location.

2. Neatly finish insulation at supports, protrusions, and interruptions.

3. Verify piping wells and P & T taps are extended so that they will be flush with the surface of the finished insulation.
4. Insulated dual-temperature piping systems and for insulated piping conveying fluids of a temperature less than the ambient temperature: Install vapor-retardant jacket with self-sealing lap joints. Insulate the complete systems.

5. Insulated piping conveying fluids of a temperature greater than the ambient temperature: Install vapor-retardant jacket with self-sealing lap joints. Bevel and seal ends of insulation at equipment, flanges, and unions.

6. Piping conveying cold fluids: Insulate continuous through hangers. Install rigid insulation inserts at pipe hangers and supports. Butt inserts tight to insulation. Apply a wet coat of vapor-barrier lap cement on butt joints and seal the joints with three-inch wide vapor-barrier tape or band.

7. Install calcium silicate insert between support shields and piping for piping 1-1/2 inches and larger. Inserts shall not be less than the following lengths:

<table>
<thead>
<tr>
<th>Pipe Size Inches</th>
<th>Insert Length Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2</td>
<td>6</td>
</tr>
<tr>
<td>2 through 9</td>
<td>9</td>
</tr>
<tr>
<td>10 through 14</td>
<td>12</td>
</tr>
<tr>
<td>16 through 24</td>
<td>18</td>
</tr>
</tbody>
</table>

8. Exposed piping in mechanical equipment rooms and exposed piping within 10 feet of the finished floor in finished spaces: Install PVC jacket and fitting covers or aluminum jacket.

9. Exterior applications: Install PVC jacket and fitting covers or aluminum jacket over insulated pipe, fittings, joints, and valves. Locate jacket seams on bottom side of horizontal piping. Cover all valves, flanges, unions, accessories, and fittings with aluminum jacket. Seal jacket watertight and secure with lock type aluminum bands.

10. Refrigerant piping insulated with elastomeric insulation: Seal joints with elastomeric sealant made by same manufacturer as the insulation. For outdoor locations, paint insulation white or silver. Paint shall be compatible with the insulation.

11. Piping under concrete slabs on grade: Spiral wrap insulation with Protecto Wrap 200 coating (equal or better) with 50% overlap. Lay the insulated and wrapped piping on a 3-inch bed of sand and cover with 3 inches of sand all around.

C. Installation of Blanket Insulation:

1. Apply insulation with edges tightly butted. Overlap facing at least two inches at joints. Seal joint in vapor seal with fire-retardant adhesive. Secure insulation to duct with approximately four-inch wide fire-retardant adhesive spaced at 8 inches on center.
2. Ducts Exceeding 30 Inches in Width: Install mechanical fasteners at 18 inches on center for the underside insulation in addition to the adhesive. Cut off the protruding ends of the fasteners flush after speed clips are installed and seal with vapor tape or mastic.

3. Insulated ducts conveying air of a temperature less than the ambient temperature: Install vapor retardant jacket. Seal jacket seams and penetrations with UL listed tape or vapor retardant adhesive.

4. Insulated ducts conveying air of a temperature greater than the ambient temperature: Bevel and seal ends of insulation where service access is required.

5. Ducts Subject to Physical Abuse in Mechanical Equipment Rooms and Finished Spaces: Install PVC or aluminum jacket.

6. Outdoor Applications: Install insulation with a weather protection jacket.

D. Installation of Equipment Insulation:

1. Apply insulation as close as possible to equipment. Groove, score, and bevel insulation as necessary to achieve a tight fit. Secure insulation to equipment with studs, clips, pins, adhesive, wires, or bands as appropriate for the application. On cold equipment, do not use securing methods that penetrate the vapor barrier.

2. Fill joints, cracks, seams, and depressions with bedding compound. Form smooth surfaces. On cold equipment, use vapor retardant cement.

3. Insulated dual-temperature equipment and for insulated equipment that contains fluids of a temperature less than the ambient temperature: Install vapor retardant jackets.

4. Insulated equipment that contains fluids of a temperature greater than the ambient temperature: Install jacket with or without vapor barrier.

5. Cover insulation with metal mesh and finish with heavy coat of insulating cement, mastic, or aluminum jacket.

6. Do not insulate over nameplates, ASME stamps or UL labels. Bevel and seal insulation around nameplates and labels.

7. When equipment with insulation requires periodic opening for maintenance, repair, or cleaning, install insulation so that it can be easily removed and replaced without damage.

E. Installation of Insulation on Fittings and Valves:

1. Factory premolded one piece PVC insulated fitting covers: Use factory precut insulation applied to the fitting using two layers for pipe temperatures above 250 degrees F or below 35 degrees F, single layer insulation is acceptable between 35 degrees F and 250 degrees F. Tuck the ends of the insulation 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 seal at all seam edges with vapor tape or mastic.
barrier adhesive. Seal circumferential edges of all covers with pressure sensitive vinyl tape. The tape shall overlap the jacket and the cover at least one inch.

2. Where PVC covers are prohibited: Use as an alternate one of the following methods: aluminum covers, one coat insulation cement, premolded fiberglass fitting covers, or mitered segments of pipe insulation. Finish for non-PVC or aluminum shall be glass fabric embedded in fire retardant mastic lapped 2 inches over piping insulation. Finish with second coat of mastic. Mastic shall be vinyl acrylic mastic Childers CP-11 or equal for hot piping and shall be Childers CP-30 or Fosters 30-35 or equal 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 Childers CP-11 or equal for hot piping or shall be coated with vapor barrier mastic Childers CP-30 or Fosters 30-35, or equal for cold piping.

4. Insulate balancing cocks, strainer drains, hose bibs, and equipment requiring periodic maintenance with segmental insulating with an integral vapor barrier. Insulation and vapor barrier shall be easy to remove and replace.

F. Installation of Engine Exhaust and Breeching Insulation:

1. Install calcium silicate insulation on engine exhaust and breeching.

2. Install two layers of calcium silicate. Tightly butt and stagger joints. Secure with 16-gauge galvanized or stainless steel wire, or 1/2-inch by .015-inch galvanized steel bands. Install supports 12 inches maximum on center.

G. Installation of Tank Insulation:

1. Wrap insulation around tank and secure with self sealing longitudinal laps and butt strips, or all-purpose jacket with outward clinch expanding staples on maximum 4-inch centers. Remove two segments of insulation to provide for lap.

2. Cut circular sections for top and bottom of tank and insert inside of tank wrap.

3. Seal all longitudinal and circumferential joints with 3 inches wide pressure sensitive tape.

4. Apply vapor retarder mastic to all joints and staples.

H. Installation of Fire-stop Insulation:

1. Pack insulation into openings between fire-rated partitions where pipes and ducts penetrate. Compress to density recommended by manufacturer. Maintain fire-resistance ratings at penetrations of fire rated surfaces and assemblies.

2. Caulk with intumescent firestop caulk.

I. Installation of Steam and Hot Water Valves Insulation:

1. Provide custom fabricated insulated jackets for all valves and fittings.
2. Fabricate inner and outer jacketing for exposure to steam leaks on medium and high-pressure steam systems. Jacketing shall retain full flexibility after an exposure from minus 50 degrees F to plus 500 degrees F.

3. Construct and install covers to shed water. Locate closing seams at the gravitational bottom. Closely contour removable covers, ensure neat appearance and thermal performance. Individual covers or cover sequents shall not weigh more than 60 pounds.

3.3 TESTING, CLEANING AND CERTIFICATION

3.4 COMMISSIONING (DEMONSTRATION)

3.5 INSULATION SCHEDULES

A. Fiberglass:
### PIPE INSULATION SCHEDULE

<table>
<thead>
<tr>
<th>Fluid Design</th>
<th>Mean Rating Temperature</th>
<th>Nominal Pipe Diameter (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 and less</td>
<td>1-1/4 to 2</td>
</tr>
</tbody>
</table>

#### A. Heating Systems: Steam, Steam Condensate, and Heating Water

<table>
<thead>
<tr>
<th>Oper. Temp. Range (Deg. F)</th>
<th>Above 350</th>
<th>251-350</th>
<th>201-250</th>
<th>141-200</th>
<th>105-140</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>250</td>
<td>200</td>
<td>150</td>
<td>125</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>2.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>2.5</td>
<td>2.0</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>2.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>3.5</td>
<td>3.5</td>
<td>2.0</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

#### B. Domestic and Service Hot Water Systems including recirculation

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter (inches)</th>
<th>105 &amp; greater</th>
</tr>
</thead>
<tbody>
<tr>
<td>105 &amp; greater</td>
<td>100</td>
</tr>
</tbody>
</table>

#### C. Cooling Systems: Chilled Water, Brine, and Refrigerant

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter (inches)</th>
<th>40-55</th>
<th>Below 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-55</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>.75</td>
<td>1.5</td>
</tr>
<tr>
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<td>1.0</td>
<td>1.5</td>
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<tr>
<td></td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

#### D. Domestic Cold Water

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter (inches)</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
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<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

#### E. Roof Drain Bodies

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter (inches)</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

#### F. Roof Drainage, all horizontal runs

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter (inches)</th>
<th>1-1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2</td>
<td>1-1/2</td>
</tr>
<tr>
<td>1-1/2</td>
<td>1-1/2</td>
</tr>
<tr>
<td>1-1/2</td>
<td>1-1/2</td>
</tr>
</tbody>
</table>

#### G. Plumbing Vents, all horizontal runs
<table>
<thead>
<tr>
<th>Fluid Design</th>
<th>Oper. Temp. Range (Deg. F)</th>
<th>Nominal Pipe Diameter (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 and less</td>
</tr>
<tr>
<td>H.</td>
<td>Condenser Water Supply and Return</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>I.</td>
<td>Heat Recovery Water</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>J.</td>
<td>Piping Exposed to Freezing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-1/2</td>
</tr>
</tbody>
</table>

B. Elastomeric Foam:
<table>
<thead>
<tr>
<th>Fluid Design</th>
<th>Oper. Temp Range (Deg. F)</th>
<th>Mean Rating Temperature</th>
<th>Nominal Pipe Diameter (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 and less</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1-1/4 to 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2-1/2 to 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 &amp; 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8 &amp; up</td>
</tr>
</tbody>
</table>

A. Refrigerant Suction

|                         | 1 | 1 | 1 | 1 | 1 |

B. Refrigerant Hot Gas

|                         | 3/4 | 3/4 | 3/4 | ¾ | 3/4 |

C. Humidifier Piping

|                         | 3/4 | 3/4 | 3/4 | ¾ | 3/4 |

C. Duct Insulation Schedule:
### Flexible Fiberglass:

<table>
<thead>
<tr>
<th>Description</th>
<th>Thickness</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust ducts within 10 feet of exterior openings</td>
<td>1-1/2</td>
<td>Foil Scrim Kraft</td>
</tr>
<tr>
<td>Exhaust ducts exposed to outdoor air ventilation equipment casings</td>
<td>1-1/2</td>
<td>Foil Scrim Kraft</td>
</tr>
<tr>
<td>Supply ducts: Cooling systems</td>
<td>1-1/2</td>
<td>Foil Scrim Kraft</td>
</tr>
<tr>
<td>Return ducts in unconditioned spaces</td>
<td>1-1/2</td>
<td>Foil Scrim Kraft</td>
</tr>
</tbody>
</table>

### Rigid fiberglass:

<table>
<thead>
<tr>
<th>Description</th>
<th>Thickness</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion air ducts</td>
<td>3</td>
<td>All Purpose</td>
</tr>
<tr>
<td>Outside air intake ducts</td>
<td>2</td>
<td>Foil Scrim Kraft</td>
</tr>
<tr>
<td>Plenums: Cooling systems</td>
<td>2</td>
<td>Foil Scrim Kraft</td>
</tr>
<tr>
<td>Return and relief ducts in mechanical rooms</td>
<td>1-1/2</td>
<td>Foil Scrim Kraft</td>
</tr>
</tbody>
</table>

### Duct Liner:

<table>
<thead>
<tr>
<th>Description</th>
<th>Thickness</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Indicate applications] (Allowed only for sound attenuation after terminal units for six lineal feet)</td>
<td>1</td>
<td>Linacoustic or Permacote</td>
</tr>
</tbody>
</table>

### Equipment Schedule:

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible fiberglass blanket:</td>
<td></td>
</tr>
<tr>
<td>a. Heat exchangers/converters</td>
<td>1-1/2</td>
</tr>
<tr>
<td>b. Air separators</td>
<td>1</td>
</tr>
<tr>
<td>c. Chilled water pump bodies</td>
<td>1-1/2</td>
</tr>
<tr>
<td>Flexible fiberglass board:</td>
<td></td>
</tr>
<tr>
<td>a. Domestic hot water storage tanks</td>
<td>2</td>
</tr>
<tr>
<td>b. Chilled water pumps</td>
<td>1-1/2</td>
</tr>
<tr>
<td>Elastomeric foam:</td>
<td></td>
</tr>
</tbody>
</table>
a. Chiller cold surfaces: not factory insulated 1-1/2

5. Calcium silicate:
   a. Flue gas breeching 2+2
   b. Engine exhaust 2+2

END OF SECTION
SECTION 15300
FIRE PROTECTION

PART 1 - GENERAL

1.1 SUMMARY
A. This section provides standards for fire suppression systems.

1.2 REFERENCES
Section 15000 - General Mechanical Provisions
Section 15190 - Mechanical Identification

1.3 SYSTEM PERFORMANCE REQUIREMENTS
A. Automatic Fire Sprinklers:
   1. Zone system according to location. Annunciate each zone at the building fire annunciator in accordance with NFPA regulations. Provide separate zones for each flow switch and each tamper switches.
   2. Install recessed sprinklers in 8-foot ceilings. Provide wire guards on sprinklers, which protrude beyond the ceiling and are lower than 8 feet. Wire guards may be painted.
   3. The type of sprinkler to be installed must be specified and approved no later than final design completion.
   4. Consult the UC Denver CBO, through the UC Denver Project Manager, for fire protection and life safety concerns.
   5. Supply all connections to the fire system from the domestic water system through a reduced pressure backflow prevention device.
   6. Provide fire sprinkler systems for every building. Provide sprinklers throughout the building. Discuss areas without sprinklers with the UC Denver Project Manager.

B. System Design:
   1. General:
      a. Base design on requirements of NFPA 13, including Appendices.
      b. Verify fire hydrant flow test according to NFPA 13 and NFPA 291. Use hydrant flow results for system design calculations.
      c. Base design of sprinkler system on hydraulic calculations for group and occupancy listed in NFPA 13. Include outside hose flows upon the same hazard as the building. No allowance will be made for inside hose station flows. Include a safety factor of 10 psi in hydraulic calculations.
d. Room design method is not acceptable.

e. Size flow velocity in underground water mains not to exceed 16 feet per second. Size velocity in above ground sprinkler systems not to exceed 20 feet per second.

f. Protect all areas of each facility with an automatic sprinkler system unless specifically waved by the UC Denver Project Manager.

g. Provide a separate zone on each floor for buildings exceeding 3 floor levels including the basement.

2. Wet Pipe Systems:

a. Use wet pipe systems for the majority of system applications.

b. Use electronic vane type water flow detectors except for the following:

1. Alarm check valve assemblies may be used for systems installed in buildings if there is no approved fire alarm control panel installed and the system protects only one zone.

3. Antifreeze Systems:

a. Do not install antifreeze systems unless specifically approved in writing by the UC Denver Project Manager.

b. If these systems are proposed, only use them for incidental areas susceptible to freezing, as required.

c. Determine the feasibility and advantages of using other approved methods for protection of piping against freezing.

d. Include procedure in specifications for flow testing antifreeze systems without reducing antifreeze concentration.

4. Dry Pipe Systems:

a. Provide dry pipe systems in areas susceptible to freezing. Dry pipe systems are preferred over antifreeze systems. Condensate collector drain valve shall be full-port ball valve type.

b. Maintain air pressure by a nitrogen system or automatic air compressor powered from a dedicated circuit supplied from the building emergency circuit, where available. Use of a reliable plant air supply, in lieu of or in addition to an air compressor, is acceptable.

c. Monitor piping for low air pressure.

5. Pre-action Systems:

a. Provide pre-action systems as directed by the UC Denver Project Manager.

b. Supervise pre-action piping by an approved method.
c. Electronically release pre-action valve assemblies through an approved releasing panel. Coordinate the panel with Division 16 work.

d. Activate pre-action valve by means of automatic fire detection with manual release capability.

e. Space automatic fire detection devices according to NFPA 72. Detection method shall be by one or more of the following, as determined by the Engineer on specific project requirements:

1) Smoke Detectors
2) Heat Detectors
3) Loss of Air Pressure
4) Manual

f. Coordinate system activation method and sequencing with Division 16. Sequence of operation for valve actuation shall follow one or a combination of the following as determined by the Engineer:

1) Automatic Detector Signal
2) Cross-zoned or verified Automatic Detector Signals
3) Automatic Detector Signals and Loss of Air
4) Manual

6. Deluge Systems:

a. Provide deluge valve assembly, including valve, trim packages, and actuation system approved by Factory Mutual, as a complete assembly.

b. Detection systems can be pilot line or electronic as determined by the Engineer.

c. Provide a dedicated air supply system if pneumatic detection is incorporated into the design.

d. Space hydraulic or pneumatic heat detectors spaced according to NFPA 13 and manufacturer’s requirements.

e. Space fire detection in accordance with NFPA 72.

f. Provide approved agent releasing panel if deluge valve actuation is by electronic means.

7. Exposure Protection Systems:

a. Provide exposure sprinkler system with an independent supply from the vertical or main riser, prior to any other sectional controls, with a supervised control valve and distinctive flow detection.
b. Control systems incorporating open sprinklers by the operation of
detection devices designed for the specific application.

8. Standpipe Systems:

a. Design system as required by current State of Colorado approved
version of the NFPA and IBC.

b. Locate hose valves within the building stairway enclosures with
additional corridor locations as required, unless alternative locations are
approved by the UC Denver Project Manager in writing.

c. Provide approved roof manifolds where required by current State of
Colorado approved building codes or by the UC Denver CBO. Roof
manifolds shall be 4 inches in diameter, with two 2-1/2-inch gated
outlets. The interior control valve shall be operable from the roof
location. Provide accessible manual drains and automatic drip.

d. Hydraulically calculate standpipe systems.

9. Elevator and Electrical Equipment:

a. Comply with the requirements of ANSI A17.1 for the installation of
sprinkler systems in elevator machine rooms and shafts.

b. Where elevator equipment is provided with Phase I emergency service,
provide sprinkler protection in the elevator shaft and elevator machine
room. Sprinkler protection serving these areas shall be as follows.

1) Provide 286 degree F. sprinkler with guards, in elevator
machine rooms and hoistways.

2) Provide control valve with tamper switch outside elevator
machine rooms and shafts.

3) Provide one smoke detector in the vicinity of each sprinkler
for elevator recall. Coordinate between Division 15 and 16 for
proper detector and sprinkler locations.

4) Provide one 190-degree F. fixed temperature non-resetting
heat detector adjacent to each sprinkler. Heat detectors shall
automatically disconnect power to the elevator machinery and
the elevator controller.

5) Design elevator machine room and hoistway sprinkler system
as a separate zone with its own valves, flow switch and tamper
switch.

6) Protect each bank of elevators and associated equipment
rooms by an independent system unless determined otherwise
by the Engineer and approved by the UC Denver Project
Manager.

7) Protect transformer rooms by a pre-action sprinkler system.
Other systems may be approved on a case by case basis as
determined by the Engineer and approved by the UC Denver Project Manager.

10. Protection for Mechanical Shafts:
   a. Sprinklers are required in all shafts where shaft construction or contents are combustible or where the shaft is accessible by personnel. Sprinklers are not required for shafts housing a single duct which occupies the entire area of the shaft.
   b. Install sprinklers in shafts accessible for inspection, maintenance, or repair and replacement.
   c. Place sprinklers at the top of all shafts requiring protection. Additional protection may be required if the shafts have offsets.

11. Protection for Shafts Housing Hazardous Exhaust System:
   a. Provide sprinklers for protection of all shafts serving a special hazard exhaust system. Coverage is not required if the shaft is dedicated to special hazard exhaust systems, and the shaft is not accessible by personnel and is of fire resistive non-combustible construction and ductwork is completely non-combustible.
   b. Consult the UC Denver Project Manager in all situations.
   c. Refer to the appropriate NFPA standards for the design of sprinkler systems for special hazard exhaust systems such as paint spray operations or cooking exhaust.

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submittals for the following shall be made in accordance with Section 15000.
   1. Submit sample of each type and finish of sprinkler and escutcheon plate to be installed.
   2. Submit shop drawings showing all details as defined by NFPA 13. Show pipe routing and coordination of all building components.
   3. Submit hydraulic calculations including summary sheet, detailed work sheets, graph sheet, and water supply information as outlined in NFPA 13. Designer shall seal and sign hydraulic calculations, drawings, and work sheets.
   5. Submit copies of Contractor’s Material and Test Certificates similar to those in NFPA 13.

1.6 QUALITY ASSURANCE

A. Design shall be performed by a NICET Level III or IV Technician, Registered Fire Protection Engineer, or Registered Professional Engineer with experience in
fire protection design and registered for the design and installation for fire protection systems in the State of Colorado.

B. Installer shall have a minimum of five years of experience in the design and installation of automatic fire sprinkler systems and employ workmen experienced and skilled in this trade.

C. Installer shall have the capability of providing a full service maintenance, testing, and inspection program in accordance with NFPA standards and where applicable, be certified to perform these services.

D. Installer shall have an emergency service capability for response to emergency conditions and shall be capable of responding within four hours or receiving notification with 24 hour service capability.

E. Qualifications for Welding Processes and Operators: Comply with the requirements of AWS D10.9, Specifications of Qualifications of Welding Procedures and Welders for Piping and Tubing, Level AR-3.

F. Regulatory Requirements: Comply with the following codes:

1. NFPA 13 - Standard for the installation of sprinkler System.
2. NFPA 14 - Standard for the Installation of Standpipe and Hose Systems.
3. NFPA 24 - Installation of Private Fire Service Mains and their applications.
5. NFPA 1963 - Screw threads and Gaskets for Fire Hose Connections.
6. UL Compliance: Fire protection system materials and components shall be Underwriter’s Laboratories listed and labeled for the application anticipated.

PART 2 – PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Gate Valves:
   a. Nibco Inc.
   b. Mueller
   c. Grinnell
2. Butterfly and Ball Valves:
   a. Mueller
   b. Victaulic
   c. Nibco Inc.

3. Grooved Mechanical Couplings:
   a. Victaulic Company of America
   b. Gruvlok
   c. Or approved equal per Division 1 requirements.

4. Sprinklers:
   a. Central Sprinkler Corp.
   b. Viking Corp.
   c. Globe
5. Fire Protection Specialties:
   c. Guardian Fire Equipment, Inc.

6. Backflow Preventers:
   a. Febco
   b. Watts
   c. Hersey

7. Check Valves:
   a. Central Sprinkler Corp.
   b. Mueller
   c. Viking Corp

8. Fire Protection Specialty Valves (Dry, Pre-action, Deluge):
   a. Viking Corp.
   b. Central Sprinkler Corp.
9. Air Compressors:
   a. Emglo Products Corp.
   b. Gast
   c. Viking Corp.

10. Alarm, Flow, and Tamper Switches:
    a. Potter Electric Signal Corp.
    b. System Sensor
    c. Victaulic

11. Fire Department Connection:
    a. Croker
    b. Potter Roemer
    c. Elkhart
    d. Guardian Fire Equipment, Inc.

12. Inspector’s Test and Drain Module:
    a. Victaulic
    b. A.G.F.
    c. Grinnell/Gem

2.2 MATERIALS, GENERAL

A. Piping:

1. Black steel pipe for wet pipe systems and standpipes. Hot dipped galvanized pipe for dry pipe, pre-action and deluge systems.

2. Schedule 40 for pipe 2-inch and smaller and joined with threaded or cut grooved fittings.

3. Schedule 10 for pipe sizes up to 5 inch and 0.134 inches for 6 inch pipe for pipe joined by welding or roll grooved fittings.

4. Other pipe thickness is acceptable provided the pipe UL corrosion resistance ratio (CRR) exceeds 1.00. Schedule 40 black steel has a CRR of 1.0
5. Fittings: Provide hot dipped galvanized fittings for dry pipe, pre-action, and deluge systems. Threaded fittings are preferred in architecturally exposed or sensitive areas.

6. Do not use Copper pipe or fittings

B. General: Equipment shall bear the UL listing or FM approval for the intended use.

C. Valves:

1. General Requirements
   a. Suitable for a minimum of 175 psi. working pressure unless the project requirements demand higher pressures.
   b. Riser and Sectional Control Valves: Provide indicating type suitable for supervisory contact switch.

D. Check Valves:

1. 1-1/2 inch and smaller: All bronze with screwed ends.
2. 1 inch and larger: Iron or brass body.
3. Alarm Check Valve: Same size as riser. Provide with a retarding device.

E. Miscellaneous Valves:

1. Ball Drip Valves: Brass with 1/2 inch NPT.
3. Gauge Assembly Valves: 1/4 inch globe or angle 3-way valves with screwed bonnet and renewable composition disc.
4. Combination Test/Drain Valve: UL listed or FM approved.

F. Dry Pipe Valve:

1. Differential or latching differential type, sized by hydraulic calculations and supplied by pipe of equal or greater size.
2. Positive latching clapper.
3. Trim, accelerators, and exhausters provided by same manufacturer as dry pipe valve.

G. Pre-action and Deluge Valves:

1. FM approved as a complete assembly, including valve, trim packages and actuation system.
2. Sized by hydraulic calculations and supplied by pipe of equal or greater size. Valve trim includes manual control/activation capability, drain and test provision with trim for automatic operation via a 24-volt solenoid.

3. Valve wired normally closed.

H. Solenoid Release Valves:

1. Specifically listed and approved for fire protection systems and compatible with pre-action valve and fire alarm control panel.

I. Gauges:

1. Water Pressure: Brass bourdon tube with 3-1/2 inch diameter case rated for 300 psi water pressure in 5 pound increments. Equip with 1/4-inch shut-off valve.

2. Air Pressure: Brass bourdon tube with 3-1/2 inch diameter case rated for 100 psi air pressure in 1 psi increments. Equip with 1/4-inch shut-off valve.

J. Fire Department Connections:

1. Siamese connection, double 2-1/2 inch clapper, swivel plugs, and chain, threads matching local fire district equipment, and bronze escutcheon plate identifying system.

2. Single 2-1/2 inch, threads matching local fire district equipment. Use if the riser is less than 3-inches.

3. Interconnect multiple fire department connections so the entire sprinkler system is fed by each fire department connection.

K. Backflow Preventers:

1. General: Provide assemblies complete with manufacturer’s installed OS & Y control valves with indentation for monitoring and strainer on inlet. Pressure loss shall be 5 psig maximum through middle third of flow range.

2. Reduced pressure type: Use for fire suppression systems when chemical additives such as antifreeze are present or when untreated water may be pumped into the system.

3. Double check valve assembly type: Install on each automatic sprinkler and standpipe system at the base of the system riser downstream of the domestic water supply tap.

L. Fire Department Hose Valves for Standpipes:

1. Standpipes are NOT to have hoses and must be Class III, with 2 1/2 inch and 1 1/2 inch reducer (per NFPA 14, Section 3-3.3, exception 2).

2. Thread to conform to local fire department standard.

3. Stairwell standpipe connections are to be made on the intermediate landing, unless a vestibule is designed, in which case, place the connection in the vestibule (Note: per Aurora Fire Dept. Contact Campus Fire and Life Safety Officer if questions).
M. Sprinklers:

1. Nominal 1/2 inch orifice for “ordinary temperature classification except where higher temperature heads are required or shown.

2. Use quick response sprinklers where allowed by NFPA 13 and suitable for the specific project.


5. Non-finished areas: Brass finish, ordinary temperature rating.


7. Localized areas with potential for freezing: Dry pendant or dry pendant sidewall sprinklers.

8. Metal Cabinet and Spare Sprinklers: Extra heads and special sprinkler head wrenches enclosed in steel cabinet in accordance with NFPA 13. Extra heads provided shall include, as a minimum, 2 heads of each type and temperature rating installed.

9. Guards: Provide on sprinklers subject to damage or located within 7 feet of the floor, or as otherwise indicated for special conditions.

10. Spare Parts: Provide extra heads and special sprinkler head wrenches enclosed in steel cabinet in accordance with NFPA 13. Extra heads provided shall include as a minimum 2 heads of each type and temperature rating installed.

N. Electrical Equipment:

1. General: Electrical equipment, tamper switches, and devices must be compatible with the fire alarm system.

2. Supervisory Switches: Weatherproof switch housing, and cover with tamper resistant screws, automatic reset capabilities, and capable of being wired in normally open/closed position.

3. Water Flow Detectors: Electronic vane type or pressure activated, with field adjustable built-in retard device, tamper resistant screws. Switch to activate when flow of 10 gallons per minute or more occurs.

4. Low Pressure Supervisory Switches: Provide for dry pipe or supervised pre-action sprinkler systems. 1/2 inch NPT enclosure, field adjustable between 20 psi and 175 psi, weatherproof housing and cover with tamper proof screws.

5. Exterior Alarm Signals: Exterior electric bell with flashing strobe, minimum 6-inch diameter, and audible level of 85 dBA at ten feet. Mount above fire department connection at a height of ten to fifteen feet above grade.

O. Air Compressor:
1. UL listed and sized to replenish the system in 30 minutes. Provide with 20 gallon tank, air filters, safety relief valve, check valve, and pressure switch. Compressor rated for 90 psi. Obtain power from a dedicated circuit wired to the building’s emergency power system.

2. Piping: galvanized or copper.

P. Air Maintenance Device:

1. UL listed and approved for fire protection use.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. Pipe inspectors test valve discharge to a wastewater drain. Pipe main drain to a wastewater drain.

B. Coordinate the installation of fire protection materials and equipment above and below ceilings with suspension system, light fixtures, and other building components.

C. Where mounting heights are not detailed or dimensioned, install overhead fire protection services and equipment to provide maximum headroom possible. Install a minimum 1-1/4 inch threaded capped connection on the end of each cross main to facilitate flushing.

D. Do not attach the system riser to the supply connection until the underground piping is flushed, tested, and accepted by the Authority having Jurisdiction.

E. Conceal piping in all areas except mechanical rooms and areas noted on the drawings.

F. Install fire department hose valves no lower than 42 inches above the finished floor and no higher than 60 inches above the finished floor.

G. Install sight glasses on inspector’s test connections where discharge cannot be seen while valves are operated.

H. Terminate inspector’s test connection at a 45 degree elbow with a sprinkler which has the frame and strut assembly removed. Orifice size to be same as the smallest sprinkler installed on the system.

I. Pipe main drain to the outside of the building at a point free from causing water damage, terminating with a 45-degree elbow.

J. Install a concrete splash block with a minimum length of 4 feet to direct the drain or test discharge water away from the building.

K. Install tamper switches on all system shutoff valves.

L. Identification:
1. Valves: identify and label all sprinkler valves. Attach caution signs to all valves controlling water to sprinkler systems in accordance with NFPA 13.

2. Miscellaneous Fire Lines: Label inspector’s test drain lines, main drain, and fire lines.

3. Nameplate: Mount hydraulic designed information nameplate at alarm valve and include information in accordance with NFPA 13.

3.3 TESTING, CLEANING, AND CERTIFICATION

A. Record inspections and testing on a copy of Material and Test Certificates as shown in NFPA 13.

B. Prior to any test on sprinkler/standpipe systems, flush piping to remove any foreign matter.

C. Hydrostatically test all systems, including fire department connection, to not less than 200 psi for 2 hours. Read test pressure from gauge located at low point of system.

D. Additionally, test dry-pipe and pre-action systems with an air pressure of 40 psi which is allowed to stand 24 hours. Stop all leaks that allow a loss of pressure over 1-1/2 psi over 24 hours.

E. Correct leaks immediately. On threaded pipe, tighten joints. If necessary, dismantle and replace section. Caulking, preening, or stop-leak compounds are not permitted.

F. Test backflow preventer in accordance with state requirements by certified tester.

G. Function Trip Test:

1. Wet Pipe System: Functionally trip test system components and alarms by opening the inspector’s test connection.

2. Dry Pipe and Pre-action Systems: Functionally trip test system components and alarms by opening the inspector’s test connection. Maximum dry valve trip test time shall be 15 seconds from the time the inspector’s test valve is completely open. Maximum water delivery time to the inspector’s test shall be 60 seconds from the time the inspector’s test valve is completely open.

H. Provide backflow preventer state test certification.

3.4 COMMISSIONING (DEMONSTRATION)

A. Provide 4 hours of instruction to UC Denver Facilities Operations personnel. Include valve and drain locations, pipe routing, maintenance and testing procedures.

3.5 SCHEDULES

END OF SECTION
SECTION 15400
PLUMBING SYSTEMS

PART 1 GENERAL

1.1 SUMMARY

A. This section provides standards for plumbing systems.

1.2 REFERENCES

Section 15000 – General Mechanical Provisions
Section 15110 – Piping
Section 15190 – Mechanical Identification

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. Installer Qualifications: All plumbing work at the UC Denver shall be performed by a State of Colorado licensed contractor under the supervision of a licensed plumber. Contractors shall verify that plumbers are currently licensed by the State of Colorado and shall supply Project Manager with names and license numbers. Contractors shall have a minimum of 3 years of satisfactory performance in conducting the type of work specified.

1. The main sanitary sewer waste line under laboratory buildings shall be (poly pro) acid waste.

2. Provide vacuum breakers or backflow protectors on laboratory fixtures and other fixtures that present a hazard for possible contamination.

3. Provide a service sink with hot and cold water in mechanical rooms. If a water treatment station is located in the mechanical room, locate the sink within 3 feet, and include a combination emergency eye and body washing station.

4. Provide electric water coolers and drinking fountains at ADA heights. Provide duplex units with heights meeting ADA requirements and normal heights in public areas. Consider heights for children in special areas.

5. Fixtures: Provide battery operated, electronically sensing flush valves, with manual override, on core public area water closets and urinals.

B. Backflow Prevention:

1. Arrange water piping systems so back siphoning or backflow into domestic systems is not possible. Consider any water discharging through a faucet to which a hose would be attached potentially hazardous by reason of possible backflow from contaminated areas to which the open end of the hose might be exposed.

2. Install backflow prevention on all laboratory faucets and other points where cross contamination may occur in addition to backflow prevention at building supply.

3. Install backflow preventers on all feed lines to irrigation systems and heating and cooling systems.
4. Install a bypass BFP on the main building service for mains 1” and greater. It shall be sized to meet all critical building loads and be no less than 50% of the primary BFP.

5. Vertical BPFs are not acceptable.

C. Hose Bibs and Wall Hydrants:
   1. Provide a minimum of 1 domestic water, freeze-proof wall hydrant, per exterior wall, with loose key type handles at outside locations near entrances to a building for wash down and UC Denver Grounds use. Wall hydrants shall have integral backflow preventers. These should be located as inconspicuously as possible consistent with accessibility. Provide separate shut off valve inside.
   2. Provide hose bib with integral backflow preventer at all major equipment locations in mechanical rooms, on roofs and close to cooling towers.

D. Kitchen Grease Traps:
   1. Avoid interior locations for kitchen grease traps. If required, provide an engineered unit sized to accommodate area served. Locate grease traps outside for easy truck access and servicing, and properly vented.

E. Domestic Hot Water Heaters:
   1. Where steam is available, provide an instantaneous steam heat exchanger.

1.4 DEFINITIONS

1.5 SUBMITTALS
   A. Submittals shall be made in accordance with Section 15000.

1.6 QUALITY ASSURANCE
   A. Codes and Standards:
      1. Meet the requirements of the Uniform Plumbing Code.
      2. Meet the requirements of national laws regarding ADA accessibility, energy and water conservation.

DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 – PRODUCTS

2.1 MANUFACTURERS
   A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:
      1. Lavatories, Sinks, Service Sinks, Water Closets, Urinals:


a. American Standard U.S. Plumbing Products

b. Crane Co.

c. Kohler Co.

d. Eljer

2. Stainless Steel Sinks:


c. Moen; Div. Of Stanadyne

d. Eljer

3. Molded Tubs and Shower Units:

a. Fiat Products

b. Kohler Co.

c. Eljer

4. Faucets:

a. Chicago Faucet Co. (preferred)

b. American Standard; U.S. Plumbing Products

c. Zurn

5. Auto Faucets

a. Sloan Valve Co (preferred)

b. Zurn

6. Flush Valves:

a. Sloan Valve Co. (preferred)

b. Delany

c. Or approved equal per Division 1 requirements.

7. Auto Flush Valves

a. Sloan Valve Co (preferred)

b. Zurn
c. Delany

8. Water Closet Seats:
   b. Beneke Corp.
   c. Olsonite Corp

9. Water Coolers:
   a. Elkay
   c. Haws Drinking Faucet Co.

10. Service Sinks:
    a. Crane Co.
    b. American Standard
    c. Kohler Co.
    d. Eljer

11. Fixture Supports:
    b. JR Smith
    c. Zurn

12. Shower and Tub Trim (Thermostatic):
    a. Bradley
    b. Powers
    c. Speakman

13. Shower and Tub Trim:
    a. American Standard
    b. Kohler
    c. Chicago Faucets

14. Emergency Showers, And Eye/Face Washes:
    a. Guardian Equipment
b. Haws Drinking Faucet Co.
c. Bradley

15. Food Waste Disposers:
a. In-Sink-Erator
b. Waste King
c. National

16. Hose Bibs and Faucets:
a. Zurn
b. Woodford
c. Watts Regulator Co.

17. Venturi Flow Measuring Elements:
a. FDI (preferred)
b. HCI
c. Gerand

18. Calibrated Balancing Valves:
a. FDI (preferred).
b. HCI
c. Gerand

19. Automatic Balancing Valves
a. FDI (preferred)
b. Griswold
c. Approved equal

20. Wall and Yard Hydrants:
c. Woodford Mfg. Co.

21. Water Hammer Arresters:
a. Woodford
c. Watts Regulator Co.

22. Instantaneous Steam-Water Heaters:
   a. Leslie (preferred)
   b. Spirax Sarco
c. Grahm

23. Backflow Preventer Equipment:
   a. Watts Regulator Co. (Preferred)
   b. Combraco
c. Febco Sales
d. Wilkins

2.2 MATERIALS, GENERAL

A. Fixtures and Trim:
   1. All vitreous fixtures shall be of a quality commercially known as 'Twice-Fired Vitreous China'.
   2. All enameled ware shall be cast-iron with 'Acid-Resisting Enamel'.
   3. Water Closets: Wall mounted or wall-hung type. Floor mounted fixtures permitted on a special need basis. Tank type fixtures are not allowed.
      a. General: White, vitreous china, water saving siphon jet, elongated rim, wall-hung water closet, limited to 1.6 gallons per flush.
      b. Miscellaneous Requirements or Accessories:
         1) Seat: White plastic, open front seat less cover, with check hinge.
         2) Flush valves: Chrome plated valve with vacuum breaker and 1-inch screwdriver stop with vandal resistant protective cap and adjustable tail piece.
         3) Carrier: Commercial carrier with adjustable face plate and fittings.
   4. Urinals:
      a. General: White, vitreous china, siphon jet urinal with integral extended shields, flushing rim.
b. Miscellaneous Requirements or Accessories:
   
   i. Carrier: Commercial carrier with top and bottom plates.
   
   ii. Flush valve: Chrome plated valve with vacuum breaker, 1-inch screwdriver angle stop with vandal resistant protective cap and adjustable tailpiece. Limited to 1.0 gallon per flushing cycle.

5. Lavatories:
   
   a. General:
      
      1) Vitreous china, self-rimming counter top 20" x 17" lavatory.

      2) Vitreous china, self-rimming wall hung 20" x 18" lavatory with back splash.

6. Stainless Steel Sinks: 18 gauge 304 stainless, self-rimming, single or double compartment sink.

7. Showers:
   
   a. Fiberglass: Reinforced plastic shower stall with integral molded base and 2 inch drain fitting and chrome plated strainer. Provide with additional reinforcement for grab bars.

   b. Terrazzo: Precast terrazzo shower floor with single threshold and 2 inch integrally cast stainless steel drain with removable stainless steel strainer.

8. Utility Sink: Acid resistant, enameled cast iron, wall mounted high back sink with wall hangers and stainless steel rim guard; 3 inch cast iron P-trap with enameled interior, painted exterior, floor bracket and chrome plated brass sink strainer with open grid drain.

9. Mop Service Basin: Precast terrazzo, service basin with 3 inch integrally cast brass or stainless steel drain with removable strainer. Provide stainless steel guards on all sides.

10. Emergency Eye Wash: Wall mounted, vitreous china or stainless steel receptor with mounting bracket, twin chrome plated heads angled to direct water flow into eyes and ocular face area. Provide flag push-type ball valve to stay open until manually closed.

11. Emergency Shower: Ceiling mounted, 10 inch diameter deluge shower head. Rigid triangular pull-rod to actuate instant-action stay-open ball valve.

12. Combination Emergency Shower and Eye Wash: Floor mounted, free standing, all chrome plated brass construction with 10 inch diameter deluge shower head and eye wash bowl. Shower shall have rigid pull rod to actuate instant-action stay open ball valve. Eye wash shall have twin anti-squirt heads angled to direct
water flow into eyes and ocular face area with flag push-type ball valve actuator, valve to stay open until manually closed.

B. Water Coolers:
   1. Self-contained, wall mounted, stainless steel, mechanically cooled, drinking fountain. Minimum cooling capacity of 8 gallons per hour of 50 degree F drinking water at the inlet water and room ambient temperatures of 80 degree F with adjustable water temperature control. Equip drinking fountains with handicapped fittings. Care shall be taken to specify fountains with basins and spouts to minimize dripping, etc. on floor. Provide with commercial carrier.

C. Domestic Hot Water Heaters:
   1. Instantaneous heaters shall have feed-forward control. Selection shall be based upon 2 to 15 psig inlet steam, ductile iron shell with copper coils.
   2. Floor mount instantaneous water heaters on custom fabricated frames made of 1-1/2 inch angle iron, and all components shall be contained within the outside dimensions of the skid frame.
   3. Valve plugs shall be manufactured of Hastaloy C with finishes <16 RMS.
   4. Pins and retainers shall be constructed of Monel or Stainless steel.
   5. Final selection will be based on space requirements, hot water requirements, and steam availability.
   6. Electric Storage tank water heaters are unacceptable.

D. Trap Primers: Bronze body valve with automatic vacuum break and 1/2-inch connection to domestic water. Operation shall be by time clock initiation of electric solenoid valve.
   1. Neoprene sleeve trap guards are not acceptable.

E. Automatic Flow Control Valves (Flow Limiting Devices)
   1. The GPM for the automatic flow control valves shall be factory set and shall automatically limit the rate of flow to within 5% of the specified amount.
   2. For 1/2” - 2”, the flow cartridge shall be removable from the Y- body housing without the use of special tools to provide access for regulator change-out, inspection and cleaning without breaking the main piping. (Access shall be similar to that provided for removal of a Y-strainer screen).
   3. The maximum pump head for the automatic flow control valve shall be limited to 7 feet.
   4. Each valve shall have two P/T ports.
   5. All automatic flow control devices shall be supplied by a single source and certified flow tests, witnessed by a professional engineer, shall be available.
   6. Five year product warranty and free first year cartridge exchange.

F. Manual Calibrated Flow Control Valves
   1. Manual balancing devices shall be venturi type as recommended by ASHRAE.
   2. Devices shall have a precision formed throat and have a stated catalog accuracy of 3% F.S.
   3. The induced differential reading (flow signal) shall be greater than two feet water column at the design flow with the valve in the wide-open position.
   4. The permanent pressure loss at design flow shall not exceed two feet of water in the wide-open position.
5. The valves are to have differential readout ports fitted with check valve and protective cap, and are to have a memory stop to allow complete shut-off and return to set position without losing the set-point.

G. Spare Parts: Provide one valve key for each key operated wall hydrant, post hydrant, hose bib, or faucet installed.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

3.3 TESTING, CLEANING, AND CERTIFICATION

A. Provide copies of State backflow preventer certification tests.

3.4 COMMISSION (DEMONSTRATION)

3.5 SCHEDULES

END OF SECTION
SECTION 15480
SPECIAL PIPING SYSTEM

PART 1 – GENERAL

1.1 SUMMARY

A. This section includes standards for special piping systems.

1.2 REFERENCE

Section 15000 – General Mechanical Provisions

Section 15110 – Piping

SYSTEM PERFORMANCE REQUIREMENTS

B. HVAC Control Air Systems:

1. Control air shall be provided from individual building air compressors. Control air compressors shall be oil free dual motor/compressor type rated at 150%.

2. Control air must be clean and dry. Compressor must be filtered and dried. Specify a refrigerated dryer and filter system for compressors. Provide bypass piping and valves for servicing dries and filters and tank with control air system in operation.

C. Process or Lab Air System:

1. Process air is not available from a campus central air system. A building duplex compressor will be as the preferred source.

2. Process air compressors shall be selected to operate with a receiver pressure of 125 to 150 psig with pressure reducing valve to the designated system operating pressure. Install a pressure relief valve on all reduced pressure systems, set for 25 psig over reduced pressure.

3. Piping systems shall be zoned appropriately and be provided with zone isolation valves. Compressed air piping should be sized on the basis of number of outlets, using a figure of 0.5 cfm at 40 psig per outlet. Diversity will vary from 100% simultaneous use in student labs to 20% to 30% in research labs. System loss should not exceed 5 psig loss at estimated demand. Any continuous demands shall be to the above quantities.

Vacuum Piping System:

1. Vacuum piping should be sized on the basis of inlets. Use a figure of 1 cfm per outlet and 40% simultaneous use for typical laboratory rooms.

2. Friction loss should not exceed 5 inches of mercury column drop at estimated demand of system. The above should be modified to meet special conditions and types of rooms or service.

Distilled or Deionized (DI) Water Systems:
1. Laboratory areas may require DI (distilled) water systems. The water still may be provided by the Department or furnished by the project. The still may be steam or electric powered depending upon demand and availability of steam. Utilities shall be provided by the project to the still which include domestic cold water, electrical power and steam. The distribution system shall be polypropylene Schedule 40 piping from tank to laboratory benches with appropriate gooseneck faucets made of, or lined with, polypropylene or other inert material. Isolation valves shall be provided at all branches for servicing and all DI water outlets.

2. Laboratory areas may require DI (deionized) water systems. The distribution system shall be polypropylene pipe with socket weld fuse joints with mechanical joints on all service branches. The DI cartridge systems will be provided and serviced by a vendor under existing purchase order contracts. The quantity and quality of DI water shall be established by the user in cooperation with the vendor through the UC Denver Project Manager. Utilities shall be provided by the project to the DI system which includes domestic cold water and an electrical power outlet. Sometimes the DI system will be located in laboratories other times it may be centrally located in an equipment room. The distribution system shall be polypropylene Schedule 40 piping to laboratories with appropriate gooseneck faucets made of, or lined with, polypropylene or other inert material. The system will be under domestic water pressures or pump pressure if not a gravity feed system to supply the system with specified psi at each user point. Isolation valves shall be provided at all branches for servicing and all DI water outlets.

3. Systems shall be automated to produce water within the required parameters. There shall be no less than 5 gpm at 40 psi pressure at every user point. All equipment and piping will be ozone compatible with isolation valving at each service branch. All deionizing tanks shall be exchangeable for off-site recharging to include a backup bank of tank(s) with valving on a hard-piped manifold. Controls will be electro-mechanical in nature, with user serviceable parts. A dry contact for “no flow” alarm will be provided for connection to BAS systems. Pumps shall be stainless steel in construction. All control panels must be UL Listed and enclosures will be NEMA-4 rated. Isolation valving must be installed so any serviceable part can be bypassed and serviced without a total shutdown of the system. Pressure gauges will be installed at inlets and outlets of filters and pumps which will be user serviceable with a gpm gauge for a running total of DI water produced. Storage tanks will be Ester resin, FRP type. A spare parts list will be furnished with each installation, including a list of sources for their purchase.

DEFINITIONS

SUBMITTALS

A. Submittals shall be provided in accordance with Section 15000.

QUALITY ASSURANCE

DELIVERY, STORAGE, AND HANDLING

WARRANTY

PART 2 PRODUCTS
2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. DI faucets: Cambridge Brass, or equal

2.2 MATERIALS GENERAL

A. HVAC Control Air Systems Piping:

1. Control air piping shall be hard drawn type “L” copper tubing with wrought copper fittings and 50/50 soldered joints. Polyethylene tubing “FR” (flame retardant and self-extinguishing) can only be for terminal connections to devices with a maximum length of 18 inches and within control cabinets, enclosed raceways or conduits.

B. Process or Lab Air System Piping:

1. All process or lab air lines shall be Type “L” copper with brazed joints, with silver braze material.

2. All process or lab air piping to be silver soldered.

D. Vacuum Piping:

1. All vacuum piping shall be Type “L” copper with brazed or soft solder joints.

PART 3- EXECUTION

3.3 EXAMINATION

3.4 INSTALLATION, GENERAL

A. Plumbing: No lead solder shall be utilized.

B. All piping installed per most recent UPC.

3.5 HVAC Control Air Systems:

A. Provide instrument air tubing with check and hand valves to expansion tanks with Schraeder fittings and hose.

B. Leak-test the pneumatic system mains to 150% of maximum system pressure for 24-hours. Check calibration of instruments. Recalibrate or replace.

3.6 TESTING, CLEANING, AND CERTIFICATION

A. All process or lab air system piping shall be sterilized prior to use.

3.7 COMMISSIONING (DEMONSTRATION)

3.8 SCHEDULES

END OF SECTION
SECTION 15500
SPECIAL HEATING, VENTILATING AND AIR CONDITIONING (HVAC)

PART 1 - GENERAL

1.1 SUMMARY
A. This section provides standards for special heating, ventilating, air conditioning and exhaust systems.

1.2 REFERENCES
A. Section 15000 – General Mechanical Provisions
B. Section 15850 – Air Handling
C. Section 15880 – Air Distribution
D. Section 15990 – Testing, Adjusting and Balancing

1.3 SYSTEM PERFORMANCE REQUIREMENTS
A. Certain operations require special HVAC systems consisting of filtration, humidity control, special exhaust systems, or different temperature settings than surrounding spaces. These areas may include, autoclaves, lab equipment, print shop equipment, machine shop equipment, carpentry shop equipment, metal working shops, and laboratories involved in higher level chemical, biological, and radioactive material experimentation. Work with the UC Denver Project Manager to identify these areas and determine appropriate design parameters.

B. Notify the UC Denver Project Manager of all modifications affecting supply and exhaust air in animal rooms, laboratories, environmental chambers, confined spaces, trailers, office spaces, darkrooms, and buildings or spaces being renovated or modified for special occupancies.

C. Obtain a complete list of the chemicals and gases to be used and stored in laboratories. Use this list to determine fume hood exhaust for flammability, toxicity, corrosiveness, and explosion hazards.

D. If perchloric acid is used, provide a specialized, dedicated hood constructed of stainless steel, porcelain coated, or non-plasticized PVC lined. Label hood “for perchloric acid use only”. Provide the hood with its own non-reactive duct and exhaust fan and built-in water wash-down system.

E. Provide galvanized steel, aluminum, PVC coated, or stainless steel ducts for ventilating bio safety cabinets, chemical fume hoods and flammable storage cabinets. Design and install systems to ensure that hoods and ducts are under negative pressure all the way out of the building.

E. If a hood is tied into an existing central exhaust system serving multiple fume hoods, then the air system will need to be evaluated to determine if it has sufficient capacity for the addition of other exhausted equipment.

F. Provide make-up air to compensate for the air being exhausted. The location and volume of make-up air is critical to assuring proper fume hood operation and worker protection.
G. Laboratories - General:

1. Select exhaust fans in a common system to be capable of providing 30 percent extra capacity and pressure. The speed increase shall not exceed the safe recommended speed as specified by the manufacturer of the device.

2. Provide laboratory with 100% exhaust.

3. Where surrounding structures, building air intakes, public gathering places, or other areas may pocket or concentrate chemical exhaust contaminants from the exhaust systems, then the exhaust shall be treated to minimize point source air contamination by using a high plume dilution exhaust fan.

4. Locate laboratory supply air grilles to prevent unwanted cross drafts around specialty equipment such as chemical fume hoods, biosafety cabinets, and atomic absorption spectrophotometers. Airflow shall move from the entrance of the lab towards the lab hood.

5. Maintain lab and entry vestibule under negative pressure.

6. Maintain the lab more negative than the vestibule.

7. Equip hoods with audible and visual low-flow alarm set to alarm at 75-fpm face velocity.

8. Provide emergency backup power on hazardous exhaust systems and do not shut down upon activation of any alarm. Provide dedicated switches in the building fire alarm panel to allow capability for manual fan shutdown by the fire department.

H. Laboratory HVAC Control: The laboratory control system shall perform the following functions:

1. Hood face velocity

2. Laboratory pressurization

3. Laboratory temperature control

4. Proper air distribution

5. Pressurization (either positive or negative) shall be maintained by airflow based on the formula:


   b. Supply cfm: Air supplied to the space to maintain temperature and provide make-up.

   c. Exhaust cfm: Air leaving the space either through the hood’s exhaust or through the general exhaust.

   d. Offset: Is an arbitrary amount set to provide pressurization.
6. The lab controller (programmable) shall receive inputs from all controlling devices and provide outputs to control the lab’s environment.

I. Standard Laboratories - Biosafety Level 2:

1. Provide 30% reserve capacity in new HVAC systems design to accommodate future research needs and help retard system obsolescence and minimize overall capital outlay.

2. Laboratory air circulation shall comply with ASHRAE standards.

3. Maintain all laboratories under negative pressure of 0.03 to 0.05 inches water gauge relative to adjacent areas.

4. Design laboratory exhaust air grilles with inflow air velocity rates ranging between 500 and 700 linear feet per minute.

J. Standard Laboratories - Biosafety Level 3 (BL3):

1. Design in accordance with the Campus standard “Biosafety Level (BL3) Construction Standards.” Copies of this standard are available from the UC Denver EH&S.

K. Photography Darkroom: The Kodak K-13 photo darkroom design standard shall be used as a guide. All photo darkroom designs shall be specified and/or approved by UC Denver DEHS before any implementation. Minimum requirements to control photochemical vapors, fumes, and dusts are as follows:

1. All darkrooms shall have 100% outside air supply. Exhaust shall be discharged away from any building air intake. Provide a minimum of 8 air changes per hour. Maintain all darkrooms at a negative pressure to its surroundings (0.05 in wg.).

2. Desired and compatible temperature ranges for photo darkrooms shall be 69 to 75 degree F.

3. UC Denver DEHS will participate in photo darkroom design, as there may be special requirements associated with numerous processes that generate hazardous gases and shall approve all plans before any construction takes place.

L. Environmental Chambers: These units are variable and shall be evaluated individually by UC Denver DEHS before purchase and/or installation.

M. Biosafety Cabinets (BSC):

1. Construction of new facilities in campus may require the installation of biosafety cabinets. Some BSCs of the Class II Type B 2 have 100% exhaust requirements. Design of space HVAC systems shall accommodate the exhaust requirements of the BSCs. In addition, filter pressure drops across HEPA filters must be monitored for proper system airflows.

1.4 DEFINITIONS

1.5 SUBMITTALS
A. Submittals shall be in accordance with Section 15000.

1.6 QUALITY ASSURANCE

A. ANSI/AIHA 39.5; The American Standards for Laboratory Ventilation
B. ASHRAE Standard 62.
D. Factory test fume hoods in accordance with ANSI 110.
E. National Sanitation Foundation (NSF) Standard 49 for Biosafety Cabinets.
F. All exhaust fans shall be licensed to bear the AMCA Seals for Sound and air performance.

1.7 DELIVERY, STORAGE, AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. The UC Denver Project Manager shall approve manufacturers for Hoods, Bio-safety cabinets, and film processors.

2.2 MATERIALS, GENERAL

A. Fan Housings and Components: Corrosion resistant and meeting AMCA standard for spark-resistant construction. Provide vapor tight, Class I, Division I motors if motor is located in the air stream.

PART 3 - EXECUTION

EXAMINATION

3.2 INSTALLATION, GENERAL

B. Install ductwork in compliance with NFPA 91 and ANSI Z9.5, including provisions for properly sealing penetrations, grounding, and sealing duct construction materials. Avoid penetrations of fire barriers.
C. Install ductwork with a minimum number of elbows, using round ducts and sweep ells wherever possible. Install turning vanes on rectangular ducts if rectangular ducts must be used.
D. Equip multiple hoods on the same fan system with a balancing damper at each hood.
E. Clearly label fans, ducts, and power supplies to indicate which areas they serve.
F. Install fume hoods in accordance with manufacturer’s recommendations.
TESTING, CLEANING, AND CERTIFICATION

A. Test, adjust, and balance systems in accordance with Section 15990.

B. Provide certification that systems have been tested and balanced.

C. Provide certified test results.

3.2 COMMISSIONING (DEMONSTRATION)

3.5 SCHEDULES

END OF SECTION
PART 1 – GENERAL

1.1 SUMMARY
A. This Section provides standards for heating, chilled, and condenser water systems.

1.2 REFERENCES
A. Section 15000 – General Mechanical Provisions
B. Section 15100 – Valves
C. Section 15110 – Piping
D. Section 15120 – Piping Specialties
E. Section 15130 – Gauges
F. Section 15400 – Plumbing Systems
G. Section 15545 – Chemical Water Treatment

1.3 SYSTEM PERFORMANCE REQUIREMENTS
A. Design piping systems with drain valves at low points of piping, bases of vertical risers, and at equipment.
B. In hydronic systems subject to freezing provide Dowfrost solution or pumped coils. Refer to Section 15545.

1.4 DEFINITIONS

1.5 SUBMITTALS
A. Submittals shall be made in accordance with Section 15000.

1.6 QUALITY ASSURANCE
A. Comply with ASME B31.9-96 for materials, products, and installation.
B. Qualify welding process and operators as specified in Section 15110.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS

2.1 MANUFACTURERS
A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:
1. Manufacturers Qualification: Firms regularly engaged in manufacture of pipe and pipes fittings of types and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years.

2. Valves:
   a. General Purpose Valves: As specified
   b. Safety Relief Valves: As specified in Section 15100.
   c. Automatic Fill Valves:
      1) ITT Bell and Gossett, Model B7-12
      2) Amtrol, Model 11F
      3) Or approved equal
   d. Backflow Preventer: As specified in Section 15400.

3. Piping Accessories:
   a. Strainers, Test Taps, Air Vents: As specified in Section 15120.
   b. Gauges, Thermometers: As specified in Section 15130.

4. Air Separator: As specified in Section 15120.

5. Diaphragm Expansion Tank: As specified in Section 15120.

2.2 MATERIALS, GENERAL

A. Piping and Fittings:

1. General: Working pressure and temperature maximums, 125 psi and 250 degrees F; water service.

2. Copper Pipe: ASTM B88-96, copper tubing, hard drawn, Type K for underground lines and Type L for above ground lines.
   b. Joining Material:
      1) Solder: ASTM B32-96, 95-5 tin-antimony solder for above ground lines.
      2) Brazing: AWS A5.8-92, Classification BAg 1 (silver) for underground lines and where copper pipe is connected to brass.
   d. Flanges: Class 125, cast iron or cast bronze flanges.
1) Bolts and Nuts: ASME B18.2.1-96, carbon steel square head machine bolts with galvanized heavy hex nuts.

2) Gaskets: ASME B16.21-92, nonmetallic, flat, 1/16-inch, full faced, for water service.

e. Dielectric Connections: Fittings having insulating material isolating joined dissimilar metals.

1) **Dielectric Waterway Fittings**: 175 psi minimum working pressure, ends to match connections.

2) Flanges: Class 125, cast bronze, ASME Standard, with bolt insulators, dielectric gasket, bolts, and nuts.


a. Fittings:

1) Threaded: ASME B16.4-92, Class 125, cast iron, or ASME B16.3-92, Class 150, malleable-iron. Standard pattern for threaded joints. Threads shall conform to ASME B1.20.1-83.

2) Flanged: ASME B16.1-89, Class 125, cast iron, raised ground face, bolt holes spot faced.


4) Grooved Couplings and Mechanical Fittings: ASTM A536-84 ductile or ASTM A47-90 malleable iron, with enamel finish and grooves or shoulders designed to accept grooved couplings. Synthetic-rubber gasket, with central-cavity, pressure-responsive design, and ASTM A183-83 carbon-steel bolts and nuts.


c. **Dielectric Waterway Fittings**: Threaded end connections. Install to isolate dissimilar metals, prevent galvanic action, and prevent corrosion.

4. Flexible Pipe Connectors: As specified in Section 15110, 2.2, G.

B. Valves:

1. General Purpose Valves: As specified in Section 15100.

2. Safety Relief Valves:

a. Brass or bronze body with brass and rubber, wetted, internal working parts. Valves designed, built, rated, and stamped in accordance with ASME.
3. Automatic Fill Valve: Diaphragm operated, cast brass body, fill valve designed to maintain water pressure in a closed water system. Valves shall include cleanable strainer, removable seat assembly, and built-in check valve. Valves shall have factory setting of 12 psig with field adjustment range of 10 - 25 psig. Maximum operating temperature shall be 225 degrees F, maximum working pressure of 125 psig. Valve shall have 3/4-inch inlet and outlet.

C. Piping Accessories:

1. Drain Pans: Minimum 18-gauge stainless steel, reinforced to support weight of drain pan and water.

D. Expansion Loop Guides:

1. Factory fabricated cast steel, consisting of bolted two-section outer cylinder and base. Provide two-section alignment guide spider that bolts tightly to pipe.

E. Air Separator:

1. In-Line Air Separator: Heavy duty cast iron air separator constructed for 175 psi minimum working pressure and 300 degree F. Integral weir to maximize air separation. Top outlet connection for air vent and bottom connection for expansion tank.

2. Centrifugal Air Separator: Welded steel tank, ASME constructed and labeled for 125 psig minimum working pressure and 350 degree F maximum operating temperature. In-the-pipeline type air separator with tangential openings for water in and out. Inside designed to create a low velocity vortex for the separation of free air from the water stream. Internal steel strainer with perforations sized for water flow. 2-inch bottom drain and 1-1/4-inch connection located at top of air separator for expansion tank connection.

F. Diaphragm Expansion Tank:

1. Welded steel tank suitable for 125 psig working pressure and 350 degrees F maximum operating temperature. Separate air charge from system water by means of a flexible diaphragm sealed into tank. Tank shall have taps for pressure gauge, air charge fitting, and drain. Tank constructed, tested, and labeled in accordance with ASME Pressure Vessel Code-95.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. Copper Pipe:

1. Install Type L copper pipe with wrought copper fittings and solder joints for 2-inch and smaller pipe, above ground, within building.

2. Install Type K copper pipe for 2 inch and smaller pipe below ground.

B. Steel Pipe:
1. Threaded Joints: Install steel pipe with threaded joints and fittings for 2-inch and smaller in exposed locations such as mechanical rooms.

2. Welded and Flanged Joints: Install welded fittings on pipe 2-1/2 inches and larger.

3. Grooved Couplings and Mechanical Fittings: Install mechanical grooved end pipe on condenser water piping.

C. Arrange piping in horizontal groups, each group to be in one plane. Maintain indicated slope. Conceal pipe installations in walls, pipe chases, utility spaces, mechanical rooms, above ceilings, below grade or floors.

D. Install piping in accordance with the stipulations in Section 01040.

E. Sloping, Air Venting, and Draining:

1. Install piping true to line and grade, and free of traps and air pockets. Slope piping up in direction of flow at 0.2 percent grade.

2. Provide eccentric reducers for changes in horizontal piping, top side flat.

3. Connect branch piping to bottom of mains, except for up-feed risers which shall have take-off out top of main.

4. Install manual air vents at high points in hydronic piping systems and at coils other than air handling units. Provide 1/4-inch copper, 180-degree bend pipe to discharge vented water into can.

5. Install automatic air vent on air separator, water coils at air handling units, and where shown. Provide valved inlet and discharge piped to floor drain.

6. Install drain valves with hose adapters at low points in mains, risers, and branch lines. Drain shall consist of a tee fitting, 3/4-inch ball valve, and short 3/4-inch threaded nipple and cap. Provide drain valves for float type controllers.

F. Fittings: Standard manufactured fittings. Field fabricated fittings and bushings are prohibited on all piping.

G. Unions: Install unions in pipes 2-inch and smaller, adjacent to each valve, at final connections of each piece of equipment and elsewhere to permit alterations and repairs. Install dielectric waterway fittings to join dissimilar metals. Unions are not required on flanged devices.

H. Flanges: Install flanges on valves and equipment having 2-1/2-inch and larger connections.

I. Pipe Ends: Cut pipes, remove burrs and prepare ends with full inside diameter.

J. Joints:

1. Threaded Joints: Apply Teflon tape to male equipment threads. Do not use pipe with threads which are corroded or damaged.

2. Soldered Joints: Comply with procedures contained in AWS Soldering Manual-98. Clean surfaces to be joined of oil, grease, rust, and oxides. Clean socket of
fitting and end of pipe with emery cloth. After cleaning and before assembly or heating, apply flux to joint surface and spread evenly.

K. Keep openings in piping closed during construction to prevent entrance of foreign matter.

L. Install stainless steel flexible connectors at inlet and discharge connections to base-mounted pumps and other vibration producing equipment.

M. Valves:
   1. Field check valves for packing and lubricant. Replace leaking packing. Service valves with lubricant for smooth and proper operation before placing in service.
   2. Install valves accessible from floor level, located for easy access. Install valves in horizontal piping with stem at or above center of pipe. Install valves in position to allow full stem movement. Provide operating handles for valves and cocks without integral operators.
   3. Provide extended valve stems where insulation is specified.
   4. Provide separate support where necessary.
   5. Where soldered end connections are used for valves, use solder having a melting point below 840 degrees F for gate, globe, and check valves; below 421 degrees F for ball valves.
   6. Provide valves same size as line size.
   7. Provide gate blow-down valves and hose adapters at strainers; same size as strainer blow-off connection.
   8. Provide mechanical actuators with chain operators where valves 2-1/2 inches and larger are mounted more than 6 feet above the floor. Extend chains to elevation of 5 feet above floor.
   9. Check Valves: Install wafer or lift check valves on pump discharge. Install check valves for proper direction of flow as follows:
      a. Swing Check Valve: Horizontal position with hinge pin level.
      b. Wafer Check Valve: Horizontal or vertical position, between flanges.
      c. Lift Check Valves: With stem upright and plumb.

N. Equipment Piping:
   1. Provide combination balancing and shutoff valves to regulate water flow through piping, coils, and at other equipment and piping where shown or required for proportioning flow.
   2. Install automatic fill valve in cold water make-up to boilers and chillers. Install three-valve bypass with globe valve around automatic fill valve for quick filling system. Install backflow preventers upstream of fill valve and bypass.

O. Expansion Loops, Guides, and Anchors:
1. Install piping with provisions for expansion and contraction, using expansion loops. Provide for expansion and contraction in mains, risers, and run-outs. Install pipe expansion loops cold-sprung in tension for piping with operating temperatures higher than installed temperature and compression for piping with operating temperatures lower than installed temperatures. Install pipe to absorb 50 percent of total compression or tension produced during anticipated change in temperature. Do not bend piping without use of bending machine.

2. Install guides to properly direct pipe movement into expansion loops and offsets.

3. Install anchors to control movement in piping. Weld anchors to ferrous piping and braze anchors to nonferrous piping. Install pipe anchors at ends of principal pipe runs and at intermediate points in pipe runs between expansion loops.

4. Install in accordance with standards of Expansion Joint Manufacturer's Association, EJMA-93.

P. Drain Pans:

1. Provide drain pans under the entire length of any piping, including valves, joints, and fittings for any liquid-carrying piping system installed over any motor, motor starter, switch gear, transformer, or other electrical equipment. Also, under all such piping located anywhere in any transformer vault, electrical switchboard room, and telephone equipment room. Drain pans shall be not less than 2 inches deep, with a 3/4-inch drain pipe to discharge where shown or to discharge at nearest convenient drain line, floor drain, or other approved drain point.

Q. Expansion Tank and Air Separator Installation:

1. Install tanks as shown; locate appurtenances for easy servicing.

2. Install gate valve and union on air separator drain to facilitate removal of strainer. Route discharge on air separator tank to nearest drain.

3. Check expansion tank after cleaning, testing, and filling of system to ensure system is completely full.

4. Provide bracket supports, saddles, and hangers to support tanks.

5. Install air separator level in both directions, supported from structure so that all pipe can be removed without moving tank.

6. Charge expansion tank with proper air charge.

3.3 TESTING, CLEANING AND CERTIFICATION

A. Test piping systems using ambient temperature water, except where there is risk of damage due to freezing.

B. Release trapped air while filling system using vents at high points. Use drains installed at low points for complete removal of liquid.

C. Isolate equipment and parts that cannot withstand test pressures.
D. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the design pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test.

E. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components and repeat hydrostatic test until there are no leaks.

F. Clean and flush hydronic piping systems. Remove, clean, and replace strainer screens. After cleaning and flushing hydronic piping system, but before balancing, remove disposable fine mesh strainers in pump suction diffusers.

G. Mark calibrated name plates of pump discharge valves after hydronic system balancing has been completed, to permanently indicate final balanced position.

H. Prepare written report of testing, indicating locations of leaks corrected, method used to correct leaks, number of tests required, and certification that system is leak free.

3.4 COMMISSIONING (DEMONSTRATION)

A. Provide 2 hours of instruction on hydronic systems. Include following items as a minimum:

1. Location of automatic and manual air vents.
2. Location of strainers and blow down valves.
3. Location of safety and relief valves.
4. System drain valves.
5. System fill and associated devices.
6. Expansion tank and air separator.

3.5 SCHEDULES

END OF SECTION
SECTION 15510
BOILERS

PART 1 - GENERAL

1.1 SUMMARY
A. This section consists of standards for boilers and associated equipment.

1.2 REFERENCES
A. Section 15000 – General Mechanical Provisions
B. Section 15520 – Steam and Steam Condensate Piping

1.3 SYSTEM PERFORMANCE REQUIREMENTS
A. Boilers included in this Section are intended for structures constructed outside the practical limits of the campus central steam distribution system and have access to natural gas.
B. Design these systems as simple heating water hydronic systems to meet building heating and ventilating requirements.

1.4 DEFINITIONS

1.5 SUBMITTALS
A. Submittals for the following shall be in accordance with Section 15000.
   2. Completed manufacturers installation and start-up checklist.

1.6 QUALITY ASSURANCE
A. Electrical components shall comply with NFPA 70-96 and be UL listed.
B. Boilers shall comply with ASME Boiler and Pressure Vessel Code, Section IV-95.
C. Boilers tested and rated according to the Hydronics Institute’s “Testing and Rating Standard for Heating Boilers” with I=B=R emblem on a nameplate.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY
A. Boilers warranties shall be provided in accordance with Section 15000, including the manufacturer’s standard warranty of not less than 10 years.

PART 2 – PRODUCTS

2.1 MANUFACTURERS
A. Approved Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Inclined Water Tube Boiler:
   a. Anax
   b. Rite
   c. or approved equal

2. Cast-Iron Boilers:
   a. Burnham
   b. Peerless
   c. Weil-McLain

3. High-Efficiency Compact Boiler:
   a. Lochnnar
   b. Patterson-Kelly
   c. or approved equal

4. Scotch Marine Boiler:
   a. Burnham
   b. Kewaner
   c. Superior

2.2 MATERIALS, GENERAL

A. Inclined Water Tube Boiler:

1. Type: Factory assembled, packaged, and tested forced draft inclined water tube boiler. Non-condensing design to operate at 80 percent efficiency.

2. Construction:
   a. Free-floating tube bundle assembly consisting of steel tubes, 2-inch diameter supported by steel fame with expansion joint at each corner.
   b. Tubes sloped upward from rear to front to eliminate air bubbles.
   c. Full-face reinforced neoprene head gasket.
   d. 18 gauge galvanized or painted steel jacket.


4. Burner:
a. UL listed forced draft burner for operation with pressurized vent stack without barometric damper or induced draft fan.

b. Fuel: Natural gas.

c. Electronic supervised spark ignition.

d. Burner Safety Controls:
   1) Scanner or ultraviolet flame detector.
   2) Airflow switch.

e. Positive pressure at flue collar.

2. Boiler Controls and Trim:
   a. Operating control.
   b. High limit control
   c. Low water cutoff.
   d. ASME pressure relief valve set at proper psi for operating conditions.
   e. Combination temperature/pressure gauge.
   f. Built-in air elimination.
   g. Control panel with indicating lights.

3. Gas Train:
   a. UL and FM listed gas train, factory assembled.
   b. Main gas pressure regulator.
   c. Main gas valve.
   d. Main and pilot gas shut-off valves.
   e. Auxiliary gas valve.
   f. Dual safety gas valves.
   g. Low and high gas pressure gas switches above 2500 MBH.

B. Cast-Iron Boilers:

1. Factory assembled and packaged, with cast-iron sections set on an insulated steel base, sealed with high-temperature sealant, held together with tie rods, and with insulated extended jacket and vent connection.

2. Gas Burner:
a. Atmospheric or forced draft type.
b. Modulation firing.
c. Prepurge.
d. Low fire start.
e. Modulating position air control.
f. Pressure regulator.
g. Gas valves, manual shutoff, intermittent spark or glow coil ignition, flame-sensing device, and automatic 100 percent shutoff.

3. Pressure Rating: 30 psig.
5. Trim and Accessories:
   a. Safety Relief Valve: ASME rated, factory set at boiler pressure rating.
   b. Gauge: Combination water pressure and temperature. Pressure range to be 0 - 50 psig and temperature range to be 40 to 240 degrees F.
   c. Low Water Cutoff: Prevent burner operation on low water level.
   d. High Limits: Two temperature controls to limit boiler water temperature. One with automatic reset, the other with manual reset.
   e. Operating Controls: Prewired, factory assembled electric control including pilot safety and thermocouple transformer, 24-volt gas valve, manual main and pilot valves.
   f. High pressure gas switches
   g. Electronic pilot ignition.
   h. Safety pilot switches: 100% shut-off.
   i. Gas pressure regulator.
   j. Safety Controls: Energize ignition, limit time for establishing flame, prevent opening of gas valve until pilot flame is proven, and stop gas flow on ignition failure.

C. High-Efficiency Compact Boiler:

1. Radial fired, vertical hot water boiler with gas fired power burner. Non-condensing design to operate at AGA certified efficiency of 85 percent.

2. Construction:
   a. Combustion Chamber: 16 gauge corrosion resistant aluminized steel or cast iron.
b. Heating Surface: Finned copper tubes.

c. Outer Cabinet: Minimum 16 gauge steel, air tight, with an insulating air space between the combustion chamber and outer cabinet.

d. Cabinet Finish: Baked epoxy coating finished inside and out.

e. Factory assembled and fire tested.


4. Burner:
   a. Gas power burner, radial fired.
   b. Fuel-air mixture controlled by multiple brass orifices and venturi core equipped to measure air flow rate to the burner.

5. Burner Controls:
   a. Electric spark ignition with interrupted type pilot.
   b. Flame rod pilot and main flame control.
   c. AGA approved electronic flame safeguard programmer with pilot failure and lock-out with manual reset.

6. Gas Manifold:
   a. AGA lubricated plug cock.
   b. Pressure regulator.
   c. Low gas pressure switch.
   d. Two solenoid-operated diaphragm valves.
   e. Pilot gas manifold with cock, pressure regulator, gas filter and solenoid valve.
   f. Both gas manifolds, main and pilot, to be accessible without removing cabinet.

7. Smoke Venting:
   a. Boiler AGA certified as “Category 1” for venting, requiring either a double wall or an insulated type “B” vent pipe.

8. Trim and Accessories:
   a. Safety Relief Valve: ASME rated, factory set at boiler pressure rating.
   b. Gauge: Combination water pressure and temperature. Pressure range to be 0 to 50 psig and temperature range to be 40 to 240 degrees F.
   c. Low Water Cutoff: Prevent burner operation on low water level.
d. High Limits: Two temperature controls to limit boiler water temperature. One with automatic reset, the other with manual reset.


D. Scotch Marine:

1. Multi-pass, horizontal fire-tube boiler factory-mounted on heavy steel base frame. Boiler to provide 80 percent efficiency.

2. Construction:
   a. Insulated metal jacket.
   b. Insulated front flue doors.
   c. Refractory filled rear access with observation port.
   d. Bottom blowdown connection.
   e. Heating Surface: 5 square feet of heating surface per rated BHP.
   f. Cabinet Finish: Baked epoxy coating finished inside and out.
   g. Factory assembled and fire tested.

3. Burner:
   a. UL/FM approved forced-draft burner, rated to produce full output at 5200-foot elevation.
   b. Radial port flame retention type burner head and diffusers.

4. Burner Controls:
   a. Direct spark ignition electrode.
   b. Ultraviolet flame detector.
   c. Airflow safety switch.
   d. Modulating control motor with linkage to control modulating gas valve and air inlet damper for proper fuel air mixtures.

5. Gas Train:
   a. AGA lubricated plug cock.
   b. Gas regulator.
   c. Motorized gas valve with proof of closure switch.
   d. Safety gas valve.
   e. Pressure regulator.
f. High and low gas pressure switch.
g. Pilot solenoid valve.
h. Pilot gas manifold with cock, and pressure regulator.
i. Both gas manifolds, main and pilot, to be accessible without removing cabinet.

6. Smoke Venting:
   a. Boiler AGA certified as “Category 1” for venting, requiring either a double wall or an insulated type “B” vent pipe.
   b. Type B Gas Vent: Double wall gas vent complying with NFPA 211-96, inner pipe of sheet aluminum, outer pipe of galvanized steel sheet. Provide tees, elbows, increasers, draft hood connectors, metal cap with bird barrier, adjustable roof flashing, storm collar, support assembly, thimbles, fire-stop spacers, and fasteners.

7. Trim and Accessories:
   a. Safety Relief Valve: ASME rated, factory set at boiler pressure rating.
   b. Gauge: Combination water pressure and temperature. Pressure range to be 0 to 50-psig and temperature range to be 40 to 240 degrees F.
   c. Low Water Cutoff: Prevent burner operation on low water level.
   d. High Limits: Two temperature controls to limit boiler water temperature. One with automatic reset, the other with manual reset.


E. Controls:
   1. UL listed, electronic boiler control with adjustable reset ratios, adjustable offset to raise or lower reset curve, adjustable outdoor cutoff, night set back, minimum boiler water temperature adjustment, setback clock and adjustable morning warm up, manual override, LED indication of Setback, Bypass and On.

**PART 3 - EXECUTION**

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

C. Install boilers level and plumb, according to manufacturer’s recommendations.

D. Install boilers on 4-inch thick concrete base, 4 inches larger on each side than base of unit.

E. Install natural gas-fired boilers according to NFPA 54-96. Connect gas piping full size to boiler gas train inlet. Install with a union and dirt leg.
F. Connect heating water piping to boiler with shutoff valve and union or flange at each connection.

G. Install piping from safety relief valve to nearest floor drain.

H. Controls:

1. Wire boiler burner so it cannot fire unless heating water-circulating pump is running.

2. Boiler shall be started and stopped automatically through the boiler control panel. Outdoor temperature sensor shall enable reset of heating water temperature in accordance with the following schedule:

<table>
<thead>
<tr>
<th>Outdoor Air Temperature</th>
<th>Heating Water Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 degrees F</td>
<td>140 degrees F</td>
</tr>
<tr>
<td>0 degrees F</td>
<td>190 degrees F</td>
</tr>
</tbody>
</table>

3. Wire boiler burner through flow switch in heating water loop to prevent boiler operation until positive flow is proven.

4. Low water cutoff switch shall shut down boiler operation when water level drops below limit.

5. Automatic high limit shall shut down boiler operation when water temperature exceeds 200 degrees F (adjustable). Manual reset high limit shall shut down boiler operation when water temperature exceeds 205 degrees F (adjustable).

6. Install emergency shutdown switch near boiler room exit door. Wire switch through the burner controls.

3.3 TESTING, CLEANING AND CERTIFICATION

A. Test boiler performance and adjust boiler combustion efficiency to meet manufacturer’s recommendations.

1. Measure and record the following:

   a. Gas pressure on manifold.

   b. Combustion air temperature at inlet to burner.

   c. Flue gas temperature at boiler discharge.

   d. Flue gas carbon dioxide and oxygen concentration

   e. Natural flue draft.

B. Flush and clean boilers according to manufacturer’s instructions.

3.4 COMMISSIONING (DEMONSTRATION)

A. Provide 2 hours of instruction to Owners representative. Include operation of boiler including accessories and controls, procedures for startup and shutdown, troubleshooting, servicing, and preventive maintenance. Review data in the maintenance manuals.
3.5 SCHEDULES

END OF SECTION
SECTION 15520
STEAM AND STEAM CONDENSATE PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This section provides standards for steam and steam condensate piping systems.

1.2 REFERENCES

A. Section 15000 – General Mechanical Provisions
B. Section 15100 – Valves
C. Section 15110 – Piping
D. Section 15190 – Mechanical Identification
E. Section 15510 – Boilers
F. Section 15545 – Chemical Water Treatment
G. Manual Part 3, Project Planning and Design Guidelines and Considerations

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. Steam Supply:

1. High pressure steam will be supplied to buildings from a central distribution system in accordance with Manual Part 3.4.

2. Steam Pressure Classifications:

   a. Low pressure steam: 15 psig and under.
   b. Medium pressure steam: 16 psig to 100 psig.
   c. High pressure steam: Above 100 psig.

3. At each building reduce steam to 15 psig, unless other pressures are required for special equipment.

4. Design pressure reducing stations with two valves in parallel for two-step control for minimum summer and maximum winter loads. Size valves for 1/3 and 2/3 capacity.

5. Provide globe valve by-pass for manual control. Size the by-pass valve so that if left unattended in an open position, the steam flow through the by-pass does not exceed the capacity of the safety relief valve selected.

6. Install air vents in all steam condensate piping high points.

7. Install drains in all steam condensate low points.
B. Process and Humidification Steam: all secondary steam systems shall utilize clean steam generators supplied by domestic water from ion exchange water softeners.

C. Condensate Return Systems

1. Condensate return shall be gravity return throughout the building.
2. Where gravity return is impossible, condensate shall be pumped via pumping traps or steam motivated condensate pumps.

D. Expansion loops are preferred over mechanical expansion devices. Where expansion loops are not practical, provide bellows type expansion devices, not mechanical seal types.

E. Flash Tanks: Do not discharge condensate drip traps above 15 psig into condensate return mains or condensate pump receivers. Design discharge into a flash tank vented into the low pressure side of the system and drip through a low pressure F & T trap to a condensate return main or receiver.

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Qualify welders and welding process in accordance with Section 15110.

1.6 QUALITY ASSURANCE

A. Regulatory Requirements: Comply with the provisions of the following:

1. ASME B31.9 Building Services Piping for materials, products, and installation. Safety valves and pressure vessels shall bear the appropriate ASME label.


3. UMC Compliance: Fabricate and install steam and condensate piping in accordance with IAPMO “Uniform Mechanical Code.”

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. General Purpose Valves: As specified in Section 15100.


7. Gaskets: Non-asbestos, spiral wound only. Flexitalic, Garloc, or equal and approved.


9. Buried Piping: As specified in Section 15110.

2.2 MATERIALS, GENERAL

A. Steam Piping:

1. High and Medium Pressure Steam Piping, (above 15 psig):
   a. Piping 1 1/2 Inches and Under:
      1) Pipe: ASTM A53, Grade B, Schedule 40 seamless, black steel, plain ends.
      2) Fittings: Cast iron, Class 300.
      3) Joints: Screwed above ground; welded below ground.
   b. Piping 2 Inches and Over:
      1) Pipe: Schedule 40 seamless, black steel, beveled ends.
      2) Fittings: Schedule 40, seamless, black steel, butt weld type.
      3) Flanges: 300 lb. forged steel, welded neck or SORF types.

2. Low and Medium Pressure Steam Piping (Below 15 psig):
   a. Piping 2 Inches and Under:
      2) Fittings: Screwed, cast-iron, 125 lb.; welded, forged steel socket weld type, 150 lb.
      3) Joints: Screwed, above ground; welded, below ground.
   b. Piping 2-1/2 Inches and Over:
      1) Pipe: ASTM A53, Schedule 40, black steel, beveled ends.
      2) Fittings: Schedule 40 steel, butt weld type.
3) Flanges: 150 lb. forged steel, weld neck type.

B. Condensate Piping:

1. High and Medium Pressure Steam Condensate, (above 15 psig):
   a. Piping 2 - ½ Inches and Under:
      1) Pipe: ASTM A53, Schedule 80 seamless, black steel, threaded or plain ends.
      2) Fittings: Cast iron, threaded, 300 lb.
   b. Piping 2 Inches and Over:
      2) Fittings: Schedule 80, seamless, black iron, butt weld type.
      3) Flanges: 300 lb. forged steel, welding neck or SORF types

2. Low Pressure Condensate Piping (less than 15 psig):
   a. Piping 2 Inches and Under:
      2) Fittings: Screwed, cast-iron, 125 lb.; welded, forged steel socket weld type, 125 lb.
      3) Joints: Screwed, above ground; welded, below ground.
   b. Piping 2-1/2 Inches and Over:
      1) Pipe: ASTM A53, Schedule 80, black steel, beveled ends.
      2) Fittings: Schedule 80 steel, butt weld type.
      3) Flanges: 150 lb. forged steel, weld neck type.

C. Clean Steam Piping:

1. Type 316 stainless steel tubing with butt-weld fittings.
2. Ball Valves: Full-ported, three-piece valves with threaded connections, type 316 stainless steel body and ball, TFE seats and seals.

D. Clean Condensate Piping

1. Type 316 stainless steel tubing with butt-weld fittings.
2. Ball Valves: Full-ported, three-piece valves with threaded connections, type 316 stainless steel body and ball, TFE seats and seals.
E. Safety Valves:

1. Bronze Safety Valves: Cast-bronze or forged copper body, rated for design pressure, forged copper-alloy disc; fully enclosed, cadmium-plated steel spring and positive shutoff. Inlet and outlet shall be threaded for valves two inches and below. Larger valves shall be flanged.

2. Cast Iron Safety Valves: Cast-iron body, rated for design pressure; forged copper-alloy disc and nozzle; fully enclosed, cadmium-plated steel spring and positive shutoff; Inlet and outlet shall be threaded for valves two inches and below. Larger valves shall be flanged.

3. Stop-Check Valves Class 125 for 5 psig and below. Class 250 for higher pressures. Threaded bronze swing-checks for 5 psig and below, 2-inch and below pipe diameter. On higher pressure applications use wafer, ball-check, or spring-loaded types per system design.

F. Pressure Reducing Valves:

1. Valve Characteristics: Pilot-actuated, diaphragm type, with adjustable pressure range and positive shutoff; cast-iron or bronze body with flanged end connections, hardened stainless-steel trim, and replaceable head and seat. Provide main head stem guide fitted with flushing and pressure-arresting device. Provide dirt cover over pilot diaphragm.

G. Sound Diffractors:

1. Flanged, cast steel body, rated design pressure.

H. Steam Traps:

1. Steam Traps: 15 psig and less:
   a. Thermostatic Traps: Cast-brass, angle-pattern body with integral union tailpiece and screw-in cap; maximum operating pressure of 25 psig; balanced-pressure, stainless-steel or monel diaphragm or bellows element and renewable, hardened stainless-steel head and seat. Provide an external Y strainer with blow-down rated for service.
   b. Float and Thermostatic Traps: ASTM A278, Class 30, cast-iron body and bolted cap; renewable, stainless-steel float mechanism with renewable, hardened stainless-steel head and seat; balanced-pressure, thermostatic air vent made with stainless-steel or monel bellows, and stainless-steel head and seat. Provide an external Y strainer with blow-down rated for service.
   c. Inverted Bucket Traps: ASTM A278, cast-iron body and cap, pressure rated for 25 psig; stainless-steel head and seat; stainless-steel valve retainer, lever, and guide pin assembly; brass or stainless-steel bucket. Provide an external Y strainer with blow-down rated for service.

2. Steam Traps: 16 psig to 125 psig:
   a. Thermostatic Traps: Class 125, bronze angle-pattern body with integral union tailpiece and screw-in cap; balanced-pressure, stainless-steel or
monel bellows element and renewable, hardened stainless-steel head and seat. Provide an external Y strainer with blow-down rated for service.

b. Float and Thermostatic Traps: ASTM A126, cast-iron body and bolted cap; renewable, stainless-steel float mechanism with renewable, hardened stainless-steel head and seat; maximum operating pressure of 125 psig; balanced-pressure, thermostatic air vent made of stainless-steel or monel bellows, and stainless-steel head and seat. Provide an external Y strainer with blow-down rated for service.

c. Inverted Bucket Traps: Cast-iron body and cap, pressure rated for 125 psig; stainless-steel head and seat; stainless steel valve retainer, lever, and guide pin assembly; brass or stainless-steel bucket. Provide an external Y strainer with blow-down rated for service.

d. Disk Traps: Applications 100 psig and over.

I. Air Vents:

1. Quick Vents: Cast-iron or brass body, with balanced-pressure, stainless-steel or monel thermostatic bellows, and stainless-steel heads and seats.

2. Float Vents: Cast-iron or brass body, seamless brass float, balanced-pressure, thermostatic bellows, and replaceable stainless-steel seat, float, and head.

J. Strainers:

1. Wye Pattern Strainers: Minimum 125 psig steam working pressure, cast-iron body conforming to ASTM A278, Class 30; Grade 18-8 stainless-steel screen, 20 mesh for 2-inch and smaller, and manufacturer recommended perforations for 2-1/2 inch and larger; tapped blow-off plug.

2. Basket Strainers: Minimum 125 psig steam working pressure, cast-iron body conforming to ASTM A278-93, Class 30; Grade 18-8 stainless-steel screen, flanged end connections, bolted cover.

K. Condensate Cooler:

1. ASME constructed welded steel for 150 psig working pressure. Steel shell with bronze heads, and copper tube bundle. Condensate in shell, water in tubes construction. Fabricate with tapping for vents, low-pressure steam and condensate outlets, high-pressure condensate inlet, air vent, safety valve, and legs. Provide saddles and support on steel pipe stand.

L. Condensate Movers:

1. Pumpless condensate system prepped and skid-mounted:

   a. System to include condensate receiver, pumping chamber, all stainless steel, single spring mechanism, inlet and discharge type 304 stainless steel spring loaded check valves, isolation valve, motive steam y-strainer, isolation valves, pressure gauge and site glass assembly.

   b. Provide with battery operated cycle counter, motive steam pressure regulating valve and thermostatic air vent.
PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. Preparation:

1. Ream pipe and tube ends, remove burrs and bevel plain end ferrous pipe.
2. Remove scale and dirt on inside and outside before assembly.
3. Prepare piping connections to equipment with flanges or unions.
4. After completion, fill, clean and treat system.

B. Piping Installation:

1. Seal pipe penetrations at building walls, valve pits, etc., with link-seal type mechanical seal with sleeve in concrete to assure watertight penetrations at exterior foundation penetrations.
2. Route piping in orderly manner, plumb and parallel to building structure. Maintain gradient. Install piping free of sags or bends and with ample space between piping to permit proper insulation applications.
3. Install piping tight to slabs, beams, joists, columns, walls, and other permanent elements of the building. Provide space to permit insulation applications, with 1 inch clearance outside the insulation. Allow sufficient space above removable ceiling panels to allow for panel removal.
4. Locate groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.
5. Install piping to conserve building space and in such a manner that it will not interfere with use of space, other work or equipment.
6. Install piping to allow for expansion and contraction without stressing pipe, joints, or connected equipment.
7. Provide access panels or doors where valves and fittings are not exposed. Coordinate size and location of access doors as per prints.
8. Sloping:
   a. Install steam piping at a uniform grade of one inch in 40 feet, in direction of flow. Use eccentric reducers to maintain bottom of pipe level.
   b. Install steam condensate piping at a uniform grade of one inch in 40 feet. Install drip trap assembly at low points and before control valves. Run condensate lines from trap to nearest condensate receiver. Provide loop vents over trapped sections.
9. Where pipe support members are welded to structural building framing; scrape, brush clean, and apply one coat of zinc rich primer to welding.

10. Install branch connections to supply mains using 45 degree fittings in main with take-off out the top of the main. Use of 90 degree “tee” fittings is permissible, where the use of 45 degree fittings are not practical. Where the length of a branch take-off is less that 10 feet, pitch branch line down toward mains, 1/2 inch per 10 feet.

11. Install flanges on valves, apparatus and equipment having 2-1/2 inch and larger connections.

12. Install flexible connectors at inlet and discharge connections to pumps and other vibration producing equipment.

13. Install strainers on the supply side of each control valve, pressure regulating valve, solenoid valve, traps, and elsewhere as indicated. Install 3/4 inch NPS nipple and ball valve in blow down connection of strainers 2 inch and larger. Use same size nipple and valve as blow-off connection of strainer.

14. Drip Legs:
   a. Install drip legs at low points and natural drainage points in the system, such as at the ends on mains, bottoms of risers, and ahead of pressure regulators, control valves, isolation valves, pipe bends and expansion joints.
   b. On straight runs with no natural drainage points, install drip legs at intervals not exceeding 200 feet where pipe is pitched down in the direction of steam flow and a maximum of 150 feet where the pipe is pitched up so that condensate flow is opposite of steam flow.
   c. Drip leg diameter: Same diameter as the main up to 4 inch pipe size, 4 inches in diameter for mains up to 8 inches and 1/2 of the diameter on the main thereafter.
   d. Drip leg lengths: At least 1-1/2 times the diameter of the main, but never less than 10 inches for systems with supervised warm-up. For systems with automatic warm-up, the drip lengths shall be a minimum of 28 inches in length.
   e. Install steam traps close to drip legs.

15. Install unions downstream of valves and at equipment or apparatus connections. Install dielectric unions where joining dissimilar materials.

16. Terminal Equipment Connections:
   a. Size pipe for supply and return same size as equipment connections.
   b. Install bypass piping with globe valve around control valve. Install only one bypass where multiple parallel control valves are installed.
   c. Install vacuum breaker downstream from control valve and bypass, and close to coil inlet connections.
d. Install pressure gauge at coil inlet connections.

e. Pipe outlet from coils to drip legs and trap.

C. Valves:

1. Install valves with stems upright or horizontal, not inverted. Install valves in position to allow full stem movement. Locate valves for easy access.

2. Provide extended valve stems where insulation is specified.

3. Provide valves same size as line size.

4. Install gate valves for shut-off and to isolate equipment, part of systems, or vertical risers.

5. Install globe valves for throttling, bypass, or manual flow control services.

6. Install drains at low points in mains, risers, and branch lines consisting of a tee fitting, 3/4 inch ball valve, and short 3/4 inch threaded nipple and cap.

7. Install gate valves on drop legs, dirt pockets, and strainer blowdowns to allow removal of dirt and scale.

D. Safety Valves:

1. Pipe discharge from safety valves to atmosphere outside the building.

2. Install drip-pan elbow fitting adjacent to safety valve.

3. Pipe drain connection to nearest floor drain.

E. Pressure Reducing Stations:

1. Pressure reducing stations shall have two valves sized for 1/3 and 2/3 capacity of the calculated total steam load. Switch-over between valves shall be via manual gate valves.

2. Each branch of the pressure reducing station shall include a swing-joint to accommodate component removal.

3. Install pressure-reducing valves in accessible location for maintenance and inspection.

4. Install bypass around each reducing valve, with globe valve equal in size to area of reducing valve seat ring.

5. Install gate valves and unions or flanged connection around each reducing valve.

6. Install full size strainer with blow down upstream of each reducing valve.

7. Install 4½ inch pressure gauge, 0 to 200 psi on inlet side and 0 to 60 psi on medium pressure load side of station. Provide anti-siphon loop or “pig-tail” and steam-rated gauge cock. Install pressure gauges where they are clearly visible from the operating level of the reducing station.
8. Control of pressure reducing stations shall have PRVs with pilot positioners and shall fail closed. Pressure reducing station failure shall also have appropriate alarms connected to the Building Automation System.

F. Steam Traps:

1. Install traps at all low points or where condensate is trapped. Install steam traps in accessible locations close to connected equipment and drip legs. Maximum allowable distance from equipment is 4 feet.

2. Install gate valves, strainer, and union upstream from trap; install union, check valve, and gate valve downstream from trap.

3. Steam traps serving major loading, domestic hot water heat exchanger, end of line traps, HVAC heating coils, clean steam generators, (CSG) shall be directly monitored by the B.A.S.

4. Applications 15 psig and less:
   a. Thermostatic Traps: Install on convectors and finned-tube radiation.
   b. Float and Thermostatic Traps: Install on steam main and riser drip legs, laundry equipment, kitchen equipment, heat exchangers, and coils, or systems with modulated steam supply.
   c. Inverted Bucket Traps: Install on steam mains and riser drip legs.

5. Applications 16 psig to 125 psig:
   a. Thermostatic Traps: Install on convectors and finned-tube radiation.
   b. Inverted Bucket Traps: Install on steam main and riser drip legs, laundry equipment, kitchen equipment, heat exchangers, and coils.
   c. Thermodynamic Traps: Install on steam mains, riser drip legs, and heat tracer lines.

G. Flash Tanks:

1. Pitch condensate lines towards flash tank.

2. If more than one condensate line discharges into flash tank, install a swing check valve in each line.

3. Install thermostatic air vent at the top of the tank.

4. Install an inverted bucket or float and thermostatic trap at the low pressure condensate outlet, sized for triple the condensate load.

5. Install a safety relief valve at the tank top.

6. Install a pressure gage, gate valve, and swing check valve on the low pressure (flash) steam outlet.

H. Identification:
1. Label piping, valves, and equipment as specified in Section 15190

3.3 TESTING, CLEANING AND CERTIFICATION

A. Clean and flush system, with clear water, of all dirt, metal chips, sand, and foreign matter. After flushing, remove, clean, and replace all strainer baskets or screens. Inspect each run of each system for completing of joints, support, accessory items, and obvious leaks.

B. Examine and inspect piping in accordance with ANSI B31.9, Chapter VI.

C. Leak Testing:

1. Provide temporary equipment for testing, including pumps and gages. Test piping system before insulation is installed, wherever feasible, and remove control devices before testing. Subject entire steam supply and return piping systems to leak tests, either as a whole, or in sections; but leave no part untested.

2. Leak test steam supply and return piping systems complying with ANSI B31.9

3. Fill piping systems with clear water, vent all air and pressurize at 150% of design pressure, (but not less than 25 psi) for 2 hours. Test fails if leakage is observed, or pressure drop exceeds 5% of test pressure.

4. Notify Project Manager at least 5 days before performing leak tests.

5. Repair piping systems which fail required piping test, by disassembly and reinstallation, using new materials to the extent required to overcome leakage. Do not use chemicals, stop-leak compounds, mastics or other temporary repair methods.

6. Drain test water from piping systems after testing and repair work has been completed.

D. Treating: Upon completion, fill, clean, and chemically treat systems. Refer to Section 15545 for chemical treatment of systems.

E. Certification: Prepare written report of testing, indicating locations of leaks corrected, method used to correct leaks, number of tests required, and certification that system is leak free.

3.4 COMMISSIONING (DEMONSTRATION)

A. Provide 4 hours of instruction on steam system. Include operation and maintenance and locations of the following as a minimum:

1. Location of traps.

2. Location of strainers and blow down valves.

3. Location of safety and relief valves.

4. System drain valves.

5. System fill and associated devices.
3.5 SCHEDULES

END OF SECTION
SECTION 15530
PRE-INSULATED PIPING SYSTEM

PART 1 - GENERAL

1.1 RELATED DOCUMENTS
A. Drawings and general provisions if the Contract, including General and Supplementary Conditions and other Division-1 Specification sections, apply to work of this section.

1.2 SECTION INCLUDES
A. Preinsulated piping systems for direct buried applications.

1.3 SUBMITTALS
A. 1. Comply with Section 01300.
B. 2. Product Data:
C. 3. Preinsulated piping

3.2 SHOP DRAWINGS:
A. Provide engineered shop drawings per these Specifications and Sections 01300.

3.3 QUALIFICATIONS
A. The system supplier for preinsulated piping systems shall have fabricated systems of the composition defined herein for at least five years.
B. Acceptable Manufacturers:
   1. Perma-Pipe/Ricwil
   2. Thermacor Process Incorporated

PART 2 – PRODUCTS

2.01 PREINSULATED PIPING SYSTEM – CHILLED WATER SUPPLY AND RETURN
A. General Description:
   1. Preinsulated piping systems shall be provided for all underground chilled water piping.
   2. A preinsulated piping system consists of carrier pipe, insulation, protective jacket, connectors, supports, and appropriate fittings.
   3. All underground chilled water pipes with fluid temperatures up to 60 degrees shall utilize polyurethane foam insulation with HDPE jacketing.
4. All straight sections, fittings, anchors and other accessories shall be factory fabricated to job dimensions and designed to minimize the number of field welds. One square cut, plain end for field cutting and beveling is allowed per straight run of pipe. Other ends shall be factory square cut and factory beveled such that the field welds have the capability of being welded to pass x-ray testing.

5. Each system layout shall be computer analyzed by the piping system manufacturer to determine stresses, anchor forces, heat losses, and anticipated movements of the service pipe along the entire length of pipe. The conditions for analysis are as follows: installation temperature of 0°F, ambient temperature of 50°F, depth of soil cover is 10 feet, soil conductivity of 10.00 btu-in/sq.ft H-F, and a service line operating temperature of 48°F. Friction between the ground and the jacketing material must be taken into account for the anchor force and stress calculations.

6. The system design shall be in strict conformance with ASME/ANSI B31.1, latest edition, and stamped by a registered professional engineer.

B. Service Pipe:

1. Internal piping shall be ASTM A-53, Grade B, ERW carbon steel. Schedule 40 for sizes through 10 inch, 0.375-inch wall thickness for sizes 12 inch and over (standard). Domestically produced pipe is required.

2. All joints shall be butt-welded for sizes 2-1/2 inches and larger, and socket welded for 2 inches and smaller.

3. Where possible, straight sections shall be supplied in35+foot double random lengths with sufficient piping exposed at each end for field joint welding and fabrication.

C. Accessories:

1. End seals, fittings and anchors shall be designed and factory fabricated to prevent the ingress of moisture into the system during shipping, outdoor storage, installation, and operation. End caps on the ends of the service pipe are required to prevent debris from entering the pipe for the period of time up until installation.

D. Insulation:

1. Service pipe insulation (polyurethane foam) for straight sections shall be spray applied or injected such that the final foam product has a nominal 2-3 pound per cubic foot density, 90% minimum closed cell content, conforms to ASTM C-591, and has an initial K factor less than or equal to 0.16. Performed polyurethane foam for fittings is acceptable.

2. To ensure no voids are present, all insulation shall be inspected by one of the following two methods: visually checked prior to application of the protective jacket, infrared inspection of the entire length during the foaming process. After successful completion of testing, all test report documents shall be submitted to the owner for records.
3. The insulation shall be applied to the minimum thickness specified below. The insulation thickness shall not be less than indicated in these specifications.

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Insulation Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;14”</td>
<td>1”</td>
</tr>
<tr>
<td>14”+</td>
<td>1-1/2”</td>
</tr>
</tbody>
</table>

E. Protective Jacket:

1. All straight sections of the factory preinsulated piping system shall be jacketed with a High Density Polyethylene jacket conforming to ASTM D1248. PVC jackets shall not be allowed.

2. All HDPE jacketing material shall have minimum wall thickness as specified below. The wall thickness shall not be less than indicated in these specifications.

<table>
<thead>
<tr>
<th>Jacket O.D.</th>
<th>Jacket Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>O.D. ≤ 12”</td>
<td>0.125”</td>
</tr>
<tr>
<td>12”, O.D. ≤ 24”</td>
<td>0.150”</td>
</tr>
<tr>
<td>O.D.&gt;24”</td>
<td>0.175”</td>
</tr>
</tbody>
</table>

3. All fittings of the factory preinsulated piping system shall be jacketed with the same material used for the straight sections of pipe and prefabricated to minimize field joints. Fittings shall be jacketed using a molded HDPE cover over polyurethane foam. Fittings shall be waterproof from the factory without the use of any type of tape, cellophane (or other non-HDPE plastic) wrap, mastic, glue, or hot air welds.

F. Field Joints:

1. All field joints shall be made in straight sections of pipe. Field joints other than at straight sections shall not be acceptable.

2. The method of field joint closure is as follows:

   1) The field joints are pressure tested and inspected for leaks.
   2) A split sleeve with holes in the top is placed around the joint area and secured with straps and sealed to the jacket with tape.
   3) Two-part polyurethane foam is mixed properly and poured into the holes on the top of the split sleeve.
   4) After the foam insulation has expanded and cured, any excess foam shall be removed.
   5) An adhesive backed heat shrinkable sleeve is then placed around the field joint area making sure to overlap the sleeve onto the HDPE jacketing by at least 3” on each side. This 3” overlap is to be completely on the HDPE and does not include the length of overlap of the split sleeve or tape.
   6) Heat is applied using a rosebud torch to the heat shrinkable sleeve slowly and evenly across the length of the sleeve until the sleeve has drawn tight.
   7) Any spots that pucker up during the shrinking process shall be covered with a thick-bodied asphaltic mastic (black roofing compound).
   8) Backfilling of the trench shall not begin until the area has cooled to the touch.
3. The piping systems manufacturer shall furnish all the foam insulation, split sleeves, and heat shrinkable jacketing materials for making the field joints. The contractor shall furnish the straps, tape, knives, saws, torch, gas, and mastic materials.

2.02 PREINSULATED PIPING SYSTEMS – STEAM CONDENSATE RETURN

A. General Description:

1. Preinsulated piping system shall be provided for all underground steam condensate piping.

2. A preinsulated piping system consists of carrier pipe, insulation, protective jacket, connectors, supports, and appropriate fittings.

3. All underground steam condensate return pipes with fluid temperatures up to 200 degrees shall utilize polyurethane foam insulation with HDPE jacketing.

4. All straight sections, fittings, anchors and other accessories shall be factory fabricated to job dimensions and designed to minimize the number of field welds. One square cut, plain end for field cutting and beveling is allowed per straight run of pipe. Other ends shall be factory square cut and factory beveled such that the field welds have the capability of being welded to pass x-ray testing.

5. Each system layout shall be computer analyzed by the piping systems manufacturer to determine stresses, anchor forces, heat losses, and anticipated movements of the service pipe along the entire length of pipe. The conditions for analysis are as follows: installation temperature of 0°F, ambient temperature of 50°F, depth of soil cover is 10 feet, soil conductivity of 10.00 btu-in/sq.ft H-F, and a service line operating temperature of 200°F. Friction between the ground and the jacketing material must be taken into account for the anchor force and stress calculations.

6. The system design shall be in strict conformance with ASME/ANSI B31.1, latest edition, and stamped by a registered professional engineer.

B. Service Pipe:

1. Internal piping shall be ASTM A-53, Grade B, ERW carbon steel. Schedule 80 for sizes through 8 inch, 0.500-inch wall thickness for sizes 10 inches and over (extra strong). Domestically produced pipe is required.

2. All joints shall be butt-welded for sizes 2-1/2 inches and larger, and socket welded for 2 inches and smaller.

3. Where possible, straight sections shall be supplied in 35+ foot double random lengths with sufficient piping exposed at each end for field joint welding and fabrication.

C. Accessories:
1. End seals, fittings and anchors shall be designed and factory fabricated to prevent the ingress of moisture into the system during shipping, outdoor storage, installation and operation. End caps on the ends of the service pipe are required to prevent debris from entering the pipe for the period of time up until installation.

D. Insulation:

1. Service pipe insulation (polyurethane foam) for straight sections shall be spray applied or injected such that the final foam product has a nominal 2-3 pound per cubic foot density, 90% minimum closed cell content, conforms to ASTM C-591, and has an initial K factor less than or equal to 0.16. Preformed polyurethane foam for fittings is acceptable.

2. To ensure no voids are present, all insulation shall be inspected by one of the following two methods: visually checked prior to application of the protective jacket, infrared inspection of the entire length during the foaming process. After successful completion of testing, all test report documents shall be submitted to the owner for records.

3. The insulation shall be applied to the minimum thickness specified below. The insulation thickness shall not be less than indicated in these specifications.

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Insulation Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 8”</td>
<td>1-1/2”</td>
</tr>
<tr>
<td>10”+</td>
<td>2”</td>
</tr>
</tbody>
</table>

E. Protective Jacket:

1. All straight sections of the factory preinsulated piping system shall be jacketed with a High Density Polyethylene jacket conforming to ASTM D1248. PVC jackets shall not be allowed.

2. All HDPE jacketing material shall have minimum wall thickness as specified below. The wall thickness shall not be less than indicated in these specifications.

<table>
<thead>
<tr>
<th>Jacket O.D.</th>
<th>Jacket Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>O.D. ≤ 12”</td>
<td>0.125”</td>
</tr>
<tr>
<td>12”&lt;O.D.≤24”</td>
<td>0.150”</td>
</tr>
<tr>
<td>O.D.&gt;24”</td>
<td>0.175”</td>
</tr>
</tbody>
</table>

3. All fittings of the factory preinsulated piping system shall be jacketed with the same material used for the straight sections of pipe and prefabricated to minimize field joints. Fittings shall be jacketed using a molded HDPE cover over polyurethane foam. Fittings shall be waterproof from the factory without the use of any type of tape, cellophane (or other non-HDPE plastic) wrap, mastic, glue or hot air welds.

B. Field Joints:

1. All field joints shall be made in straight sections of pipe. Field joints other than at straight sections shall not be acceptable.

2. The method of field joint closure is as follows:
a) The field joints are pressure tested and inspected for leaks.
b) A split sleeve with holes in the top is placed around the joint area and secured with straps and sealed to the jacket with tape.
c) Two-part polyurethane foam is mixed properly and poured into holes on the top of the split sleeve.
d) After the foam insulation has expanded and cured, any excess foam shall be removed.
e) An adhesive backed heat shrinkable sleeve is then placed around the field joint area making sure to overlap the sleeve onto the HDPE jacketing by at least 3" on each side. This 3" overlap is to be completely on the HDPE and does not include the length of overlap of the split sleeve of tape.
f) Heat is applied using a rosebud torch to the heat shrinkable sleeve slowly and evenly across the length of the sleeve until the sleeve has drawn tight.
g) Any spots that pucker up during the shrinking process shall be covered with a thick-bodied asphaltic mastic (black roofing compound).
h) Backfilling of the trench shall not begin until the area has cooled to the touch.

3. The piping systems manufacturer shall furnish all the foam insulation, split sleeves, and heat shrinkable jacketing materials for making the field joints. The contractor shall furnish the straps, tape, knives, saws, torch, gas, and mastic materials.

2.03 PREINSULATED PIPING SYSTEMS-STEAM

A. General Description:

1. Preinsulated piping systems shall be provided for all underground steam piping.

2. A preinsulated piping system consists of carrier pipe, carrier pipe insulation, steel casing pipe, casing pipe insulation, HDPE casing pipe insulation protective jacket, connectors, supports, internal moment guides, and appropriate fittings.

3. All underground steam distribution pipes with fluid temperatures up to 355°F shall utilize mineral wool carrier pipe insulation, steel conduit, and polyurethane foam conduit insulation with HDPE jacketing.

4. All straight sections, fittings, anchors and other accessories shall be factory fabricated to job dimensions and designed to minimize the number of field welds. One square cut, plain end for field cutting and beveling is allowed per straight run of pipe. Other ends shall be factory square cut and factory beveled such that the field welds have the capability of being welded to pass x-ray testing.

5. Each system layout shall be computer analyzed by the piping system manufacturer to determine stresses, anchor forces, heat losses, conduit/polyurethane insulation interface temperature, and anticipated...
movements of the service pipe and conduit along the entire length of pipe. The conditions for analysis are as follows: installation temperature of 0°F, ambient temperature of 50°F, depth of soil cover is 10 feet, soil conductivity of 10.00 btu-in/sq.ft H-F, and a service line operating temperature of 355°F. Friction between the ground and the jacketing material must be taken into account for the anchor force and stress calculations.

6. The system design shall be in strict conformance with ASME/ANSI B31.1, latest edition, and stamped by a registered professional engineer.

B. Service Pipe:

1. Internal piping shall be ASTM A-53, Grade B, ERW Carbon steel. Schedule 40 for sizes through 10 inch, 0.375-inch wall thickness for sizes 12 inches and over (standard). Coated pipe is not acceptable. Domestically produced pipe is required.

2. All joints shall be butt-welded for sizes 2-1/2 inches and larger, and socket welded for 2 inches and smaller.

3. Where possible, straight sections shall be supplied in 35+ foot double random lengths with sufficient piping exposed at each end for field joint welding and fabrication.

C. Subassemblies:

1. End seals, gland seals, internal moment guides, fittings (tees and elbows), and anchors shall be designed and factory fabricated to prevent the ingress of moisture into the system during shipping, outdoor storage, installation, and operation. End caps on the ends of the service pipe are required to prevent debris from entering the pipe for the period of time up until installation.

2. All subassemblies shall be designed to allow for complete draining and drying of the conduit system.

D. Service Pipe Insulation:

1. Carrier pipe insulation shall be mineral wool in non-supported sections. Split insulation shall be held in place by stainless steel bands installed on 18 inch centers, or two bands per insulation section, whichever is closest together. The insulation shall have passed the most recent boiling tests and other requirements specified in the Federal Agency Guidelines.

2. Support/guide sections shall have calcium silicate of the same thickness as the mineral wool with a protective sheet metal sleeve attached to the calcium silicate with screws.

3. The minimum insulation thickness shall not be less than indicated in these specifications.

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Minimum Insulation Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;-4&quot;</td>
<td>1.5&quot;</td>
</tr>
<tr>
<td>6&quot;-10&quot;</td>
<td>2.0&quot;</td>
</tr>
<tr>
<td>12&quot;-14&quot;</td>
<td>2.5&quot;</td>
</tr>
<tr>
<td>16&quot;-20&quot;</td>
<td>3.0&quot;</td>
</tr>
</tbody>
</table>
E. Outer Conduit:

1. The steel conduit casing shall be a smooth wall, welded steel conduit of the thicknesses specified below:

<table>
<thead>
<tr>
<th>Nominal Conduit Size</th>
<th>Minimum Conduit Thickness</th>
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</thead>
<tbody>
<tr>
<td>6”-26”</td>
<td>10 Gauge (0.1345”)</td>
</tr>
<tr>
<td>28”-36”</td>
<td>6 Gauge (0.1943”)</td>
</tr>
<tr>
<td>38”-42”</td>
<td>4 Gauge (0.2242”)</td>
</tr>
</tbody>
</table>

2. Changes in casing size, as required to allow for carrier pipe expansion into the conduit, shall be accomplished by eccentric and/or concentric fittings and shall provide for continuous drainage of the conduit along the entire length of pipe.

F. Pipe Supports and Guides:

1. All pipes within the outer casing shall be supported at not more than 10-foot intervals.

2. The supports shall be designed to allow for continuous airflow and drainage of the conduit.

3. The carrier pipe supports in straight runs shall be designed to occupy not more than 10% of the annular air space between the carrier pipe insulation and the steel conduit.

4. Supports shall be of the type where insulation thermally isolates the carrier pipe from the outer conduit. Support/guide sections shall have calcium silicate of the same thickness as the mineral wool with a protective sheet metal sleeve attached to the calcium silicate with screws. This sleeve shall be as long as the corrugated supports, with a minimum length of 12 inches.

5. The corrugated metal supports shall be a minimum of 12” long and of sufficient strength (thickness) to support the pipe without the annular air space being encroached upon.

6. Moment guides and rotational arrestors internal to the outer conduit shall be provided on the locations shown on the drawings and additionally where required by the manufacturer’s analysis.

G. Outer Conduit Insulation:

1. Outer conduit insulation (polyurethane foam) for straight sections shall be spray applied or injected such that the final foam product has a nominal 2-3 pound per cubic foot density, 90% minimum closed cell content, conforms to ASRM C-591, and has an initial K factor less than or equal to 0.16. Preformed polyurethane foam for fittings (elbows and tees) is acceptable.

2. To ensure no voids are present, all insulation shall be inspected by one of the following two methods: visually checked prior to application of the protective jacket, infrared inspection of the entire length during the foaming process. After successful completion of testing, all test report documents shall be submitted to the owner for records.

3. The insulation shall be applied to the minimum thickness of 1-1/2 inches. The insulation thickness shall not be less than indicated in these specifications.
H. Protective Jacket

1. All straight sections of the factory preinsulated piping system shall be jacketed with a High Density Polyethylene jacket conforming to ASTM D1248. PVC jackets shall not be allowed.

2. All fittings of the factory preinsulated piping system shall be jacketed with the same material used for the straight sections of pipe and prefabricated to minimize field joints. Fittings shall be jacketed using a molded HDPE cover over polyurethane foam. Fittings shall be waterproof from the factory without the use of any type of tape, cellophane (or other non-HDPE plastic) wrap, mastic, glue, or hot air welds.

3. All HDPE jacketing material shall have minimum wall thickness as specified below. The wall thickness shall not be less than indicated in these specifications.

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I. Field Joints

1. All field joints shall be made in straight sections of pipe. Field joints other than at straight sections shall not be acceptable.

2. The method of field joint closure is as follows:

   1) The welds on the carrier pipe field joints are pressure tested and inspected for leaks.

   2) Shipping supports on the ends of the pipe sections are cut off.

   3) Mineral wool insulation (matching the properties of the straight sections) is applied to the joint area and secured in place using stainless steel bands.

   4) A split metal casing is welded to the conduit and each other to form a pressure testable seal around the conduit. This area should allow water to drain freely past the field joint area and not become trapped in a low spot in the conduit.

   5) A split sleeve with holes in the top is placed around the joint area and secured with straps and sealed to the jacket with tape.

   6) Two-part polyurethane foam is mixed properly and poured into the holes on the top of the split sleeve.

   7) After the foam insulation has expanded and cured, any excess foam shall be removed.

   8) An adhesive backed heat shrinkable sleeve is then placed around the field joint area making sure to overlap the sleeve onto the HDPE jacketing by at least 3” on each side. This 3”
overlap is to be completely on the HDPE and does not include the length of overlap of the split sleeve or tape.

9) Heat is applied using a rosebud torch to the heat shrinkable sleeve slowly and evenly across the length of the sleeve until the sleeve has drawn tight.

10) Any spots that pucker up during the shrinking process shall be covered with a thick-bodied asphaltic mastic (black roofing compound).

11) Backfilling of the trench shall not begin until the area has cooled to the touch.

3. The piping systems manufacturer shall furnish all the mineral wool and foam insulation materials, split metal casing, stainless steel bands, split sleeves, and heat shrinkable jacketing materials for making the field joints. The contractor shall furnish the straps, tape, knives, saws, torch, gas, and mastic materials.

PART 3 – EXECUTION

3.01 PREINSULATED PIPING SYSTEM

1. Installation:

1. The installing contractor shall handle the system in accordance with the directions furnished by the manufacturer and as approved by the engineer.

2. Provide the service of a manufacturer’s representative to instruct the contractor on the installation procedures of the piping system and to be present on site to assist during critical stages of installation and testing. The representative must be qualified by the piping system manufacturer who’s responsibility is to provide Field Technical Assistance (FTA).

3. When the manufacturer’s representative is on-site, a report shall be produced consisting of the installation log indicating actually installed conditions, field observations, and pressure test results signed by the manufacturer’s representative, the contractor, and the engineer’s representative. Include documentation by the manufacturer’s representative that the installations in conformance with the manufacturer’s recommendations.

4. A minimum of six inches (6") of sand or fine gravel bedding shall be placed all around the pipe in the trench. This bedding/fill shall be hand tamped and compacted around the pipes in six-inch (6") lifts until the fill is six inches (6") above the top of the jacketing material. The remaining height of the trench shall be evenly and continuously backfilled and compacted in uniform six inch (6") lifts with suitable clean excavated soil.

5. The field joints shall be installed as described in each product section.

B. Testing – Chilled Water and Condensate Piping

1. The internal pipe shall be hydrostatically tested to 150 psig or 1-1/2 times the operating pressure, whichever is greater. The hydrostatic test pressure shall be
held for no less than one hour. In large diameter pipes, pneumatic testing may be an acceptable alternative (at the discretion of the Engineer and UC Denver). Proper safety precautions and coordination must be completes with the UC Denver Health and Safety department before testing is initiated.

C. Testing – Steam Piping

1. The service piping shall be hydrostatically tested to 150 PSIG or 1-1/2 times the operating pressure, whichever is greater. The hydrostatic test pressure shall be held for no less than one hour. In large diameter pipes, pneumatic testing may be an acceptable alternative (at the discretion of the Engineer and UC Denver). Proper safety precautions and coordination must be completes with the UC Denver Health and Safety department before testing is initiated.

END OF SECTION 15530
SECTION 15545
CHEMICAL WATER TREATMENT

PART 1 - GENERAL

1.1 SUMMARY

A. This standard includes water treatment for:

1. Closed System Heating Water
2. Closed System Chilled Water
3. Closed System Glycol Heating Water
4. Open Water Systems
5. DI Water
6. Piping System Cleaning and Flushing

1.2 REFERENCES

A. Section 15000 – General Mechanical Provisions

B. Section 15546 – Chemical Water Treatment – Flushing, Cleaning, Treating, and System Start-up

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. General Information:

1. Coordinate with UC Denver Facilities Operations for supplies and consulting. New projects should utilize the existing chemical treatment protocols.

2. Coordinate all start-ups with water treatment technician and vendor by notifying the UC Denver Project Manager.

3. Chemical treatment sites shall be over concrete dams with a retention volume equal to the volume of the chemical tank. Coordinate with the Architect to provide a curbed area for storage of on-site water treatment chemicals.

4. Separate freeze protection of systems exposed to outside air conditions into those requiring burst protection and those requiring freeze protection.

   a. Snow melt system shall be provided with 40% Dowfrost.

   b. Burst Protection: Systems that have some expansion capability and will remain dormant during the winter and will not require automatic start-up during cold weather shall be protected with concentrations of 35% Dowfrost.

   c. Freeze Protection: Systems that have no expansion capability or will require start-up during cold weather shall be protected with concentrations of 35% Dowfrost.
5. Treatment shall be as automated as possible with controllers and pumps installed in serviceable locations.

B. Hydronic Piping Systems:

1. Equip all closed water systems with a pressure pot feeder. Arrange for shot feeding or for continuous feed as appropriate.

2. Ethylene glycol is prohibited.

3. Provide ion exchange water softener for all boilers and clean steam generators capable of producing a consistent supply of make-up water containing less than 0.5 ppm total hardness. Provide a single softener vessel system for boilers that shut down at least 4 hours per day and a dual vessel system on boilers that run continuously.

4. Provide corrosion coupon racks on all chilled water, heating, hot water, and condenser water systems.

C. Closed System: One bypass feeder on each system with isolating and drain valves installed around balancing valve downstream of circulating pumps.

D. Steam System:

1. Bypass feeder on feedwater line to each boiler.

2. Sequestering agent and base pumped from solution tank into boiler, condensate tank, or feedwater line near boiler. Agitator as required.

3. Oxygen scavenger pumped from solution tank into deaerator storage section, feedwater tank or feedwater line as far as possible from boiler. Pumps and agitator as required.

4. Carbon dioxide neutralizer or filming amine pumped from solution tank into steam header. Agitator as required.

5. Solution pumps shall be activated when feedwater pumps are running.

6. Conductivity controller shall sample boiler water on timed cycle and operate solenoid blowdown valve in line to blowdown tank.

7. Liquid level switch in each solution tank shall deactivate solution pump and agitator, and signal alarm.

E. Open System: Provide the system below for small open systems such as humidifiers, air washers, evaporative condensers, liquid coolers or small cooling towers.

1. Two glass-mesh feeder bags per unit, suspended in sump, filled with sequestering agent.

2. Drip feeder feeds sequestering agent into sump. Spray pump interlocked with solenoid valve on drip system.

3. Bleed-off with globe valve piped to drain located above flood line.
4. Conductivity controller samples sump water when activated by pump and operates bleed-off solenoid valve in line to drain.

5. Use automated controllers which start and start pumps to feed corrosion inhibitors, algaecide, microbicide and biocides.

F. Condenser Water Treatment: Provide the system below for medium to large systems such as cooling towers.

1. Automatic systems for inhibitor, blowdown and biocide, shall be activated by a water meter that is located on the system makeup and by a conductivity controller that has its probes located in condenser water line.

2. Sequestering agent and corrosion inhibitor pumped from solution tank into condenser water supply to tower. Agitator as required.

3. Meter feed biocide with blowdown locked out to ensure biocide retention time.

4. Conductivity controller samples water and operates solenoid bleed valve when condenser water pump is operating.

5. Biocide introduced to tower by continuous feed with solution pump or solenoid valve on tank.

6. Liquid level switch, in each solution tank, deactivates solution pump and agitator, and signals alarm.

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Provide chemical safety data sheets for inclusion in Operation and Maintenance manuals.

1.6 QUALITY ASSURANCE

A. All services shall be performed by a qualified full-time representative. All products supplied shall meet with all regulations for safe handling and discharge into waste systems.

B. Supplier shall have 24 hour emergency spill response cleanup for any spills resulting from either the filling process or failure of the system. The individuals performing the cleanup must be OSHA certified and shall follow OSHA standards during the spill response process.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Chemical Feeders:
a. LMI
b. Pulsafeeder
c. or approved equal

2. Water Meters:
   a. Carlon
   b. LMI
   c. Pulsafeeder

3. Conductivity Meters:
   a. LMI
   b. Pulsafeeder.
   c. or approved equal

4. Pot Feeders:
   a. Neptune, Model FTF-5
   b. or approved equal

5. Glycol Feeder Pressure Switch:
   a. Furnas Electric Company, Model 69WA
   b. or approved equal

6. Deionized Water System:
   a. Culligan
      b. Siemens Water Technologies
   c. Continental

7. Deionized Water:
   a. Carbon Filter
      1) Culligan HR-12
      2) or approved equal
   b. Sediment Filter Housing:
      1) Gelman 961062
      2) or approved
c. Storage Tank:
   1) Raven D9725
   2) or approved equal

d. Glycerine Filled Gauges:
   1) APAN LSF217
   2) or approved equal

e. Quality Monitor/Controller:
   1) Thornton 702
   2) Or approved equal

8. Glycol
   a. Dow Chemical Company, Dowfrost
   b. Or approved equal

2.2 MATERIALS, GENERAL

A. Chemical Feeders:

1. Positive Displacement Pump: Diaphragm-type metering pump with adjustable flow rate, continuous-duty, fully enclosed electric motor and drive, and built-in relief valve. Construct pump parts in contact with chemical solution of PVC, Teflon, Viton, 316 stainless steel, polyethylene, or other corrosion resistant material.

2. Chemical Solution Tanks: Chemical-resistant, double walled tanks sized from 60 to 110 gallons to accommodate four treatment products. Inner and outer tanks constructed of polyethylene. Provide tanks with 2 X 2-inch female threaded openings with bung and 1 X 8-inch man way fitting. Tanks shall have no fittings below liquid level. Supply tanks with transfer fittings and level indicator devices.

3. Packaged Conductivity Controller: Micro-processor based with digital display, acceptance of 4 – 20 mA signal and capable of BACNET communications interface for building automation. Provide with the following control features:
   a. Conductivity control.
   b. ORP control.
   c. Inhibitor feed based on “bleed”, water meter input or percent time.
   d. Chemical time out.
   e. Dual biocide timer.
4. **Cold Water Meter**: Positive displacement type with sealed, tamperproof magnetic drive; impulse contact register, single-pole, double-throw, dry-contact switch.

5. **Solenoid Valves**: Forged-brass body, globe pattern, general purpose solenoid enclosure, and continuous-duty coil.

**B. Pot Feeders:**

1. **Bypass type chemical feeder of 5-gallon capacity, steel or cast iron construction, 125 psig working pressure.** Provide a filter bag inside the feeder. Provide complete with fill funnel, 2 spare bags, shutoff valve, air release valve, and recirculation shutoff valves on inlet, outlet, and drain valve.

**C. Glycol Feeder Assembly:**

1. **Assembly shall consist of storage drum, feeder pump, pressure switch and low water cutoff.**

2. **Glycol Tanks**: Chemical-resistant 50-gallon reservoir fabricated from high density opaque polyethylene with graduated markings; molded fiberglass cover with mounting for liquid level switch, drain connection near bottom of tank.

3. **Pressure Switch**: Corrosion resistant and rust proof construction, visible double break contacts which are silver-cadmium oxide, reinforced neoprene diaphragm, no-drift adjustable pressure setting, pilot duty NEMA-A600.

4. **Low Water Cut-Off Switch**: Switch to stop pump when water level reaches 3 inches (adjustable) above outlet supply fitting in storage drum. Switch shall also light a red warning light at the temperature control panel when activated. Label light "Glycol Storage Low Level".

**D. Condenser Water Treatment Control Panel:**

1. **Control Panel**: Solid-state integrated circuits and digital LED displays, in NEMA 250, Type 12 steel enclosure with gasket and lockable door.

2. **Control dissolved solids on conductivity and include the following:**
   a. LED digital readout display (micro-ohm/cm).
   b. Temperature-compensated sensor probe.
   c. HIGH, LOW, and NORMAL conductance indicator lights.
   d. HIGH or LOW conductance alarm light, trip points field adjustable, with SILENCE switch.
   e. HAND-OFF-AUTOMATIC switch for solenoid bleed valve.
   f. BLEED light to indicate valve operation.
   g. Adjustable internal hysteresis or dead band.

3. **Control inhibitor feed on makeup volume and include the following:**
a. Solid-state reset counter (1 to 15, selectable).
b. Solid-state timer (adjustable 15 seconds to 5 minutes).
c. Test switch.
d. HAND-OFF-AUTOMATIC switch for chemical pump.
e. Illuminated legend shall indicate FEED when pump is activated.
f. Solid-state lockout timer (adjustable 15 minutes to 3 hours) and indicator light. Lockout timer shall deactivate the pump and activate alarm circuits.
g. Panel totalizer for amount of makeup.

4. Biocide programmer to include the following:
   a. 24-hour timer with 14-day skip feature
   b. Solid-state bleed lockout timer (0 to 9 hours) and biocide pump timer (0 to 2.5 hours), clock controlled.
   c. Solid state alternator to enable use of two different biocide formulations.
   d. Digital display of time of day (24 hours).
   e. Battery back-up on clock.
   f. HAND-OFF-AUTOMATIC switches for biocide pumps.
   g. BIOCID E A and BIOCID E B illuminated legends indicate pump running.

E. Condenser Water Filtration Assembly:
   1. Filtration unit to remove suspended solids from condenser water.
   2. Filter pump shall be all bronze with TEFC motor, strainer, and manual reset motor overload switch with pilot light.
   3. Sand filter shall include glass-fiber-reinforced polyester tank, internal distribution piping, differential gage panel, manual and automatic pressure relief valves, backwash valve and sight tube, and graded silica sand.
   4. Backwash control shall be automatic including time clocks and/or differential pressure switches, mounted in NEMA 250, Type 4 control panel. Backwash shall use city water versus system water.

F. Deionized (DI) Water:
   1. Provide DI water piping system that is looped with a circulation pump. Complete system shall be unpigmented polypropylene with polypropylene stainless steel valves and accessories.
2. The system shall provide 18.0 and not less than 1.0 megohm/cm quality water. Provide complete system including, but not limited to, the following:
   a. One automatic backwashing granular activated carbon filter. Filter shall be used for chlorine and organic removal at a flow rate of 30 gpm.
   b. Supply one, cartridge type, sediment filter housing constructed of 316 SS, electro-polished. Housing shall use one micron (minimal) filler cartridges. The empty housing flow rate shall be 30 gpm at a pressure loss of less that 2 psi.
   c. Supply sufficient grain tribed deionizers. Each tribed deionizer shall consist of one cation, one anion (strong base), and one mixed bed.
   d. Tanks shall be stainless steel or constructed of non-corrosive fiberglass surrounding an inner-molded lining of ABE plastic. Supplies shall be capable of regeneration of resins within the tank so that no U. of C. Resins are mixed with other resins. Supplier shall have a 24 hour emergency response capability include 1,000,000 ohm quality indicator light. Tank fittings shall be quick-disconnect, union style, and be made of inert materials.
   e. Supply enclosed annular head, flat bottom storage tanks. Tanks shall be factory steam cleaned. Tank shall come complete with all necessary fittings and shall be vented.
   f. Supply one level control with high level cutoff, low level pump cutoff, and mid-level fill. Mid level will energize n/c solenoid on the make-up line and cut power to the DI water recirculation pump. High level will close solenoid valve and start DI water recirculation pump.
   g. All necessary pumps
   h. Glycerine filled gauges with ss stems.
   i. Quality Monitor/Controller 35,000-5,000,000 ohm/cm 0.1 constant cell, meter, 10' cord.
   j. All necessary controls and hardware to make system complete.
   k. Polishing units will be required at the lab outlet.

G. Chemicals:
   1. Chemicals compatible with piping materials, seals, and accessories.
   2. Store all chemicals in a secured location on approved containment devices, with all required safety precautions. All chemicals are to be stored in a location that is warm enough to keep the chemical from freezing.
   3. System Cleaner: Liquid alkaline compound with emulsifying agents and detergents to remove grease and petroleum products.
   4. Biocide: Chlorine release agents or microbiocides.
5. Closed System Chemicals: Sequestering agent to reduce deposits and adjust pH, corrosion inhibitors, and conductivity enhancers.

6. Steam System Chemicals: Sequestering agent to reduce hardness and prevent feedline congestion, base to provide alkalinity, oxygen scavenger, carbon dioxide neutralizer, and filming amines.

7. Condenser Water (Cooling Tower) System Chemicals: Sequestering agent to inhibit scaling, acid to reduce alkalinity and pH, corrosion inhibitor, and biocide.

8. Open System Chemicals: Sequestering agent to inhibit scaling, acid to reduce alkalinity and pH, corrosion inhibitor, and biocide.

9. Provide quantity of extra chemicals equal to 50% of amount initially installed.

10. Provide “Material Safety Data Sheets” for all chemicals products that are onsite.

H. Glycol:

1. Dowfrost

I. Chemical Treatment Test Equipment:

1. Test Cabinet: White enamel with local fluorescent light, capable of accommodating 4 to 10 ml zeroing, titrating burettes and associated reagents.

2. Test kits shall be provided for determining water hardness and water characteristics. Test kits shall include carrying case and spare reagents. Provide as follows:
   a. Alkalinity titration.
   b. Chloride titration.
   c. Sulfite titration.
   d. Total hardness titration.
   e. Low phosphate.
   f. Conductivity bridge, range 0 to 10,000 micro-ohms.
   g. Creosol red pH slide, complete with reagent.
   h. Portable electronic conductivity meter.
   i. High nitrite.

J. Coupon Racks:

1. Constructed of 3/4 inch, schedule 80 PVC except schedule 80 mild steel pipe for hot water systems. Size coupon rack to accept four corrosion test specimens. Provide orifice valve in each rack to adjust water flow to 3 to 4 feet/second, throughout the rack.
2. Install coupon racks in condenser water systems with the warmest water supplying water to the rack.

K. Spare Parts:

1. Provide two manufacturers' recommended spare part kits for each chemical feeder pump.

2. Spare parts shall include valve cartridges with O-rings, head, diaphragm, secondary O-ring seal, head screws, and washers.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. All mechanical and electrical installation shall be provided by the mechanical contractor except that electrical installation which is indicated on electrical drawings and/or specifications as a part of the electrical contract.

B. Chemical Feeders:

1. Mount chemical feeders in accordance with manufacturer's instructions. Injection point for chemicals shall be higher than top of solution supply tank to prohibit gravity feeding. Interlock conductivity controller with recirculating pump on cooling tower. Install electric solenoid valve in bleed-off line with y-strainer ahead of valve. Chemicals shall be fed into pump discharge line on continuous metered basis.

C. Pot Feeders:

1. Install shot feeders on closed system in upright position with top of funnel not more than 48-inches above floor. Pipe drain, with ball valve, to nearest equipment drain. Install piping adjacent to equipment to allow servicing and maintenance.

D. Glycol Feeders:

1. After cleaning and flushing piping, refill glycol piping system and glycol tank with mixture of propylene glycol and water solution.

2. Perform tests to determine the strength of glycol and water solution. Submit written test results to Contracting Officer and include in maintenance manuals. Provide test prior to end of first year of operation and replenish as required.

3. Run full size discharge line from relief valve to storage tank.

3.3 TESTING, CLEANING AND CERTIFICATION

A. General: Ensure system is operational, filled, started, and vented prior to cleaning. Place terminal control valves in open position during cleaning. Add cleaning chemicals as recommended by equipment manufacturer. See section 15546 for the specific flushing, cleaning, and treating process.
B. Heating Water Systems: Hot water heating systems, including converters, pumps, coils and piping shall be cleaned with a solution of trisodium phosphate. This cleaning also applies to glycol systems prior to filling. Apply heat while circulating, slowly raising system to design temperature; maintain for a minimum of 24 hours. See section 15546 for the specific flushing, cleaning, and treating process.

C. Chilled Water Systems: See section 15546 for the specific flushing, cleaning, and treating process.

D. Steam and Condensate Systems:

1. Steam System: Fill only steam boilers with cleaner and water. Apply heat and maintain for minimum of 12 hours. Cool and drain. Refill with clean water, drain, refill, and check for sludge. Repeat until system is free of sludge. Apply heat to produce steam for piping system and maintain for minimum of 8 hours.

2. Before placing steam and condensate piping system in service, the piping shall be thoroughly blown out with steam to remove dirt, rust, scale or other contaminants. Blow down to drain or into a container all system strainers once an hour for the first 4 hours and then twice a day until the entire steam and condensate system is interfaced with the UC Denver Steam and Condensate systems. Remove all screens and clean them. The UC Denver Facilities Operation Representative will witness the inspection and cleaning of an agreed upon number of strainer screens to verify their condition.

3. Bypass traps and waste condensate until approved by the UC Denver Facilities Operations Representative. Following approval by the UC Denver Facilities Operations Representative, return condensate to collection system and put traps back in line.


E. All Systems:

1. When the flushing, cleaning, and treating process is complete, remove all startup screens from the strainer element(s), if installed.

F. Chemical Treatment:

1. System Start-Up:

   a. The water treatment supplier shall put the treatment equipment into operation, and make adjustments necessary for proper operation.

   b. The water treatment supplier shall provide a written report to the mechanical contractor indicating that all equipment is operating properly.

2. General: Test hydronic water systems one week after each system start-up and perform a second test one week after the first test. Test for total dissolved solids, inhibitors, and hardness. Provide a certified report after each test indicating initial findings, treatment required and future recommendations. Chemical treatment shall contain no chromates and be bio-degradable. Provide water analysis to determine the type and level of chemicals required for prevention of scale and corrosion.
3. Provide chemicals and service program for period of three months from project closeout. Vendor must provide “drumless delivery” (transfer of material into customer’s receiver tanks) thereby eliminating any chemical handling on the part of in-house personnel. No drums will be stored on site. Service shall include monthly analysis of water systems. Adjust treatment as needed to maintain system quality as specified. Provide written report of each visit including initial and final water tests, chemicals and amounts used. Provide 24 hour spill response capabilities.

4. Test Equipment:
   a. The water treatment chemical and service supplier shall furnish basic water test equipment, including carrying case and reagents for use with the supplier’s products, include apparatus for determination of treatment residual. Where specialized or supplementary equipment is required, it shall be furnished as part of the offering.
   b. Provide test equipment as needed to monitor cycles of concentration and the level of treatment chemicals with the respective systems.

5. Treat raw water available at the project site to sustain the following water characteristics:
   a. Closed System:
      1) Hardness: 0.5 times the make-up water hardness.
      2) Iron: 0.0.
      3) Total Dissolved Solid: 1500 to 2400 ppm (as CaCO3).
      4) Silica: 60 ppm or less.
      5) PH: 9.6 to 10.5
   b. Steam System:
      1) Hardness: 0.0
      2) Iron: 0.0.
      3) Total Alkalinity: 1026 ppm or less.
      4) Silica: 120 ppm or less.
      5) PH 10.5 or above.
   c. Open System:
      1) Hardness: 6 times the make-up water hardness.
      2) Iron: 0.0.
      3) Total Alkalinity: 1026 ppm or less.
4) Silica: 120 ppm or less.

5) PH: 7.5 or above.

6) Total Algae: 0 growth.

3.4 COMMISSIONING (DEMONSTRATION)

A. Provide the operating personnel 8 hours of instruction so as to familiarize them with all treatment equipment and procedures. Demonstrate procedure for taking weekly water test on open-loop systems and demonstrate the application and safe handling of supplied chemicals

B. Provide a written report to the mechanical contractor indicating that operator training has been completed.

3.5 SCHEDULES

END OF SECTION
SECTION 15546
CHEMICAL WATER TREATMENT -
FLUSHING, CLEANING, TREATING, AND SYSTEM START-UP

PART 1 - GENERAL

1.1 SUMMARY

A. This standard includes flushing, cleaning, and treating the following systems:

1. Flushing, Cleaning, and Treating of water filled systems that interface with the CUP

2. Flushing, Cleaning, and Treating of water filled systems that do not interface with the CUP

3. Steam and condensate systems

4. Pre-cleaning and passivation of condenser water and cooling tower systems

1.2 REFERENCES

A. Section 15000 - General Mechanical Provisions

B. Section 15545 - Chemical Water Treatment

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. Flushing, Cleaning, and Treating of Systems into the UC Denver Distribution System(s).

1. The UC Denver Facilities Operations Department personnel are highly motivated to employ the best possible treatment practices to insure the boilers, chillers and associated piping meet or exceed their expected lifespan. The UC Denver Central Utility Plant (CUP) personnel coordinates the cleaning process for all Chilled Water, Heating Water, Steam, Condensate, Condenser Water, and Cooling Towers.

2. Expansion to the distribution system of the UC Denver requires the interface of new piping with the existing piping. With this in mind, the UC Denver CUP requires that consistent cleaning and passivation practices are performed throughout the campus on all projects. The goal is for all new facilities are as follows:

a. Insure that all systems are properly flushed, cleaned, and passivated to minimize foulants returned to the CUP when opened to the existing distribution system.

b. Insure that the treatment practices employed are compatible with current treatment programs.

c. Insure that pretreatment practices meet the minimum requirement of the UC Denver CUP.

3. Due to the size of the campus chilled water system, creative approaches are being applied to the treated water to manage the inevitable conditions where various contaminants may enter the loop as a result of system expansion. The general goals will be consistent with industry standards for proper treatment of the systems on site. Below is a summary of these standards:

a. Chilled water mild steel corrosion rates of <0.5 MPY.
b. Chilled water copper corrosion rates of no greater than 0.1 MPY.

c. Aerobic biological counts in the chilled water not to exceed 50,000 CFU/ml, sulfate reducing bacteria counts <10 CFUs.

d. No scale in the chilled water system.

e. Condensate mild steel corrosion rates of <5.0 MPY.

f. Condensate copper corrosion rates of <0.1 MPY.

g. Steam will contain <10 ppb of dissolved oxygen at all times.

4. An equivalent chemical may be used after it has been approved for compatibility by the UC Denver CUP. The contractor’s chemical vendor will provide data sheets to the UC Denver CUP with the request for approval for an equivalent chemical. Equivalent chemicals can not be used until they have been approved by the UC Denver CUP.

5. It is the contractor’s responsibility to ensure that the system(s) is clean, and has been properly treated. It is the UC Denver Water Treatment contractor’s responsibility to verify that the system(s) has been properly treated and is ready to be opened into the UC Denver Distribution System(s).

6. Co-ordinate with the UC Denver CUP personnel and the current UC Denver CUP Water Treatment contractor to determine which tests and inspections will be monitored.

7. Contact the UC Denver Outage Coordinator to schedule the opening of any/all system(s) into the same UC Denver system(s). The UC Denver Outage Coordinator must have all required paperwork on file before they will schedule a system startup.

PART 2 - PRODUCTS

PART 3 - EXECUTION

A. Chilled Water and Heating Water Systems

1. Chilled water piping must be pre-cleaned and passivated prior to operation. To accomplish this, a method must be provided to circulate these lines at design flow during cleaning. Design minimum flows are stated as a function of pipe diameter in the table below:

<table>
<thead>
<tr>
<th>Pipe diameter in inches</th>
<th>Cross sectional area in feet</th>
<th>Minimum flow GPM for 2 ft/sec velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.2</td>
<td>180</td>
</tr>
<tr>
<td>8</td>
<td>0.35</td>
<td>314</td>
</tr>
<tr>
<td>12</td>
<td>0.79</td>
<td>708</td>
</tr>
<tr>
<td>16</td>
<td>1.4</td>
<td>1256</td>
</tr>
<tr>
<td>24</td>
<td>3.14</td>
<td>2818</td>
</tr>
<tr>
<td>36</td>
<td>7.06</td>
<td>6284</td>
</tr>
</tbody>
</table>

2. Taps will be installed, in the vault, on the building side of the supply and return isolation valves. The building pump or temporary circulation pump will
3. Circulate the water during the pretreatment process.

3. The addition of Isothiazolin biocide is required. It needs to be added after the system cleaning has been accepted. The nitrite must be added 24 hours after the nitrite has been added.

4. During the flushing, cleaning, and treating process, insure that the minimum flow of 2 feet/second is met. Flow less than 2 feet/second is not acceptable. Flows greater than 2 feet/second, up to the maximum design flow of the system, are acceptable and will assist in the flushing, cleaning, and treating process. Maximum flow is preferred but not required.

5. If possible, on heating water systems, heat the bulk water to 120 degrees F during the circulation period.

6. The UC Denver CUP must approve all products that will be used prior to the start of the process. Only factory blended products will be considered. Products blended onsite are not allowed.

7. Biological samples can only be taken Monday through Thursday (Holidays excepted). The sample is sent overnight to the lab. Until the test results return acceptable, a system will not be allowed to be opened into the existing UC Denver Distribution system.

8. Two options exist for pre-cleaning. One approach is an alkaline based approach and the other is a nitrite based approach. Consult the UC Denver CUP prior to choosing an approach. The alkaline based pre-cleaner applies a minimum of 500 ppm of total inorganic phosphate within the treated water. The pre-cleaner should also contain detergents and dispersants designed to perform an effective cleaning at pH values of 11.5 or higher. The pretreatment plan should also include a minimum of 10 ppm of organic copper corrosion inhibitor such as “TT” in the bulk water. An alternative nitrite based approach uses nitrite, detergents, dispersants and 10 ppm of organic copper corrosion inhibitor such as “TT”. This product is applied to achieve nitrite residuals of in excess of 600 ppm as NO2. These treatment levels can be achieved by adding 2.5 gallons of Nalco-2859, or an equivalent product, to the system per 1000 gallons of system capacity.

a. Flushing, Cleaning, and treating Chilled Water and Heating Water systems using an Alkaline Based Cleaner. Remember that the timeline below is dependant upon all things occurring as they are written. The timeline below is bare bones for an average sized system. Smaller projects may be able to save some time during the filling and draining periods.

1) Day 1: Fill the entire system that is available with city water and continuously circulate the water with one of the system pumps throughout the building, through all chilled water lines, including lines to vaults. If there is more than one pump in the system, alternate the pumps at least once during this process to ensure each pump is run.

2) Day 2 (24 hours after step #1): The UC Denver CUP and/or the UC Denver Water Treatment contractor, the contactors water treatment vendor, and the contractor to test the water for
conductivity and view the water for clarity. If there are no
issues, the UC Denver CUP will give a verbal “OK” to the
contractor onsite to proceed with the drain down. This “OK”
will be followed up with an e-mail to all interested parties.

3) Day 3: Refill the entire system that is available with city water
and add the approved alkaline based cleaner. Your water
treatment consultant will need to calculate the correct amount of
cleaner needed. Circulate the water with one of the system
pumps throughout the building, through all chilled water lines,
including lines to vaults. If there is more than one pump in the
system, alternate the pumps at least once during this process to
ensure each pump is run. Run each pump at least two separate
times.

4) Day 4: Continue to circulate the entire system with the cleaner in
it throughout the building, including lines to vaults (If required).
If there is more than one pump in the system, alternate the
pumps at least once during this process to ensure each pump is
run. We would like to see each pump to run two separate
times.

5) Day 5 (A minimum of 48 hours after step #3 has been
completed): The UC Denver CUP and/or the UC Denver Water
Treatment contractor, the contactors water treatment vendor, and
the contractor to test water for pH and conductivity. If the pH
test is above 11.5 and the conductivity is elevated well above
city water conductivity, a verbal “OK” will be given that the pH
of the water is acceptable and the drain down and flushing out of
the cleaner can start. This “OK” will be followed up with an e-
mail to all interested parties.

6) Day 6: If the following does not occur as written, all dates below
this will be affected. When the conductivity is within 10% of
the conductivity of the City of Aurora water, contact the UC
Denver CUP. The UC Denver CUP will meet with the
 contactors water treatment vendor and the contractor at the site
and test the water for conductivity and pH. If the conductivity
test is within 10% of the conductivity of the City of Aurora
water, a verbal “OK” will be given that it is acceptable to add
the Isothiazolin biocide. Circulate the system for 24 hours and
then proceed to step #7. This “OK” will be followed up with an
e-mail to all interested parties.

7) Day 7 (24 hours after step #6 has been completed): Add enough
of the approved inhibitor (Nitrite) to raise the level of nitrite in
the system to a minimum of 600 ppm. Your water treatment
consultant will need to calculate the correct amount of chemical
needed.

8) Day 9 (A minimum of 48 hours after step #7 has been
completed): Contact the UC Denver CUP. The UC Denver CUP
and/or the UC Denver Water Treatment contractor will meet
with the contactors water treatment vendor and the contractor at
the site and test the water for conductivity and nitrite, and a
biological sample will be taken and sent overnight to the lab. If
the nitrite is at 600 ppm or higher and the conductivity is
elevated, a verbal OK of the nitrite level will be given. If the nitrite level is low, a verbal denial will be given and more nitrite will need to be added. Conductivity will be tested to verify that the conductivity is elevated above city water conductivity. A sample for biological testing will be taken and sent overnight to the UC Denver Water Treatment contractors testing lab. We encourage you to have your water treatment consultant to have biological testing performed on the water. Ensure that the lab that performs the testing will test for aerobic, anaerobic, and denitrifying bacteria.

9) Keep the system flowing until it is opened up to the UC Denver Chilled Water Distribution system.

10) When the test results become available, we will share them with all interested parties. If the sample passes the biological tests, proceed to the next step. If the sample fails one or more of the tests, we will need to meet as a group and discuss re-cleaning and re-treating of the system.

11) Once the system has successfully passed all tests, schedule with UC Denver Outage Coordinator to open the system up to the UC Denver Chilled Water Distribution system.

b. Flushing, Cleaning, and treating Chilled Water and Heating Water systems using a Nitrite Based Cleaner. Remember that the timeline below is dependant upon all things occurring as they are written. The timeline below is bare bones for an average sized system. Smaller projects may be able to save some time during the filling and draining periods.

1) Day 1: Fill the entire system that is available with city water and continuously circulate the water with one of the system pumps throughout the building, through all chilled water lines, including lines to vaults. If there is more than one pump in the system, alternate the pumps at least once during this process to ensure each pump is run.

2) Day 2 (24 hours after step #1): The UC Denver CUP and/or the UC Denver Water Treatment contractor, the contract's water treatment vendor, and the contractor to test the water for conductivity and view the water for clarity. If there are no issues, the UC Denver CUP will give a verbal “OK” to the contractor onsite to proceed with the drain down. This “OK” will be followed up with an e-mail to all interested parties.

3) Day 3: Refill the entire system that is available with city water and add the approved nitrite based cleaner. Circulate the water with one of the system pumps throughout the building, through all chilled water lines, including lines to vaults. If there is more than one pump in the system, alternate the pumps at least once during this process to ensure each pump is run. Run each pump two separate times.

4) Day 4: Continue to circulate the entire system with the cleaner in it throughout the building, including lines to vaults (If required). If
there is more than one pump in the system, alternate the pumps at least once during this process to ensure each pump is run. We would like to see each pump to run two separate times.

5) Day 5 (A minimum of 48 hours after step #3 has been completed): The UC Denver CUP and/or the UC Denver Water Treatment contractor, the contactors water treatment vendor, and the contractor to test water for nitrite and conductivity. If the nitrite test is above 600 ppm and the conductivity is elevated above city water conductivity, a verbal “OK” will be given that the nitrite level in the water is acceptable and the bleed/fill of the nitrite based cleaner can start. With the pump still running, open a ¾” drain to a sanitary sewer and start to purge water from the system. At the same time add water to the system to replace the water that is being purged down the drain. Continue to do this until the nitrite level is down to 200 to 300 ppm. 300 ppm is preferred. DO NOT do this bleed/fill if there is nobody to monitor the process. This “OK” will be followed up with an e-mail to all interested parties.

6) Day 6: If the following does not occur as written, all dates below this will be affected. When the nitrite level in the water is between 200 and 300 ppm, contact the UC Denver CUP. The UC Denver CUP will meet with the contactors water treatment vendor and the contractor at the site and test the water for conductivity and nitrite. If the nitrite is between 200 to 300 ppm, a verbal “OK” will be given that it is acceptable to add the isothiazolin biocide. Circulate the system for 24 hours and then proceed to step #7. This “OK” will be followed up with an e-mail to all interested parties.

7) Day 7 (24 hours after step #6 has been completed): Add enough of the approved inhibitor (Nitrite) to raise the level of nitrite in the system to a minimum of 600 ppm. Your water treatment consultant will need to calculate the correct amount of chemical needed.

8) Day 9 (A minimum of 48 hours after step #7 has been completed): Contact the UC Denver CUP and/or the UC Denver Water Treatment contractor. The UC Denver CUP will meet with the contactors water treatment vendor and the contractor at the site and test the water for conductivity and nitrite, and a biological sample will be taken and sent overnight to the lab. If the nitrite is at 600 ppm or higher and the conductivity is elevated, a verbal OK of the nitrite level will be given. If the nitrite level is low, a verbal denial will be given and more nitrite will need to be added. Conductivity will be tested to verify that the conductivity is elevated above city water conductivity. A sample for biological testing will be taken and sent overnight to the UC Denver Water Treatment contractors testing lab. We encourage you to have you water treatment consultant to have biological testing performed on the water. Ensure that the lab that performs the testing will test for aerobic, anaerobics and denitrifying bacteria.

9) Keep the system flowing until it is opened up to the UC Denver Chilled Water Distribution system.
10) When the test results become available, we will share them with all interested parties. If the sample passes the biological tests, proceed to the next step. If the sample fails one or more of the tests, we will need to meet as a group and discuss re-cleaning and re-treating of the system.

11) Once the system has successfully passed all tests, schedule with UC Denver Outage Coordinator to open the system up to the UC Denver Chilled Water Distribution system.

A. Steam and condensate systems

1. Steam lines do not need to be cleaned or passivated prior to being put in-service since steam is oxygen free, and produces a non-corrosive environment. Steam blows on steam mains that are six inches in diameter or larger are required. A steam blow involves performing a series of cyclic brief venting of steam to atmosphere. The objective is to purge loose particulate material from the steam lines. Remove all strainer screens and check for debris. Clean the screens before reinstalling them. The UC Denver CUP Operations staff and/or the UC Denver Water Treatment contractor will be present to inspect a limited number of screens. Once this is accomplished the steam line may be put into service.

2. The condensate receivers will need to be initially “dumped” down the drain during the first few days of operation. Add tempering water as need to ensure that the condensate going down the drain is less than 160 F. If possible inspect the receiver for evidence of oil or organic contamination prior to putting the receiver in service. In the unlikely event that oil or organic material has contaminated the condensate receiver contact the CUP for consultation. System cleaning would be required prior to interfacing with the bulk condensate system.

3. Once the conductivity of the condensate is less than 20 and the hardness is 0.5 ppm or less, the condensate can be opened into the UC Denver Condensate System.

B. Pre-cleaning and passivation of condenser water and cooling tower systems

C. Pre-cleaning and passivation of condenser water and cooling tower systems

1. To perform an effective system cleaning and passivation, a phosphate prep is recommended. The use of N-2578 or an equivalent phosphate based cleaner is suggested to perform the procedure. N-2578 is a blend of inorganic phosphate, detergent, dispersants and organic copper corrosion inhibitors. Sufficient product should be added to the system to boost total inorganic phosphate residuals to a level in excess of 500 ppm as PO₄. It is important to maintain good biological control during the passivation process. The use of an oxidizing biocide such as bromine or chlorine is not recommended since it will interfere with the passivation process. The use of a non-oxidizing biocide at a heavy dose is recommended during the passivation.

2. For most effective results, system pH must be maintained in the 7.0-7.5 range, targeting 7.25. The procedure will still work with pH as high as 8.0. If system pH rises to 8.5 the pH should be lowered by gradually adding dilute sulfuric acid. Add acid very slowly and check the pH every 30 minutes. When adding acid, gradually lower the pH into the 7.0-7.5 range, targeting 7.25. If pH goes down to 6.5, gradually add soda ash in a slurry form to raise pH into the 7.0-7.5 range, targeting 7.25.
3. **DO NOT OPERATE CHILLERS IN THIS SYSTEM DURING THE CLEANING PROCEDURE.**

4. When the PH of the system has been stabilized between 7.0 and 7.5, circulate the treated system at design flows through the entire system for a minimum of 8 hours. Purge all strainers in the system every hour during the pre-cleaning process. After 8 hours of circulation, shutdown the pump(s) and drain the entire system.

5. Fill and flush the entire system with city water until the flush water is clear and free of particulate material. Refill the system with city water. Perform cleaning method as follows:
   a. Add a 300 ppm dose of N-2593 biocide or an equivalent to the system while circulating. N-2593 is an isothiazolin based biocide
   b. Gradually add N-2578 to the system. Recommended dose is 2.5 gallons per 1000 gallons of system capacity. Check system pH and insure the concentration is in the range stated above. Contact the UC Denver Water Treatment contractor to confirm total inorganic phosphate levels are above 500 ppm
   c. Continue to circulate for 24-48 hours with the system off-line and all legs of the system circulating. Check system pH once every 12 hours. Add anti-foam N-7465 as needed
   d. When the cleaning is complete, drain the system several times until system conductivity is within 200 microsiemens of city water. Contact the UC Denver Chemical contractor to confirm total inorganic phosphate levels are below 10 ppm. If the phosphate level remains high, continue to drain and flush. Remove all strainer screens and check for debris. Clean the screens before reinstalling them. The UC Denver CUP Operations staff and/or the UC Denver Water Treatment contractor will be present to inspect a limited number of screens.
   e. The system is now ready for normal operation with a properly run chemical treatment program. It is critical bulk water alkalinity is maintained in the 300-400 ppm range, targeting 350 ppm, in the early phases of operation. If sufficient load is not available to concentrate alkalinity we may artificially boost alkalinity into the recommended range by adding soda ash to the system.

6. Recommended ongoing treatment is using N-23208 phosphonate inhibitor, application of N-2593 isothiazolin based biocide at a 150 ppm dose weekly and the use of N-ST-20 bromine based biocide fed daily.

7. An equivalent chemical may be used after it has been approved for compatibility by UC Denver. The contractor’s chemical vendor will provide data sheets to UC Denver with the request for approval for an equivalent chemical. Equivalent chemicals can not be used until they have been approved by UC Denver.

END OF SECTION
SECTION 15625
SNOW MELT SYSTEMS

PART 1 – GENERAL

1.1 SUMMARY

A. The work of this section consists of furnishing and installing pipe and appurtenances for snow melt systems. The use of snow melt systems is discouraged because of high energy use. Snow melt systems should be reviewed on a case by case basis with UCD Project Manager and Building Maintenance rep prior to considering.

1.2 REFERENCES

A. Section 15000 – General Mechanical Provisions
B. Section 15100 – Valves
C. Section 15190 – Mechanical Identification

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. Snow melting installations are divided into two classes.
   1. Class I: Main pedestrian entrances, walks or driveways on the north side of the buildings.
   2. Class II: Commercial sidewalks and driveways.

B. Design snow melt systems for areas critical to safety. It is unacceptable to have snow on the snow melt surface for any length of time. Consider snow melt systems for sidewalks, loading docks, service entrances, main entrances and steps.

C. Base typical system for 150 Btu-h per square foot with a 10-mph wind at 0 degrees F.

D. Provide systems with 60 percent water and 40 percent Dowfrost.

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submittals shall be made in accordance with Section 15000, including product data for all equipment and materials.

1.6 QUALITY ASSURANCE

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

A. Snow Melt Systems warranties shall be provided in accordance with Section 15000 including the manufacturer’s standard warranty of 25 years for tube and 18 months for manifolds.
PART 2 – PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Tube, Fittings, Pipe, and Manifolds:
   a. Uponor
   b. Watts Radiant
   c. Quest Hydronics

2. Controls:
   a. Integrated into BAS (preferred)
   b. Tekmar
   c. Or approved equal.

2.2 MATERIALS, GENERAL

A. Provide components of the buried tubing system by one manufacturer, including tubing, fittings, manifolds, and ancillary items.

B. Small Systems, Less Than 5000 Square Feet:

1. Tube: ASTM F876, cross linked polyethylene, 5/8-inch inside diameter, rated at 180 degree F maximum working temperature and 100 psi working pressure, with oxygen diffusion barrier capable of limiting oxygen diffusion through the tube to no greater than 0.10 g/m3/day at 104 degree F. Minimum bend radius for cold bending shall no be less than six times the outside diameter.

2. Fittings: Dezincification resistant brass fittings consisting of a barbed insert, compression ring, and compression nut.

3. Manifolds: Cast brass construction, manufactured of alloys to prevent dezincification, with integral circuit balancing valves. Provide with support brackets and tube bend supports. Isolate manifolds from supply and return tubing with valves suitable for isolation and balancing. Manifolds shall be capable of venting air from the system.

C. Large Systems, Over 5000 Square Feet:

1. Tube: ASTM fd3350, cross linked, low density polyethylene without oxygen diffusion barrier. 7/8-inch inside diameter, rated at 140 degree F maximum working temperature and 55 psi working pressure.

2. Fittings: Dezincification resistant brass fittings or HDPE, SDR 11 polyethylene fittings.
3. Manifolds: Pre-manufactured of HDPE, fusion welded, designed for balanced flow. Include proper fittings or compression clamping sleeve and locking caps.

D. Supply and Return Main Pipe:

1. 2 Inch and below: ASTM F876, cross linked polyethylene, rated at 180 degree F maximum working temperature and 100 psi working pressure with oxygen diffusion barrier capable of limiting oxygen diffusion through the tube to no greater than 0.10 g/m3/day at 104 degree F.
   a. Fittings: Brass or Bronze

2. Above 2 Inches: Industrial pressure pipe, HDPE polyethylene pipe, fusion welded.
   a. Fittings: HDPE, SDR 11, fusion welded.

E. Access Covers:

1. Removable access covers constructed of reinforced concrete formed in place or precast concrete over pipe connections, fittings, and distribution manifolds. Provide tapered forms for covers. Covers subject to vehicular traffic shall be traffic rated.

F. Controls:

1. Microprocessor control with indicator lights, LCD display of temperatures, automatic snow detection, outdoor temperature compensation, warm weather cut off, and cold weather cut off. Controller capable of operating a floating action valve, variable speed pump or 4-20 mAmp modulating valve. Provide with snow/ice sensor and socket.

PART 3 – EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. Install snow melt tubing loops according to manufacturer’s recommendations.

B. Secure tubing to wire mesh or rebar every 4 feet along straight runs and on 180 degree turns secure at the top of the arc and on each side, 12 inches from the top of the arc.

C. Install fittings accessible for maintenance. Install tubing loops without splices, as a minimum, from the point at which the tubing enters the panel to the point at which it exists the panels.

D. Pressurize the tubing system with water or air to a pressure of 60 psig 24 hours prior to encasement in the radiant panel. Maintain pressurization during the panel installation and for a minimum of 24 hours after panel installation to ensure system integrity.

E. Label piping, valves, and equipment in accordance with 15190.
F. Drain water or air from the system after leak testing the system and fill with 60 percent water and 40 percent propylene glycol water mix.

G. Do not extend pipe through expansion, construction, or working joints in concrete slab unless specifically addressed during design. Carefully coordinate expansion joints installed during or cut after concrete pour with the tubing layout and snow melt manufacturer.

H. Hydraulically balance mains. Coordinate balancing with Section 15990 and include balancing information in balancing report.

I. Controls:

1. Control each snow melt zone by a microprocessor based control panel furnished by the snow melt system manufacturer. The snow melt manufacturer shall also furnish the outdoor temperature sensor and snow/ice sensor.

2. The control panel shall continuously monitor the snow/ice sensor located in the slab. When snow, ice, or water are detected the melting mode shall be initiated, unless the warm weather or cold weather cut-off controls have been activated.

3. The snow melt zone shall enter the warm weather cut-off mode if the outdoor air temperature is above the melting temperature setpoint. It shall remain in this mode until the outdoor air temperature drops below the melting temperature setpoint. The warm weather cut-off mode shall deactivate the snow melt zone. The snow melt system shall enter the cold weather cut-off mode if the door air temperature falls below the cold weather cut-off setpoint. The cold weather cut-off mode shall deactivate the snow melt system.

4. The melting mode shall be capable of being activated either through the snow/ice sensor or through a remote signal. The control valve shall be energized when the melting mode is activated and the heat relay shall operate the control valve to maintained the slab surface at the melting temperature setpoint.

5. Maintain the slab at an idling temperature when the snow melt system is not in the melting mode. Control operation is similar to the melting mode except the slab is maintained at a higher idling temperature setpoint.

6. Activate a warning light at the control panel if a sensor fault occurs.

7. Desired slab surface melting temperature, slab surface idling temperature, and cold weather cut-off temperature setpoints shall be adjustable at the control panel.

3.3 TESTING, CLEANING AND CERTIFICATION

3.4 COMMISSIONING (DEMONSTRATION)

3.5 SCHEDULES

END OF SECTION
PART 1 – GENERAL

1.1 SUMMARY

A. This section consists of standards for chillers and associated equipment.

1.2 REFERENCE

A. Section 15000 - General Mechanical Provisions
B. Section 15100 - Valves
C. Section 15110 - Piping

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. Chillers included in this section are intended for structures that are constructed outside the practical limits of the campus central chilled water system or are chillers utilized to provide chilled water for a specific process.
B. Comply with Colorado Department of Health Regulation 15 and all applicable EPA rules and regulations regarding the purchase, disposal and handling of refrigerants.
C. Do not locate chillers near noise sensitive areas.
D. Monitor machine room and sound audible alarm if refrigerant concentrations exceed 10 ppm.
E. Compressors over 100 ton Capacity:

1. Motors and Starters:
   a. Dual winding, wye-delta design with matching two-step, closed transition, time-delay starting switch gear is preferred. Provide an auxiliary timer in the starting circuit.
   b. Set timer to limit starts to a minimum of 30 minutes apart or greater.
   c. An auto-transformer with reduced voltage start is an acceptable alternate starter.
   d. Provide heat sensors on all motors in the windings for thermal protection.

2. Full-running Protection:
   a. Specify compressors equipped with high and low pressure safety cut out, external overload protection, thermal protection, and low oil pressure.
   b. Manual reset type safeties which cause an electrical lock-out of the starting circuit when it has tripped, with an indication of which safety device has operated.
3. Gauges and Lubrication:
   a. Include gauges, indicating high side, low side and oil pressures. Gauges are not required if unit is equipped with a micro-processor control which shows pressures at control panel.
   b. Forced-feed lubrication system with filter, cooler, and visual inspection port in the oil reservoir.

4. Heaters:
   a. Provide crankcase heaters wired on a separate electrical circuit.
   b. Provide oil pump starter wired on a separate electrical circuit.

5. Refrigerant Transfer: Provide provisions for pump out/down into unit-mounted receiver if application warrants.

6. Pressure Relief: Show on drawings, safety valve pressure relief piping, vented to outdoors in accordance with ASHRAE 15. Provide self-closing, resealing type pressure relief valve.

F. Compressors of 60 to 100 ton Capacity:
1. Semi-hermetic, reciprocating type, helical rotor or scroll.

2. Full-running Protection:
   a. Specify compressors equipped with high and low pressure safety cut out, external overload protection, thermal protection, and low oil pressure.
   b. Manual reset type safeties which cause an electrical lock-out of the starting circuit when it has tripped, with an indication of which safety device has operated.

3. Include gauges, indicating high side, low side and oil pressures. Gauges are not required if unit is equipped with a micro-processor control which shows pressures at control panel.


5. Oil reservoir sight glass.

6. Replaceable refrigerant filter-dryers in liquid line.

7. Hydraulic capacity control by cylinder unloading for adjustments to load fluctuations.

8. Positive unloaded start.

9. Discharge muffler.

10. Internal vibration isolation.

11. Closed transition starting switch-gear. Part-winding is acceptable.
12. Refrigerant Transfer: Provide provisions for pump out/down into unit-mounted receiver if application warrants. If condenser will hold the full charge, this is an acceptable alternative.

G. Compressors under 60 but over 15 ton capacity:
1. Hermetic or semi-hermetic, reciprocating type, helical rotor or scroll.
2. Inherent thermal overload protection for motors.
3. Include gauges, indicating high side, low side and oil pressures. Gauges are not required if unit is equipped with a micro-processor control which shows pressures at control panel.
5. Oil reservoir sight glass.
6. Replaceable refrigerant filter-dryers in liquid line.
7. Hydraulic capacity control by cylinder unloading or staging of multiple compressors.
8. Positive unloaded start.
9. Discharge muffler.
10. Internal vibration isolation.
11. Closed transition starting switch-gear.
12. Refrigerant Transfer: Provide provisions for pump out/down into unit-mounted receiver if application warrants. If condenser will hold the full charge, this is an acceptable alternative.

H. Compressors between 7-1/2 and 15 ton capacity.
1. Same requirements as 15 to 60 ton compressors except that cylinder unloading and unloaded start features are not required on the small units.

I. Compressors below 7-1/2 tons:
1. Same requirements as 7-1/2 to 15 ton compressors except gauges are not required.

J. Condensers:
1. Select air cooled condensers with sufficient capacity to compensate for altitude deration of 5200 feet and 105 degree F inlet air temperature.
2. Do not specify vertical blow-type condenser fans for systems that operate during winter.
3. For winter operation, specify a horizontal blow-type condenser fan with a weather-protecting shroud designed to prevent possible blade icing and unbalance.

4. Arrange water-cooled condensers so that tubes can be rodded without hindrance from walls, piping, or equipment.

5. Provide low ambient accessory package to consist of variable speed condenser fan control based upon outside air temperature or refrigerant gas temperature/pressure on air-cooled condensers with intermittent winter cooling requirements down to 40 degree F outside air temperature. Provide thermostatic expansion valves with these systems. Orifice type valves are not permitted.

6. Provide flooded condenser control with liquid receiver and 3-way head pressure control valves on systems requiring continuous and critical winter cooling operation. As described above, thermostatic expansion valves are required.

K. Chillers:

1. Centrifugal chillers with oil coolers, which are cooled with chilled water, should have pressure and temperature gauges installed on inlet outlet of chiller out of the influence of the oil cooler circuit.

2. Install the following components on all chilled and condenser water systems.
   a. Chiller Water Temperature Sensors:
      1) Supply temperature sensor
      2) Return temperature sensor
   b. Low Water Temperature Cut-out.
   c. Water Flow Sensors:
      1) Chiller water system
      2) Condenser water system
   d. Relief Valves.

3. Install noise and vibration apparatus in accordance with state and federal regulations, and ARI Standard 575-87.

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submittals shall be in accordance with Section 15000 and shall include part loading data and sound data.

1.6 QUALITY ASSURANCE

A. Electrical components shall comply with NFPA 70-96 and be UL listed.
B. Centrifugal and rotary screw chillers shall comply with certification requirements of ARI 550.

C. Comply with ASHRAE 15 for chiller design, construction, leak testing, and installation.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

A. Chillers warranties shall be provided in accordance with Section 15000 including manufacturer’s standard warranty of not less than 5 years with extended 5 years warranty for compressors of 60 to 100 ton capacity and under 60 but over 15 tons capacity.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Centrifugal or Rotary Screw Chillers:
   a. Carrier.
   b. McQuay.
   c. Trane.
   d. York.

2.2 MATERIALS, GENERAL

A. Centrifugal or Rotary Screw Chillers:


2. Factory assembled and wired consisting of one or compressors, an evaporator or cooler, an air or water-cooled condenser, safety controls and operational controls.

3. Refrigerant: R-22 or R134a; provide full operating charge of refrigerant and oil. Provide refrigerant charging port.

4. Compressor: Hermetic or semi-hermetic, rebuildable.

5. Motor: Refrigerant cooled, hermetic or semi-hermetic motor; or open, drip-proof induction motor; with the following features: Overvoltage protection, Undervoltage protection, Single-phasing protection, Current-overload protection.

6. Evaporator: Shell and tube cooler with refrigerant totally enclosed by shell; water in tubes.
   a. Shell: Carbon steel plate.
   b. Cooler Tubes: Seamless copper; expanded into tube sheets.; individually replaceable; externally finned.
c. 300 psig refrigerant working pressure.
d. 150 psig water side working pressure
e. Insulation: factory applied, ¾-inch thick, flexible elastomeric insulation evaporator, suction lines, and other surfaces where condensation might occur.

7. Water Cooled Condenser: Shell and tube condenser with water enclosed in tubes; refrigerant enclosed by shell.
   a. Shell: Carbon steel plate.
   b. Cooler Tubes: Seamless copper; expanded into tube sheets; individually replaceable; externally finned.
   c. 300 psig refrigerant working pressure.
   d. 150 psig water side working pressure
   e. Safety and operating options include the following; pressure relief safety valve, purge valve, subcooler circuit.

8. Air Cooled Condenser: Factory assembled, wired, and tested; consisting of casing, air-cooled condenser coils, fans, and controls integrated with compressor operation.
   b. Fans: Propeller type, statically and dynamically balanced; vertical discharge.
   c. Fan Motor: Direct drive, weather proof, with bearings permanently lubricated, and having built-in current and thermal overload protection.
   d. Condenser Coil: Copper tubes with mechanically bonded aluminum fins.

B. Controls:

1. General: Manufacturer’s standard microprocessor-based chiller controls.

2. Temperature Controls: Modulating slide valve to maintain chilled water temperature set point without hunting within throttling range. Include the following features:
   a. Throttling Range: Full load to 10 percent of full load.
   b. Chilled water temperature control.
   c. Chilled water temperature setback.
   d. Load limit controller.
3. HVAC Controls: Furnish appurtenance to monitor and control chilled water set point, to monitor condenser water set point, and to monitor chiller alarms from building automation system.

4. Safety Controls: Automatic and Manual reset controls to perform the following functions:
   a. Low evaporator pressure cutout.
   b. Low chilled water temperature cutout.
   c. Low oil sump temperature cutout.
   d. Low oil pressure cutout.
   e. High oil temperature cutout.
   f. High condenser pressure cutout.
   g. Water Flow Interlock: Water flow switch to prevent starting compressor without chilled and condenser water flow.

5. Power Controls: Manufacturer’s standard, unit mounted, factory wired, single-point connection, with the following power control options:
   a. External overload protection.
   b. Control circuit fuse.
   c. Power terminal block.
   d. Lockout restart timer.
   e. Combination controller and disconnect.

C. Refrigerant Monitor:

1. UL 2075 refrigerant monitor to continuously monitor mechanical equipment rooms for refrigerant concentrations between 0 and 1000 PPM. Unit enclosed in NEMA 4 cabinet. Monitor shall draw room air through an infrared photo-acoustic sensing device allowing accurate measurement of refrigerant vapors. Unit shall be inherently zero-stable and include sample filters. Monitor shall signal alarm levels at three concentration levels plus a unit "trouble" alarm that indicates internal problems with monitor.

2. Interface Module: Backlit, 2 line, and 16-character language display. Module capable of remote mounting.

3. Input: 4-20 mA.

4. Output: 0-10vdc and a 4-20 mA analog output proportional to the displayed refrigerant concentration.

5. Latched alarms re-settable from a remote source via a contact opening.
6. Accessories: Alarm package consisting of 3 flashing lights and audible alarm mounted in one assembly for remote mounting.

D. Self Contained Breathing Apparatus (SCBA):

1. OSHA approved reentry device as required by ASHRAE 15. The SCBA shall use compressed air and comply with all requirements of the NFPA and shall be jointly certified by NIOSH and the MSHA for 30-minute-rated service life. The apparatus shall be certified for use at temperatures above –25 degree F.

2. The SCBA shall include:
   a. A single lens face piece with speaking diaphragm and detachable breathing tube.
   b. Pressure demand regulator.
   c. High pressure hose.
   d. Audible warning bell.
   e. Cylinder, compressed air.
   f. Harness assembly.
   g. Wall mounted storage case with hinged door.

3. The SCBA shall be suitable for use with refrigerants specified. Provide documentation that the face piece remains clear (frost free) when subjected to liquid spray for 30 seconds duration.

4. Provide documentation to ensure compliance with OSHA training and maintenance requirements.

5. Regulator shall have a true independent bypass system with a quick acting mainline valve for instant airflow. Valve shall be belt mounted.

6. Provide SCBA with speaking diaphragm allowing short range communications with optional provisions for a microphone in the face piece to interconnect with a portable radio.

7. Equip SCBA with a loud bell that sounds when air pressure reaches 540 psig.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. Install chillers level and plumb, according to manufacturer’s recommendations.

B. Install chillers on 4-inch thick concrete base, 4 inches larger on each side than base of unit. Anchor chiller and vibration isolators to concrete base.

C. Maintain manufacturer’s recommended clearance for service and maintenance.
D. Connect piping to chiller with shutoff valves and flanges at each connection.

E. Label the amount of refrigerant in the system in pounds.

F. Provide flanges at each condenser and chilled water connection to chiller. Provide removable sections to permit removal for access to tube bundles for cleaning. Pipe sections shall be no longer than 4 feet or shall consist of a removable elbow in order to be removable without heavy equipment.

G. Place isolation valves on piping to permit removal of sections described above without draining of chilled or condenser water.

H. Controls:
   1. Wire chiller so it cannot start unless chilled water and condenser water circulating pumps are running.
   2. Start and stop chillers automatically through the chiller control panel.

3.3 TESTING, CLEANING, AND CERTIFICATION

A. Test each chiller before shipment. Provide certified test report to confirm performance, include capacity test, power consumption test, and Part Load Value at ARI standard conditions.

B. Complete manufacturer’s installation and startup checklist.

C. Test and adjust controls and safeties.

D. Test reciprocating chillers in accordance with ASHRAE Standard 30.

E. Test centrifugal chillers and rotary screw compressors in accordance with ARI 550.

F. Test, adjust, and balance chillers as specified in Section 15990.

G. Flush and clean chillers according to manufacturer’s instructions.

3.4 COMMISSIONING (DEMONSTRATION)

A. Provide services of a factory authorized service representative to provide startup services and to demonstrate and train UC Denver’s representative. Before start-up, manufacturer shall scope the chiller tubes to ensure they are not damaged or twisted.

B. Provide 4 hours of instruction to UC Denver’s representative. Include operation of chillers including accessories and controls, procedures for startup and shutdown, troubleshooting, servicing, and preventive maintenance. Review data in the maintenance manuals.

3.5 SCHEDULES

END OF SECTION
SECTION 15650
REFRIGERATION

PART 1 - GENERAL

1.1 SUMMARY
A. This section provides standards for refrigeration systems.

1.2 REFERENCES
A. Section 15000 – General Mechanical Provisions
B. Section 15100 – Valves
C. Section 15110 – Piping
D. Section 15190 – Mechanical Identification
E. Section 15250 – Insulation

1.3 SYSTEM PERFORMANCE REQUIREMENTS
A. General Information:
   1. All systems purchased shall utilize HCFC or HFC refrigerants.
   2. All new systems installed shall include refrigerant isolation/service valves that permit pump down of refrigerant into condenser coil or liquid receivers to permit servicing of systems without venting of refrigerant. Isolation/service valves shall also permit removal of refrigerant through a recovery machine to a DOT and ASME approved storage vessel.
   3. Provide all new systems with 50 or more pounds of refrigerants with a pressure activated release plug and a re-settable pressure valve to minimize loss of refrigerants.
   4. Provide all new systems with 10 or more pounds of refrigerant with a dual pressure cutout control.
   5. The type of copper piping shall be Type L or better.

1.4 DEFINITIONS

1.5 SUBMITTALS
A. No additional requirements

1.6 QUALITY ASSURANCE
A. Testing Laboratory Qualifications: Engage inspection and test service agencies, including independent testing laboratories, which are prequalified as complying with “Recommended requirements for Independent Laboratory Qualification” by American Council of Independent Laboratories. They must be recognized in the industry as specialized in the types of inspections and tests to be performed and which have no less than five years experience in such testing.
1. Each inspection and testing agency shall be authorized to operate in the State of Colorado.

2. Maintain a full time registered engineer on staff to review services.

B. Regulatory Requirements: All equipment, parts and controls shall meet or exceed UL and/or ASME Standards as well as any State or Federal Standards. The most stringent standard shall be adhered to. All State and Federal Regulations shall be followed.


1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

A. Refrigeration Systems warranties shall be provided in accordance with Section 15000, including a 5-year warranty on all refrigeration compressors. Address extensions at the time of purchase.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Provide piping materials and factory-fabricated piping products of sizes, types, pressure ratings, temperature ratings, and capacities as indicated.

2. Filter Dryers:
   a. Sporlan
   b. Alco
   c. Or approved equal

3. Expansion Valve:
   a. Sporlan
   b. Alco
   c. Or approved equal

2.2 MATERIALS, GENERAL

A. Pipe: Air conditioning and refrigeration ACR, hard drawn copper tube manufactured in accordance with ASTM B280, and ANSI 15.

B. Fittings: Wrought copper solder joint

C. Solder: silver solder and applicable flux.
D. Valves: Special valves required for refrigerant piping include the following:

1. Globe Shutoff Valves: Forged brass, packed, back seating, winged seal cap, 300 degree F. temperature rating, 500 psi working pressure.

2. Check Valves: Forged brass, accessible internal parts, soft synthetic seat, fully guided brass piston and stainless spring, 250 degree F. temperature rating, 500 psi working pressure.

3. Thermal Expansion Valves: Sized and selected per equipment manufacturer’s recommendation.

E. Refrigerant Specialties:

1. Refrigerant Strainers: Brass shell and end connections, brazed joints, monel screen, 100 mesh, UL-listed, 350 psi working pressure.

2. Moisture Indicators: Forged brass, single port, removable cap, polished optical glass, solder connections, UL-listed, 200 degree F. temperature rating, 500 psi working pressure.

3. Refrigerant Filter Dryers: Steel shell, ceramic fired desiccant core, solder connections, UL-listed, replaceable filter dryer core, 500 psi working pressure.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. Piping:

1. Install refrigerant piping with ¼-inch per foot downward slope in direction of oil return to compressor. Provide oil traps and double risers where indicated and where required to provide oil return.

2. Bleed dry nitrogen through refrigerant piping during brazing operations.

3. Insulate refrigeration suction and hot gas piping in accordance with Section 15250 - Insulation.

3.3 TESTING, CLEANING, AND CERTIFICATION

A. General: Provide temporary equipment for testing, including pump and gages. Test piping system before insulation is installed, and remove control devices before testing.

B. Work to be installed shall remain uncovered until the required tests have been completed.

C. Test piping which is to be concealed before being permanently enclosed.

D. As soon as work had been completed, conduct preliminary tests to ascertain compliance with specified requirements. Make repairs or replacements as required.

E. Give a minimum of 5 days notice to the UC Denver Project Manager for dates when acceptance test will be conducted. Conduct tests as specified for each system in presence of UC Denver Facilities Operations representative. Submit three (3) copies of successful
tests to the Engineer, through the UC Denver Project Manager, for his review. Report shall state system tested and date of successful test.

F. Contractor shall obtain certificates of approval and acceptance. Work shall not be considered complete until such certificates have accepted by the UC Denver Project Manager.

G. All costs involved in these tests shall be borne by the Contractor.

H. System Tests:

1. Refrigerant Piping Leak Test:
   a. Clean and test refrigerant piping in accordance with ANSI B31.5.
   b. Perform first test with dry nitrogen using soap solution to test all joints.
   c. Perform second test as follows: Fill system with 20 psi refrigerant and charge to 200 psi with nitrogen. Let stand for 24 hours and check to see that the charge has held.
   d. Perform final test by pulling a 2-mm Hg vacuum. System must hold this vacuum for a period of 24 hours.
   e. Evacuate refrigerant system with vacuum pump until temperature of 35 degree F. is indicated on vacuum dehydration indicator.
   f. During evacuation apply heat to pockets, elbows, and low spots.
   g. Maintain vacuum on system for minimum of 5 hours after closing valve between vacuum pump and system,
   h. Break vacuum with refrigerant gas, allow pressure to build up to 2 psi.
   i. Complete charging of system using new filter dryer core in charging line. Provide full operating charge.

2. Hydrostatic Test: Accomplished by pumping the system up to the specified water pressure, and maintaining that pressure until the entire system has been inspected for leaks, but in no case for a time period of less than four hours.

3. Other recommended guidelines for testing.
   b. ANSI/ASHRAE Standard 23-93
   c. ASHRAE 1994 I-P Chapter 45.

I. Adjusting and Cleaning:

1. General: Clean exterior surfaces of installed systems of superfluous materials, and prepare for application of insulation. Inspect each system for completion of joints, supports and accessory items.
3.3 COMMISSIONING (DEMONSTRATION)

3.4 SCHEDULES

END OF SECTION
SECTION 15710
COOLING TOWERS

PART 1 - GENERAL

1.1 SUMMARY
A. This section includes standards for cooling towers including induced-draft, propeller fan, and cross-flow types.

1.2 REFERENCES
A. Section 15000 – General Mechanical Provisions
B. Section 15100 – Valves
C. Section 15110 – Piping
D. Section 15170 – Motors and Drivers
E. Section 15190 – Mechanical Identification
F. Section 15505 – Hydronic Systems
G. Section 15545 – Chemical Water Treatment

1.3 SYSTEM PERFORMANCE REQUIREMENTS
A. General Information:
   1. Use outdoor conditions of 95 degree F dry bulb and 64 degree F wet bulb to size cooling tower capacity.
   2. Consider closed loop, evaporative sprayed cooling towers to use in conjunction with heat exchangers for systems having winter cooling requirements.
B. Provide chemical water treatment in accordance with Section 15545.
C. Remote Sump:
   1. Allow minimum water level of 4 feet of suction head under operating conditions or greater, if required to meet NPSH of pump.
   2. Provide a minimum of 150 percent of drain down storage capacity.
   3. Drain down capacity to consist of volume of cooling tower water retention plus all piping exposed to freeze conditions.
   4. Provide ventilation in sump room to control humidity.
D. Provide ladders and safety cages to meet ANSI standards.

1.4 DEFINITIONS

1.5 SUBMITTALS
A. Provide manufacturer’s certification of tower cooling capacity, based on factory-performance tests, and provide performance curve plotting Leaving-Water Temperature (LWT) against Wet-Bulb Temperature (WBT).

B. Provide certification of tower wind resistance to withstand pressure indicated, in any direction.

1.6 QUALITY ASSURANCE

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Baltimore Aircoil Co., Inc.

2. Marley Cooling Tower Company

3. Evapco

2.2 MATERIALS, GENERAL

A. General Information:

1. Supply cooling towers with 2-1/2 inch minimum size drain outlet in bottom of sump and located on opposite side of suction outlet of sump. Pipe drain lines to nearest roof drain. Consider indoor sumps as an alternative with the benefit of cold weather operation.

2. Provide tower sections with access ladders from top to bottom in accordance to OSHA standards.

3. Locate tower fan motors outside of the air stream for access for maintenance and not in air stream. Fan motors shall utilize VFD for capacity control.

4. Provide access openings to sumps, valves, motors, belts, sheaves sprays, etc.

5. Provide water treatment piping with bleed solenoid valve, wye strainer and blow down valve upstream. Lockout timer shall have a 3-hour minimum setting.

B. Factory-fabricated Cooling Towers:

1. General: Fabricate cooling towers using manufacturers’ standard design, materials, and construction in accordance with published product information, except as otherwise indicated.

2. Design structural system for the following live loading in addition to dead-loads and operating-loads.

   a. Wind Loading: 30 psf on exposed vertical surfaces.
b. Earthquake Resistance: Acceleration on 1.0 G horizontally through the center of gravity.

3. Fabricate structural system including assembly of collecting basin and steel casings by one of the following methods:
   a. Bolt connections with fasteners having equal or better corrosion-resistance than the materials being fastened; seal joints to make a watertight enclosure.
   b. Weld connections and weld metal seams continuously to make unit watertight.
   c. Provide rigging supports on structure for final rigging.

4. Casings: Install galvanized steel, fabricated and installed by manufacturer to make tower watertight.

5. Provide integral type collecting basin with depressed side outlet sumps with lift-out strainer with openings smaller than nozzle orifices, and with connections for drain, overflow and water make-up.

6. Wetted Surface Fill: Provide vertical sheets of polyvinyl chloride plastic having a flame spread rating of 5 per ASTM E 84 and fabricated into wave-formed configurations installed by the manufacturer to assure break-up of water into droplets.

7. Drift Eliminators: Provide vertical sheets of polyvinyl chloride plastic having a flame spread rating of 5 per ASTM E 84 fabricated by the manufacturer into a three-pass configuration to limit drift-loss to indicated maximum percentage of circulating-water flow-rate.

8. Louvers: Provide galvanized steel designed and installed by manufacturer, and of sufficient thickness and rigidity to prevent visible sagging.

9. Water Distribution System: Galvanized steel, open basin, gravity-flow type with plastic metering orifices; installed by manufacturer to ensure even distribution of water over wetted-surface-fill. Schedule 40 PVC pipe header and removable schedule 40 PVC pipe branches.

10. Nozzles: Provide removable plastic, brass or ceramic nozzles with a maximum pressure drop of 5 psi.

11. Basin Covers: Galvanized steel sheet, removable and with handles, installed by the manufacturer to prevent debris from entering basin and to inhibit algae growth by eliminating sunlight.

12. Inlet Screens: Galvanized steel mesh mounted in removable frames by the manufacturer.

13. Discharge Hoods: Galvanized steel, including access doors, fabricated and installed by the manufacturer to prevent the recirculation of discharge air.

14. Basin heaters: Provide electric immersion heaters including thermostat and low-water cutout, in a weatherproof enclosure, adequate for field wiring. Size basin
heaters to maintain basin water at 40 degree F. (4.4 degrees C) at an ambient temperature of -10 degrees F. and with a wind velocity of 15 mph.

15. Handrails: Provide galvanized steel pipe rails of required height above tower. Include knee and toe rails of required diameter and heights.

16. Water Level Control: Provide electric float switch and solenoid make-up valve.

17. Flow Control Valves: Provide heavy duty cast iron, high capacity flow control valves for balancing flow to each distribution basin, and for shut-off during servicing.

18. Fans and Drives:
   a. Provide cast aluminum propeller fan of adjustable pitch type.
   b. Provide a gear-drive including speed reducer, with oil level sight glass.

19. Fan Bearings: Provide bronze sleeve bearings with extended external oil lines, sight glass and fittings.

20. Motor Type: Provide totally enclosed, fan-cooled energy efficient type motor. Rated for cooling tower duty service. Efficiency and construction shall comply with Section 15170.

21. Assemble components by one of the following methods:
   a. Use galvanized or stainless fasteners and accessories to assemble components.
   b. Weld metal seams and joints.
   c. Apply phosphatized pretreatment on zinc coated surfaces which have not been mill-phosphatized or polymer-coated. Apply gasoline-soluble rust preventative compound on ferrous parts that cannot be galvanized, including shafts and machined parts.

22. Finish components with zinc-coated metal surfaces using one of the following methods:
   b. Provide 2-1/4 oz. (per sq. ft. of sheet) zinc coating on basin and sump, after fabrication, by hot-dip galvanizing process. Coat abraded areas and welded areas of work with galvanizing repair paint.
   c. Apply to metal surfaces not galvanized, zinc-rich paint which has been tested and accepted by UL as being equivalent to hot-dipped galvanized steel.

23. Vibration Cutout Switch: On induced towers with propeller fans provide switch to de-energize fan motors if excessive vibration occurs due to fan imbalance.
24. For polymer-coated surfaces, electrostatically spray with thermosetting hybrid polymer fuse bonded to hot-dipped galvanized substrate during thermally activated curing stage. Provide polymerized metal surfaces that are capable of:
   a. When “X” scribed to base substrate, withstand 6,000 hrs. of 5% salt spray test according to ASTM B 117, with no blistering or chipping around intersection of scribes, nor any undercutting or creepage along scribes.
   b. When directly impacted with 160 in. lbs. from 0.625 in. radius impact tool, in accordance with ASTM D 2794, show no fracture or delamination.
   c. When exposed to 6,000 hrs. of continuous ultraviolet exposure, equivalent to 120,000 hrs. of normal sunlight radiation, show no cracking.
   d. When subjected to 200 thermal shock cycles between -25 and 180 degree F (-32 and 82 degree C), show no signs of deterioration.
   e. When exposed continuously for 6,000 hrs. to high pressure (60 psig) water jet, show no signs of erosion.

C. Spare Parts: Furnish the following spare parts:
   1. Three spare spray nozzles for each tower cell.
   2. One spare gasket for each gasketed access and inspection opening.
   3. One spare set of matched fan belts for each belt driven fan.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions under which factory-fabricated cooling towers are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

A. General Installation: Install cooling towers where indicated, in accordance with equipment manufacturer’s written instructions and with recognized industry practices, to ensure that cooling towers comply with the requirements and serve intended purposes.

B. Access: Provide access and service space around and over cooling towers as indicated, but in no case less than that recommended by the manufacturer.

C. Support:
   1. Install roof-mounted units on structural steel mechanical equipment stand. Anchor cooling tower to stand with removable fasteners.
   2. Install floor-mounted units on 4-inch high reinforced concrete pad, 6-inches larger on each side than cooling tower base. Cast anchor bolt inserts into pad.
D. Construct mechanical equipment stand as indicated, and in accordance with NRCA handbook and Accepted Roofing Knowledge.

E. Placement: Mount unit on vibration isolators if recommended by cooling tower manufacturer. Install gaskets or sealants between cooling tower cells. Level units to tolerance of 1/8" in 10'-0", in both directions.

F. Condenser Water Piping: Provide flanged or mechanical coupling connections to cooling tower, with flexible pipe connections if tower is mounted on vibration isolators. Pitch lines so water will drain into sump. Connect inlets to cooling tower with shutoff valve and balancing valve (if two or more inlets) Connect outlets with shutoff valves.

G. If the tower consists of more than one cell, in order to facilitate cleaning and maintenance, each cell shall have the capability to be completely drained and isolated from the other cell through a network of piping and valves. Provide equalizing piping between cells with automatic control valve.

H. Make-up and Water Piping: Provide flanged, mechanical couplings, or union connections to cooling tower. With flexible pipe connections if tower is mounted on vibration isolators. Pitch lines so that the water will drain into the sump. Connect to automatic fill valve with a 3-valve bypass, and backflow preventer.

I. Drain Piping: Connect drain, overflow, and bleed lines to cooling tower as indicated, full size of connection on cooling tower.

J. Electrical Wiring: Install electrical devices furnished by manufacturer but not specified to be factory-mounted. Furnish copy of manufacturer’s wiring diagram submittal to Electrical Installer.

3.3 TESTING, CLEANING, AND CERTIFICATION

A. Testing: Test each cooling tower to show that it will operate in accordance with indicated requirements.

B. Cleaning: Clean inside of cooling tower thoroughly before filling for start-up. Clean factory-finished surfaces. Repair any marred or scratched surfaces with manufacturer’s touch-up paint.

C. Verify that electrical wiring installation is in accordance with manufacturer’s submittal and installation requirements of Division 16 Sections. Do not proceed with equipment start-up until wiring installation is acceptable.

D. Start-up: Comply with manufacturer’s instructions for filling and start-up of operation, but not less than the following:

1. Verify lubrication of rotating parts; lubricate as needed.

2. Verify fan for correct rotation.

3. Verify that the motor amperage is in accordance with the manufacturer’s data.

4. Balance condenser water flow to each tower, and to each inlet for multiple inlet towers.

5. Adjust water level control for proper operating level.
6. Adjust bleed valve for indicated percentage of circulated water volume.
7. Balance equalizer lines between multiple towers (if necessary).
8. Adjust temperature controls and verify operation.

3.4 COMMISSIONING (DEMONSTRATION)

A. Provide services of a manufacturer’s technical representative for one 8-hour day to instruct UC Denver’s personnel in operation and maintenance of the cooling tower.

B. Schedule training with at least seven (7) days notice to the Contractor, UC Denver Project Manager and the Engineer of the training date.

3.5 SCHEDULES

END OF SECTION
SECTION 15750
HEAT TRANSFER

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes standards for heat exchangers, accessories, and trim.

1.2 REFERENCES

A. Section 15000 – General Mechanical Provisions
B. Section 15100 – Valves
C. Section 15110 – Piping
D. Section 15130 – Gauges
E. Section 15505 – Hydronic Systems
F. Section 15520 – Steam and Condensate Piping

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. The campus central steam distribution will provide the source for producing clean steam, heating water, and domestic hot water for the buildings whenever possible.

B. Provide steam in shell and water in tubes to convert steam heat to hot water for hydronic heating systems.

C. Hot Water Heating Systems:

1. Design hot water heating system with duplex converters and duplex main circulating pumps each capable of meeting the load individually.

2. Locate heat exchangers to allow removal of tube bundles without interference.

3. Provide air separators on systems.

4. Reset hot water temperature based upon outdoor air temperature and control by the BAS.

D. Steam Humidification:

1. Use clean steam generators for humidification.

2. Humidifiers shall be self-cleaning if available as an accessory.

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submittals shall be made in accordance with Section 15000.

1.6 QUALITY ASSURANCE
A. Regulatory Requirements Conform to ANSI/ASME Boilers and Pressure Vessels Code for the manufacture of tubular heat exchangers and heat exchanger shells.

1. ASME Compliance: Construct heat exchangers in accordance with ASME Boiler and Pressure Vessel Code, Section VIII “Pressure Vessels”, Division 1.

2. TEMA Compliance: Construct and install heat exchangers in accordance with “Standards of the Tubular Exchanger Manufacturer’s Association”.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Shell and Tube Type and Plate and Frame Type Heat Exchangers
   a. Bell & Gossett ITT
   b. Alfa Laval.
   c. Armstrong
   d. Spirax Sarco

2. Steam to Steam Generators:
   a. Patterson-Kelley Co
   b. Or approved equal.

2.2 MATERIALS, GENERAL

A. Shell and Tube-type Heat Exchanger:

1. Tubes: U-tube type with 3/4 inch OD minimum seamless copper tubes suitable for 250 psig working pressure.

2. Shell: Steel with threaded or flanged piping connections and necessary tappings, steel saddle and attaching U-bolts, prime coated.

3. Heads: Cast iron or fabricated steel tube sheets threaded or flanged for piping connections.


B. Plate and Frame Heat Exchangers:

1. General: Pre-assembled, pressure tested at the factory, and flushed clean, ready for connection to piping.
2. Designed, fabricated, and tested for operation in accordance with the ASME Unfired Pressure Vessel Code, Section VIII, Division 1, including the latest addenda and code stamped.

3. Enclose plate rack in a removable painted, rust protected carbon steel metal shroud designed to protect the plate rack from debris and damage.

4. All exterior steel surfaces shall be sharp steel shot blasted followed by one coat of two part epoxy spray enamel baked at 250 degrees F.

C. Clean Steam Generators:

1. General: Unfired, skid mounted, packaged steam to steam generator constructed of welded steel, with copper tube bundle.

2. Tank: Designed, constructed, and stamped to meet requirements of ASME Code Section VIII for Unfired Pressure Vessels.

3. Tube Bundles: U-tube design pitched and arranged to enable exterior cleaning.

4. Insulation: Cover shell with 2-inch fiber insulation and protected by a zinc-plated sheet steel jacket.

5. Controls: Provide electrical signal to the steam regulator valve. Provide liquid level controls to the feed water pump or valve. Provide electrically steam regulator valve with bypass connections, strainers and steam traps.

6. Gauges and Valves: Provide unit with gage glass to permit visual inspection of water level. Provide thermometers or steam gages to monitor unit performance. Provide safety valves per ASME Section I Boiler Code. Provide blow-off valves in tandem arrangement on the bottom of the shell.

7. Supply water shall be softened through an independent ion exchange softener

D. Spare Parts:

1. General: Furnish one spare gasket for each flanged connection for each heat exchanger.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. Install in accordance with manufacturer’s instructions.

B. Install to permit removal of tube bundle with minimum disturbance to installed equipment and piping.

C. Support heat exchangers on welded steel angle from floor structure above.

D. Pitch shell to completely drain condensate.
E. Pipe relief valves to the nearest roof or floor drain.

F. Pipe drain valves to nearest floor drain.

G. Steam Piping: Provide piping as indicated, including control valve with 3-valve bypass, strainer, and pressure gauge on inlet; condensate dirt leg steam trap with 3-valve bypass, strainer and check valve on outlet; air vent or vacuum breaker on shell.

H. Water Piping: Provide piping as indicated, including union, shutoff valve, and thermometer on inlet and outlet. Pipe relief valve outlet to floor drain.

I. Steam-to-Water Heat Exchanger Trim:
   1. Shell: Pressure gauge tapping with pigtail siphon, vacuum breaker.
   2. Water Inlet: Thermometer well, pressure gauge tapping, valved drain.
   3. Water Outlet: Thermometer well for temperature regulator sensor, ASME rated pressure and temperature relief valve, thermometer well, pressure gauge tapping.

3.3 TESTING, CLEANING, AND CERTIFICATION

A. Clean factory-finished surfaces. Repair any marred or scratched surfaces with manufacturer’s touch-up paint.

3.4 COMMISSIONING (DEMONSTRATION)

A. Provide factory start-up services for the Steam to Steam generator to witness system start-up and check the performance of all controls and to provide operation and maintenance instruction of the equipment.

3.5 SCHEDULES

END OF SECTION
SECTION 15850
AIR HANDLING

PART 1 - GENERAL

1.1 SUMMARY

A. This section includes standards for air handling units and fans for air distribution and exhaust.

1.2 REFERENCES

A. Section 15000 – General Mechanical Provisions
B. Section 15170 – Motors and Drives
C. Section 15190 – Mechanical Identification
D. Section 15500 – Special HVAC
E. Section 15990 – Testing, Adjusting and Balancing

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. General:

1. Locate roof-mounted equipment as inconspicuous as possible by placing equipment far away from edge of roof, painting, screening or a combination of these,

2. Locate fans, motors, and drives for safe and easy access for periodic inspection and maintenance.

3. Show air handling unit arrangements on schematic diagrams.

4. Scheduled fan sound ratings where noise levels are critical.

5. All fans shall be licensed to bear the AMCA Seals for Air and Sound Performance.

B. Fan specifications and accessories for all fans 12 inch and larger wheel shall include the following.

1. Fans shall be belt driven. Direct drive fans are not permitted.

2. Provide building air handling unit fans with external bearings only. Shafts 3/4 inches and larger shall have roller bearings. No internal bearings recessed into fan housing shall be allowed. All bearings shall be accessible for lubrication, maintenance, and replacement.

3. Aluminum wheels are not allowed except for spark proof applications.

4. Install weatherproof housing over motor and drive when exposed to weather. Metal interior casings and wheels shall be coated if fumes are corrosive.
C Fan Vibration Isolation:
1. Provide spring isolators either within the air handling unit housing or independently mounted to reduce the transmission of distributing vibration of the fan to the supporting structure by a minimum of 90%.

D. Drives:
1. Single belt drives shall be utilized only on equipment with 1 Hp motors or less.

E. Exhaust Systems:
1. Exhaust systems that may transport offensive odors, noxious gases, etc., are to be separate systems. Provide identifying labels on exterior stacks per the instructions of the Project Manager.
2. Locate fans so that negative pressure exists in all exhaust ducts within buildings.
3. Conditioned make-up air shall be provided to compensate for exhaust.
4. Recirculation systems are not allowed in laboratory spaces.
5. Refer to Section 15500 for Special HVAC Systems including fume exhaust systems.

F. Air Handling Units:
1. Inlet Louver: Shall be sized with 300 fpm face velocity to slow down the snow induced into the unit. Bird screen 1/2” x 1/2” shall be utilized in such a manner that vacuuming of the screen can be done.
2. Air handling units shall be designed and installed with sufficient room to allow the installation of all control components including but not limited to preheat coil discharge air temperature averaging sensors.
3. Heat Recovery Coil: When applied, shall be a minimum 4-row coil with the face velocity not to exceed 600 fpm. Access for vacuuming on both sides.
4. Preheat Coil: Steam coils shall be vertical tube with integral face and bypass. No steam control valve shall be installed to modulate the flow of steam.
5. Cooling Coil: Shall be located far enough from the preheat coil so that an averaging sensor can be located to measure the leaving air temperature.
6. Air ratings are based on actual site elevation of 5200 feet.

1.4 DEFINITIONS

1.5 SUBMITTALS
A. Submittals shall be made in accordance with Section 15000.

1.6 QUALITY ASSURANCE
A. Codes, Regulations and Standards: Comply with the following:
ARI 410 Standard for Forced Circulation, Air Cooling and Air Heating Coils.
ARI 430 - Standard for Central Station Air Handling Units.
NFPA 90A - Installation of Air Conditioning and Ventilation Systems.
ANSI-AFBMA 9 - Load Ratings and Fatigue Life for Ball Bearings.
SMACNA - HVAC Duct Construction Standards.
ANSI/UL 900 - Test Performance of Air Filter Units.
AMCA 300 and 301 - Method for Publishing Sound Ratings for Air Moving Devices.

Test fans in accordance with AMCA 210 and meet the AMCA standards where applicable standard exists.

Manufacture shall certify that fans have been tested in accordance with AMCA 330 where sound ratings are shown.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2- PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Fans:
   a. Acme
   b. New York Blower
   c. Greenheck

2. Fan Motors
   a. Baldor (preferred)
   b. Or approved equal.

3. Pillow blocks
   a. Seal Master Gold Line, equal or better, on shafts 1/2 inch to 1-7/16 inch.
   b. RSAO bearings acceptable on larger shafts.
   c. Or approved equal.

2.2 MATERIALS, GENERAL
A. Centrifugal Fans:

1. Unit Casing: Galvanized steel panels, formed and reinforced, seams continuously welded. All interior and exterior surface steel shall be coated with a minimum of 2-4 mils of Polyester Urethane, electrostatically applied and baked. No uncoated metal fan parts will be allowed. Provide access doors or panels to allow access to internal parts and components.

2. Fan Wheel: Non-overloading single width airfoil centrifugal type. Wheels shall be statically and dynamically balanced to balance grade G6.3 per ANSI S2.19. Fan wheel shall be manufactured with continuously welded steel airfoils and coated with a minimum of 2-4 mils of Polyester Urethane, electrostatically applied and baked.

3. Shaft: Turned, ground, polished, and rust protected steel. Designed to operate at no more than 70 percent of the first critical speed at the top of the fan’s speed range.

4. Shaft Bearings: Air handling quality self-aligning, heavy duty, pillow block type, roller or ball type bearings with L-10 rated bearing life of 80,000 operating hours. Provide extended lube lines.

5. Belt Drives: V-belt drives rated at not less than 200% of motor nameplate rating. Belt speeds shall not exceed 4500 feet per minute. Center distances between driver and driven sheaves must meet the manufacturer's minimum and maximum. Belts shall be notched AX, BX or CX series.

6. Sheaves: All sheaves shall be fixed pitch type. Variable pitch sheaves are not permitted. Fixed pitched sheaves supplied with units shall be replaceable by fixed pitched sheaves for balancing purposes. No sheave shall be less than 3.9 inch PD.

7. All accessible inlet or exhaust openings in fans shall have 1/2 inch square wire mesh guards covering those openings as well as belt and pulley guards.

8. Motor nameplate to include stamped bearing size.

9. All large motors will have double pull, adjustable motor mounts.

10. Size fans to provide design airflow at 15% below maximum rpm as suggested by the manufacturer.

11. Belt Guard: Fabricated to OSHA and SMACNA requirements.

12. Accessories:
   a. Scroll access doors shaped to conform to scroll with quick-opening latches and gaskets.
   b. Galvanized steel companion flanges for duct connections.
   c. 2-inch drain connections.
   d. Removable inlet and outlet safety screens for access to fan for maintenance.
B. Propeller Fans

1. Panel: Painted steel fan panel with welded corners, pre-punched mounting holes, deeply spun venturi, integral stiffening flanges, and motor support.


3. Fan Shaft: Ground, polished, and coated steel.

4. Drive Type:
   a. Belt drive:
      1) Motor Pulleys: Fixed pitch, cast iron, sized for 150 percent of maximum cataloged speed.
      2) Bearings: Heavy duty ball bearings with L10 rated bearing life exceeding 80,000 operating hours.

5. Fan Blades: Statically and dynamically balanced steel or aluminum blades.

6. Accessories:
   a. Rear Fan Guard: Removable or with removable access section for fan maintenance, conforming to OSHA requirements.
   b. Wall Shutter:
      1) Gravity shutter with heavy aluminum frame, blades interconnected with tie-rods, and nylon bearings.
      2) Motorized shutter with heavy aluminum frame, blades interconnected with tie-rods, nylon bearings, and actuator motor to power open and spring return.
   c. Wall Sleeve: Galvanized steel sleeve with moveable angle frame.

C. Roof and Wall Ventilators:

1. Housing: Weatherproof, heavy-gauge spun aluminum with rigid steel internal support structure.


3. Motor: Open drip proof, high-efficiency motor, mounted out of the air stream.

5. Shafts: Solid steel, precision ground, polished, and treated for rust resistance.

6. Drive:
   a. Belt drive:
      1) Bearings: Heavy duty, with L-10 rated bearing-life exceeding 80,000 operating hours.
2) Pulleys: Cast iron fixed pitch, sized for 150 percent of the driven horsepower.


9. Roof Curb:
   a. Field-built.
   b. Prefabricated, galvanized curb with welded seams and fastening flange for “self-flashing”. Closed cell neoprene rubber gasketing around the top of the curb and 1-1/2-inch thick, 3-pound density rigid insulation along the sides. Curbs shall be minimum 14” high.

10. Nameplate: Each fan shall bear a permanently affixed manufacturer's nameplate containing the model number and individual serial number for future identification.

11. Accessories:
   a. Hinged Sub-base: Rust-proof hinge arrangement permits access to curb well for access to curb mounted dampers.

D. Upblast Roof Ventilators:

1. Housing: Heavy-gauge spun aluminum housing with rigid steel internal support structure, spun aluminum windband, and aluminum base with continuously welded curb cap corners.


3. Motor: Heavy duty type, permanently lubricated, sealed ball bearing, open drip proof, high-efficiency motor, mounted out of the air stream.

4. Shafts: Solid steel, turned, ground, and polished.

5. Drive:
   a. Belt drive, cast iron, keyed and securely attached to wheel and motor shafts:
      1) Bearings: Heavy duty, greasable ball type mounted in cast iron housing, L10 rated 100,000 operating hours.
      2) Pulleys: Fixed pitch, sized for 150 percent of the driven horsepower.

7. Screen: Aluminum bird screen.

8. Roof Curb:
   a. Field-built.
   b. Prefabricated, galvanized curb with welded seams and fastening flange for “self-flashing”. Closed cell neoprene rubber gasketing around the top of the curb and 1-1/2-inch thick, 3 pound-density rigid insulation along the sides.

9. Accessories:
   a. Hinged Sub-base: Rust-proof hinge arrangement permits access to curb well for access to curb mounted dampers.
   c. Provide fans with UL-762 listing for all grease applications.

E. Ceiling Fan:
   1. Housing: Acoustically insulated, galvanized steel housing with chatter proof damper.
   2. Fan Wheel: Centrifugal type, dynamically balanced.

E. Fume Hood Exhaust Systems:
   1. General:
      a. Fans selected shall be capable of accommodating static pressure and flow variations of +/-15% of scheduled values.
      b. Each fan shall be belt driven in AMCA arrangement 9 according to drawings.
      c. Fans to be equipped with 316 stainless steel lifting lugs for corrosion resistance.
      d. Fasteners exposed to corrosive exhaust shall be stainless steel.
      e. Curb cap shall be 316 stainless steel for corrosion resistance.
      f. Fan assembly shall be designed for a minimum of 125-mph wind loading, without the use of guy wires.
      g. Motor cover shall be split design and hinged for ease of maintenance on units with a housing diameter of 60 inches and larger.
   2. Fan Housing And Outlet
a. Fan housing shall be aerodynamically designed with high-efficiency inlet, engineered to reduce incoming air turbulence.

b. Fan housing shall be bifurcated, allowing all drive components, including the motor, to be serviced without contact of the contaminated airstream. Must be manufactured of welded steel coated with minimum 4 mils of Hi-Pro Polyester resin, electrostatically applied and baked. Finish color shall be gray. No uncoated metal fan parts will be acceptable.

c. A multi-stage air induction discharge nozzle shall be supplied by the fan manufacturer, be integral to the fan body, and be designed to efficiently handle an outlet velocity of up to 7000 FPM. The multi-stage nozzle shall induce ambient air up to 270% of fan capacity. Nozzle / Windband assemblies that are manufactured by third party vendors, or that are fabricated of plastic or resins, having mechanical properties less than steel shall not be acceptable.

d. Optional induction discharge windband, including an integral packed acoustic attenuator fabricated of corrosion-resistant coated steel and a perforated 304 stainless steel inner liner, shall be provided by the fan manufacturer. The acoustic attenuation windband shall not increase the overall height of the fan / nozzle assembly. Acoustic insertion loss shall be as follows:

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<tr>
<th>Frequency</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1K</th>
<th>2K</th>
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<td>15</td>
<td>20</td>
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e. An integral fan housing drain shall be used to drain rainwater when the fan is de-energized.

f. An access door shall be supplied for impeller inspection and service.

g. Fan assembly shall be AMCA type C spark resistant construction minimum or as noted on the schedule.

3. Fan Impeller

a. Fan impeller shall be mixed flow design with non-stall characteristics. The impeller shall be electronically balanced both statically and dynamically exceeding AMCA Standards.

b. Fan impeller shall be manufactured of welded and coated steel with minimum 4 mils of Hi-Pro Polyester resin, electrostatically applied and baked. Finish color shall be gray.

c. Fan impellers that are fabricated of polypropylene or fiberglass that have lower mechanical properties than steel and lower maximum tip speeds are not acceptable.

d. Vacuum Seal: Fan impeller shall include a secondary fan blade located on the impeller back plate. This secondary impeller shall create a negative pressure at the shaft opening; preventing hazardous or toxic exhaust fumes from escaping through the housing shaft opening.
Mechanical shaft seals that wear out and need to be replaced or seal systems that use hoses or tubes that can leak, are not acceptable.

4. Bypass-Air Plenum

a. For variable volume systems, a bypass-air plenum shall be provided as shown on drawings. The plenum shall be provided with bypass-air damper(s) for introducing outside air at roof level upstream of the fan, complete with bypass-air rain hood and bird screen. Plenum shall be mounted on factory fabricated roof curb.

b. The plenum shall be constructed of welded cold rolled steel, and coated with minimum 4 mils of Hi-Pro Polyester resin, electrostatically applied and baked. Plenums that are fabricated of plastics or resin that are combustible and have mechanical properties less than steel shall not be acceptable.

c. Bypass air damper(s) shall be opposed-blade design for airflow control, airfoil design, fabricated of steel for structural rigidity, and coated with a minimum of 4 mils of chemically resistant Hi-Pro Polyester resin, electrostatically applied and baked. Bypass dampers shall have stainless steel damper rods, bearings and jamb seals and the blades shall have polymer edge seals. Dampers shall be suitable for application up to 15 inches w.g. Damper blade drive linkage shall be set by manufacture and welded to eliminate linkage slippage. All damper access and service (drive actuators) shall be performed outside of the contaminated plenum interior.

d. Optional, integral bypass-air packed acoustic attenuator fabricated of 304 Stainless steel shall be provided by the fan manufacturer (if shown on the drawings). Acoustic insertion loss shall be as follows:

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<th>Frequency (Hz)</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1K</th>
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</table>

e. Fan isolation damper(s), shall be parallel-blade design, airfoil design, fabricated of steel for structural rigidity, and coated with a minimum of 4 mils of chemically resistant Hi-Pro Polyester resin, electrostatically applied and baked. Bypass dampers shall have stainless steel damper rods, bearings and jamb seals and the blades shall have polymer edge seals. Dampers shall be suitable for application up to 15 inches w.g. Damper blade drive linkage shall be set by manufacture and welded to eliminate linkage slippage. All damper access and service, (including removal and replacement and drive actuators) shall be performed outside of the contaminated plenum interior.

f. Isolation damper shall include a factory mounted and wired actuator complete with a mounted and wired step down transformer that is wired to the fan disconnect. Transformer shall be mounted in a NEMA 3R panel, minimum, or that shown on the schedule notes.

g. Blower / Plenum vibration isolation shall be limited to neoprene / cork vibration pads.

5. Curb
a. Curb shall be factory fabricated of a minimum of 12 gauge corrosion-resistant coated steel and structurally reinforced. Height as shown on the drawings. When properly anchored to the roof structure, the standard curb / plenum / blower assembly shall withstand wind loads of up to 125 mph without additional structural support.

b. Vertical exhaust inlet plenums shall have curbs that are insulated. Horizontal exhaust inlet plenums shall have un-insulated plenums.

G. Air Handling Units:

1. Panels:
   a. Low pressure casings, less than 1-1/2 inch static pressure: Single wall construction, galvanized steel with 1-inch, 3/4-pound mat faced glass fiber insulation.

   b. High-pressure casings, above 1-1/2 inch static pressure inch sandwich panels filled with insulation. Exterior panel sheet to be 18 gauge galvanized steel and interior panel sheets 22 gauge perforated galvanized steel.

2. Access Doors: Same material and finish as cabinet with hinges, latches, handles, and gaskets. Provide neoprene gaskets around full perimeter of access doors. Doors shall be 24 inches wide and 60 inches high when possible. Provide view window with safety reinforcement mounted in access door. Doors shall open against the air pressure.

3. Light: Marine type, vapor tight, incandescent light fixture. Each light controlled by an individual switch. Provide light in each fan section with an access door.

4. Fan Section:
   a. Fan statically and dynamically balanced for continuous operation at maximum rated fan speed and motor power.

   b. Shaft: Hot-rolled steel; turned, ground, and polished, with keyway to secure fan wheel hub. Shaft shall not pass through its first critical speed as the unit comes up to its rated rpm.

   c. Shaft Bearings: Greasable, self-aligning, pillow block type ball or roller bearings with L50 rated bearing life of 200,000 operating hours. Factory lubricated and equipped with grease fittings extended to the motor side of fan.

5. Coil Module:
   a. Insulated, 16 gauge galvanized steel casing for heating and cooling coils. Coil headers and return bends enclosed in casing. Coils accessible for service and removable through access doors or removable panels.

   b. Coil performance certified in accordance with ARI 410.
c. Water Coils: Drainable with threaded plugs. Serpentine with return bends or return headers. Coils tested to 300 psig air pressure under water. Coil circuited for counter flow of air and water.

d. Steam Coils: Pitch coils for proper drainage of steam condensate. Coils tested to 300-psig air pressure under water.

6. Filter Module: Galvanized steel filter racks, access door, and block-offs to prevent air bypass around filters.

7. Dampers: Galvanized steel blade, air foil design, Low leakage dampers rated according to AMCA 500 shall not exceed 2 percent of air quantity at 2000 fpm face velocity through damper and 4-inch wg pressure differential.

8. Spare Parts:

   Provide one complete set of spare filters for each air-handling unit.

   Provide one set of belts for each unit. Label each belt clearly identifying to which fan the belt belongs.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL:

   A. Install equipment such that filters, motors, bearings, and belts can be easily serviced.

   B. Install filters prior to starting fans.

   C. Connections:

      1. Connect piping to air handling units with flexible connectors.

      2. Connect drain piping to condensate drain pans with deep trap. Route piping to nearest floor drain. Install cleanouts at changes in direction.

      3. Install flexible connections at inlet and outlet of fans connected to ductwork.

   D. Label fans in accordance with Section 15190.

   E. Locate motor control disconnect within 3 feet of the motor.

   F. Fan Drive:

      1. Align belts with proper tension prior to start-up.

      2. Final sheave shall be fixed. Balancing firm’s variable sheaves will be removed and replaced with the proper sized fixed sheaves.

      3. Original sheaves shall be changed when required for proper balancing.

   G. Fans:
1. Access shall be provided to allow cleaning of fan and blades without disassembling ductwork

2. Install fans in accordance with manufacturer’s printed data. Prior to starting fan, clean ductwork and lubricate bearings.

H. Air Handling Units:

1. Allow access for cleaning coils from both sides. Provide a means to catch and dispose of cleaning solutions with pipe to drain on larger coils.

2. Provide space for removing and repairing coils and other components.

3.3 TESTING, CLEANING, AND CERTIFICATION

A. Test, adjust, and balance air handling equipment in accordance with Section 15990.

B. Clean fan interiors. Vacuum clean fan wheels, cabinets, and coils entering air face.

C. Provide one (1) new set of filters to be installed by contractor at the time of system acceptance.

D. Provide air handler schedule listing for each unit, location, filter sizes, coil sizes, motor Hp, belt size, and areas served.

3.4 COMMISSIONING (DEMONSTRATION)

A. Provide 2 hours of operating instructions for each fan and air handling unit. Include procedures and schedules related to startup and shutdown, troubleshooting, servicing, and preventive maintenance. Review data in the operation and maintenance manuals.

3.5 SCHEDULES

END OF SECTION
SECTION 15856
DIRECT EVAPORATIVE COOLING

PART 1 - GENERAL

1.1 SUMMARY

A. For additional information, also see Design Criteria (web-base standard) - Part 3.4 UC Denver Utilities Mechanical Infrastructure Guidelines/Considerations. Both the Design Criteria and the Construction Standards are co-equal in authority.

B. This applies to single stage or multi-stage evaporative cooling sections.

1.2 DIRECT EVAPORATIVE COOLING SECTION

A. The casing shall be constructed of reinforced stainless steel panels and shall be designed for front access to the pump, strainer, and float assembly. The top cover is to be hinged for service access to the media and spray distribution header. Dielectric gasketing shall be installed between the evaporative cooling section and other non-compatible metals which come in contact at wet surfaces.

B. The sump shall be 12 inches deep minimum, of 14-gauge stainless steel construction, with bleed, 2” overflow, and 2” drain connections for complete sump drainage. Sump shall extend 6” (min.) upstream of the media and shall be large enough to accommodate the pump(s) on the downstream side.

C. Include adequately sized brass float valve assembly for makeup water control.

D. The sump shall be sloped to the drain outlet for complete drainage.

E. Provide a 12-inch deep pad of Munters Glasdek media. Maximum face velocity without water carryover shall be 500 fpm. Evaporative cooling effectiveness shall be 90% at 450 fpm face velocity.

F. Media spray pump(s) shall be submersible type with stainless-steel inlet strainer. Pump motor(s) shall be thermally protected and capable of being operated dry for up to 12 hours without damage.

G. Provide factory-installed float switch to lock-out spray pumps until sump fill level is sufficient to submerge the pump inlet.

H. Pumps shall be sized to provide 2 GPM per square foot of top surface of the pad (2 GPM per linear foot for a 12-inch thick pad).

I. Piping and distribution header shall be Type L copper, with non-clogging spray distribution nozzles and hose-end blowdown valves on both ends of the unit. Provide with brass balancing valve and a brass bleed-off valve. The drain and fill valves shall be motorized, full-port ball valves, provided by the temperature control contractor. Valves shall conform to specification Section 15110 (Valves).
J. Construction shall conform to the Evaporative Cooling Module Piping and Construction Detail on the drawings and the design guidelines issued by the Munters Corporation.

PART 2 - PRODUCTS

PART 3 - EXECUTION

3.1 TRAINING

A. Schedule a minimum of four (4) hours of training with Owner. The manufacturer’s representative, and the Division 15 Contractor shall be present. The training shall be coordinated by the Division 15 Contractor and the Owner in conjunction with the other mechanical equipment on the project.

B. Train the Owner's maintenance personnel on start-up and shutdown procedures, troubleshooting procedures, and servicing and preventative maintenance schedules and procedures. Review with the Owner's personnel, the contents of the Operating and Maintenance Data.

C. Schedule training with Owner through the Architect/Engineer with at least seven (7) days prior notice.

END OF SECTION
SECTION 15880
AIR DISTRIBUTION

PART 1- GENERAL

1.1 SUMMARY

A. This section includes standards for ductwork, duct accessories, filters, air cleaning devices, air terminal devices, louvers, diffusers, registers, and grilles.

1.2 REFERENCE

A. Section 15000 – General Mechanical Provisions
B. Section 15190 – Mechanical Identification
C. Section 15500 – Special HVAC
D. Section 15850 – Air Handling
E. Section 15950 – Building Automation System

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. Ductwork:

1. Ductwork shall be installed in accordance with ASHRAE and SMACNA guidelines, recommendations, and standards unless otherwise.

2. Fiberglass ductwork is not permitted.

3. Designer should evaluate cost effective means to achieve sound alleviation in the ductwork or at the air-handling unit.

4. For larger duct systems, sheet metal cost savings can be realized by specifying different Duct Pressure Classes for the portions of the system that do not experience as much static pressure due to being farther away from the fan. Indicate on drawings the points in the ductwork system where duct construction should change because of change in Duct Pressure Class. Use the SMACNA symbol for “Point of Change in Duct Construction (by the Static Pressure Class)” Be aware of possible static pressure changes in system due to abnormal or emergency conditions.

5. Kitchen hood exhaust ductwork shall conform with NFPA 96 and the Uniform Mechanical Code.

6. Special exhaust systems shall conform with NFPA 91 and the Uniform Mechanical Code.

7. Acoustical Criteria: Refer to Section 15000 for space sound levels associated with air borne noise.

8. Supply air ductwork between fan and terminal boxes (medium and high): Galvanized steel, (Grade G90 or better) shop fabricated rectangular, spiral, round or oval factory fabricated.
9. Rectangular supply air ductwork from discharge or terminal box to air devices (low pressure): Galvanized sheet metal (lined where noted on drawings); factory or shop fabricated.

10. Return air ductwork: Galvanized Steel (lined where noted on drawings); factory or shop fabricated.

11. General building exhaust ductwork: Galvanized sheet metal (lined as noted on drawings); factory or shop fabricated.

12. Transfer Ducts: Internally lined galvanized sheet metal as described above for low-pressure supplies; factory or shop fabricated.


14. Radioisotope exhaust ductwork: 304 stainless steel all welded construction; factory or shop fabricated.

15. Laboratory ductwork: Unlined galvanized or stainless steel ductwork as required by lab service.

16. Duct sizes on drawings shall be **outside sheet metal** dimensions.

17. Pressure Classifications:
   
a. Low Pressure: Three pressure classifications: 1/2 inch WG positive or negative static pressure and velocities less than 2,000 fpm; 1 inch WG positive or negative static pressure and velocities less than 2,500 fpm and 2 inch WG positive or negative static pressure and velocities less than 2,500 fpm.

b. Medium Pressure: Three pressure classifications: 3 inch WG positive or negative static pressure and velocity less than 4,000 fpm, 4 inch WG positive static pressure and velocities greater than 2,000 fpm, 6 inch WG positive static pressure and velocities greater than 2,000 fpm.

c. High Pressure: Positive static pressure over 6 inches WG and less than 10 inches WG and velocities greater than 2,000 fpm.

18. Air Leakage:
   
a. Review the duct sealing requirements listed in SMACNA HVAC Duct Construction Standards, and specify the appropriate requirements, adjusting the SMACNA sealing requirements as necessary.

b. Pressure testing of ductwork in the 3-inch and higher Duct Pressure Class is required.

19. Plenums:
   
a. Obtain approval from the UC Denver Project Manager for the use and arrangement of return air plenums.

b. Materials in plenums must be in full compliance with NFPA 90A and the Uniform Mechanical Code.
c. Return air grilles for return air plenums shall have sound attenuation boots in accordance with SMACNA standards.

B. Duct Accessories:

1. Volume Control Dampers:
   a. Show all required locations for volume control dampers in the ductwork required for air balancing. Main ducts, branch ducts, and zone ducts must have dampers to permit proper division of air quantities. Each supply branch and outlet, and each exhaust branch must have a damper control. Parallel and opposed-blade dampers shall have 4 diameters of straight duct downstream of damper. Avoid locating dampers where it is obvious they won’t be needed because of the inherent pressure drops in the system due to duct layout, longest run, etc.
   b. Do not install a volume damper with a frame that protrudes into an airstream due to excessive noise and pressure drop.
   c. Provide locking, indicating quadrant regulators on volume control dampers.
   d. Dampers that are integral parts of supply or exhaust diffusers or grilles are not permitted for balancing. Provide dampers at branches or takeoffs for balancing.

2. Take-offs:
   a. Provide conical take-offs with a manual damper if warranted. If the main duct is not deep enough for a conical fitting, specify a 45 degree fitting with a round collar.
   b. Do not put manual dampers in take-offs to VAV terminals.

3. Fire and Smoke Dampers:
   a. Indicate all fire and smoke dampers on the drawings where ducts pass through fire rated walls or ceilings. Provide schedules for fire and smoke dampers.
   b. Coordinate locations with code review authority during design process.
   c. Provide fire and smoke dampers with a frame style that does not impinge on the duct’s cross-sectional free area to decrease excessive pressure drop and noise.
   d. Provide only “dynamic” rated fire dampers.
   e. Where ventilation ductwork or grills are installed in fire rated walls or partitions install fire/smoke dampers and frames such that its fire resistance shall be equal to that of the wall or ceiling in which it is located. Size dampers to provide full duct size opening through wall, partition, or ceiling.

4. Flexible Duct:
a. Provide flexible duct to meet the pressure class requirements.

b. Provide a maximum length of 6 feet.

C. Air Filtration and Cleaning Devices:

1. Filter all air supplied to the building. Main building ventilation systems shall filter the air at central filter banks. Central filter banks shall have pre-filters.

2. Varicel and HEPA filters shall be accessible for either upstream or downstream servicing. Pleated panel filters shall be removable from the upstream side without disturbing the filters.

3. Provide manehelic gauges on all air handling unit filter banks.

4. Exhaust air systems, which have filters for protection of heat recovery coils, shall be 1 inch filters of 30% efficiency. Filters shall be easily accessible and removable through side access frames.

5. All filter doors and frames (when applicable) shall utilize closed-coil gasketing.

6. Provide extended surface high efficiency media filters where the filtering of biological organisms is required.

7. Provide activated carbon filters where odor control is required.

8. Provide filters upstream of all coils.

D. Air Terminal Devices:

1. All air flow dampers need to be far enough away from the heating coil to ensure proper heating of the air at minimum flows.

2. Design systems to minimize maintenance or service requirements in occupied spaces.

3. Provide all air filtering requirements at the central air handling stations.

4. Provide aspirating air outlets to prevent dumping of air into occupied spaces at minimal air volumes.

5. Design system flexibility to revise zoning with minimal changes in ductwork and controls.

6. Provide required minimum outside air, ventilation air, for occupied spaces even when the supply airflow rates are reduced because of decreased cooling loads.

7. Air terminal units to be used in a healthcare, clean room or lab facility shall have a special VAV unit liner to meet healthcare facility standards.

8. Provide VAV units to meet sound levels specified on drawings and in Section 15000 for both radiated and discharge sound levels. When calculating sound levels use 1.5 inch w.g. inlet pressure.
9. Schedule sound power ratings for air terminal units to meet radiated and discharge sound criteria indicated in Section 15000. Schedule sound power level ratings at 1.5-inch static pressure.

E. Building Air Inlets and Outlets:

1. In buildings where exhaust air may be contaminated, locate the building air supply intake to avoid recirculation of the building exhaust air.

2. Provide air intake louvers in vertical position with a face velocity and arrangement to mitigate snow intake. Provide 1/2-inch bird screen.

3. Locate air intakes as high as possible above grade.

F. Diffusers, Registers, Grilles:

1. Indicate provisions for balancing airflow from outlets or into inlets on the drawings.

2. Provide for quantities and distribution patterns as shown on the drawings.

1.4 DEFINITIONS

1.5 SUBMITTALS

A. Submittals shall be made in accordance with Section 15000, including the following:

1. Submit 1/4 inch scaled fabrication and layout drawings of metal ductwork and fittings including, but not limited to, duct sizes, locations, elevations, and slopes of horizontal runs, wall and floor penetrations, and connections. Show interface and spatial relationship between ductwork and proximate equipment. Show modifications of indicated requirements, made to conform to local shop practice, and how those modifications ensure that the area materials and rigidity are not reduced.

2. Submit diffuser, register, and grille performance characteristics including, CFM ratings, pressure drops, NC levels, and throw patterns.

3. Submit louver color samples for selection and approval.

4. Submit duct access door coordination drawing for approval.

1.6 QUALITY ASSURANCE

A. SMACNA Standards:

1. Comply with SMACNA’s “HVAC Duct Construction Standards, second edition”.

2. Comply with SMACNA’s “HVAC Air Duct Leakage Test Manual”.


C. NFPA Compliance: Comply with NFPA 90A “Standard for the installation of Air Conditioning and Ventilating Systems” and NFPA 90B “Standard for the Installation of Warm Air Heating and Air Conditioning Systems”.
D. Filter media shall be ANSI/UL 900 listed, Class 1 or Class 2, as approved by local authorities.

E. Air terminals shall comply with ARI 880, “Industry Standard for Air Terminals” and shall bear the ARI certification seal.


1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

PART 2- PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Flexible Duct:
   a. Flex-Master
   b. Thermaflex
   c. Hercules

2. Balance Dampers:
   a. Greenheck
   b. Ruskin
   c. Pottorff

3. Fire Dampers and Combination Fire/Smoke Dampers:
   a. Greenheck
   b. Ruskin
   c. Pottorff

4. Ductwork:
   a. Hercules
   b. Equal and approved

5. Filters:
   a. American Air Filter
   b. Farr
c. Koch

6. Air Terminal Units:
   a. Price
   b. Environmental Technologies
   c. Titus

7. Grilles, Registers and Diffusers:
   a. Metalaire
   b. Titus
   c. Price

8. Louvers:
   a. Greenheck
   b. American Warming/Air Balance
   c. Ruskin

2.2 MATERIALS, GENERAL

A. Ductwork:
   1. Galvanized Ducts: Lock-forming quality, ASTM A527, Coating designation G 90. Provide mill phosphatized finish for exposed surfaces of ducts exposed to view. Provide flat seam construction where standing seams are a hazard to the UC Denver operating personnel.
   3. Stainless Steel Ducts: ASTM A480 Type 316 with No. 4 finish on surfaces of ducts exposed to view; Type 304 with No. 1 finish for concealed ducts. Protect finished surfaces with mill applied adhesive protective paper, maintained through fabrication and installation.
   4. Sealant: UL listed, Class 1, flame spread 0, fuel contributed 0, smoke developed 0, water based sealer.
   6. Flexible Duct Fan Connections: Fabricate in accordance with SMACNA Low Pressure Duct Construction Standards. UL 181 fire-resistant, neoprene coated, woven glass fiber fabric, minimum 30 oz. per square yard, crimped into metal edging strip. Suitable for 1-1/2 times duct pressure at connection. Outside flexible duct connectors shall be rated for outdoor use.
a. Uninsulated: Spiral-wound galvanized steel helix, mechanically locked to fiber glass cloth fabric.

b. Insulated: Inner core of one ply corrugated aluminum duct, 1-inch thick, ¾ pound insulation and aluminized vapor barrier.

8. Accessories:

a. Turning Vanes: Multi-blade device with blades aligned in short dimension; steel or aluminum construction; with individually adjustable blades and mounting straps.

b. Duct Access Doors:

1) Fabricate in accordance with SMACNA Low Pressure Duct Construction Standards and as indicated.

2) Fabricate rigid and close fitting doors of galvanized steel with sealing gaskets and quick fastening locking devices. For insulated ductwork, install minimum one inch thick insulation with sheet metal cover.

3) Access doors smaller than twelve inches square may be secured with sash locks.

4) Provide two hinges and two sash locks for sizes up to 18 inches square, three hinges and two compression latches with outside and inside handles for sizes up to 24 x 48 inches. Provide an additional hinge for larger sizes.

5) Access doors with sheet metal screw fasteners are not acceptable.

B. Dampers:

1. Backdraft Dampers: Parallel blades, gravity balanced backdraft dampers shall be made of 16 gauge galvanized steel. Provide center pivoted blades of maximum six inch width, with flexible vinyl sealed edges, linked together in a rattle-free manner with 90 degree stop, steel ball bearings, and plated steel pivot pin, and adjustment device to permit setting for varying differential static pressure.

2. Low Pressure Manual Dampers: Single or multi-blade type with position-indicating device and lock.

3. Fire Dampers: Fabricated in accordance with NFPA 90A and UL555. Fabricate curtain type dampers of galvanized steel with interlocking blades. Provide stainless steel closure springs and latches for horizontal installations. Configure with blades out of air stream except for low pressure ducts up to 12 inches in height. Fabricate multiple blade fire dampers with 16 gauge galvanized steel frame and blades, oil-impregnated bronze or stainless steel sleeve bearings and plated steel axles, 1/8 X 1/2 inch plated steel concealed linkage, stainless steel closure spring, blade stops and lock. Fusible links, UL 33, shall separate at 160 degrees F. Provide adjustable link straps for combination fire/balancing dampers.
4. Combination Fire Smoke Dampers: Fabricated in accordance with NFPA 90A, 92A, 92B, and UL Standards 555 and 555S. Dampers shall have a UL555 fire rating of 1 1/2 hours. Each damper shall be equipped with a heat responsive device which has been tested and approved for use with the damper assembly in accordance with UL555. The heat responsive device shall have a temperature rating of 165 F or 212 F. Dampers shall be UL labeled for use in dynamic systems. The damper shall have a dynamic closure airflow rating equal to or greater than the airflow at the damper's installed location and a dynamic closure pressure rating of 4 in wg.

Dampers shall have a UL555S Leakage rating of Class II and a Temperature rating of 350 F. Dampers shall have a UL555S operational airflow rating equal to or greater than the airflow at its installed location and an operational pressure rating of 4 in wg. Damper actuators shall be factory mounted and qualified for use with the damper in accordance with UL555S. Damper actuators shall be electric type for 120, 24 volt operation or pneumatic type for 20 PSI minimum operation.

The Damper Manufacturer's submittal data shall certify all air performance pressure drop data is licensed in accordance with the AMCA Certified Ratings Program for Test Figures 5.2, 5.3 and 5.5. Damper air performance data shall be developed in accordance with the latest edition of AMCA Standard 500-D.

Damper blades shall be 16 ga galvanized steel 3 Vee type with three longitudinal grooves for reinforcement. Blades shall be completely symmetrical relative to their axle pivot point, presenting identical resistance to airflow and operation in either direction through the damper (blades that are non-symmetrical relative to their axle pivot point or utilize blade stops larger than 0.5 in are unacceptable).

Damper frames shall be galvanized steel formed into a structural hat channel shape with reinforced corners. Bearings shall be sintered bronze sleeve type rotating in extruded holes in the damper frame. Jamb seals shall be stainless steel compression type.

5. Spare Parts:

a. Provide three extra fusible links for fire dampers.

C. Filters:

1. Disposable Pre-filters:

a. Media: 2 inch thick, fiber blanket, factory sprayed with flameproof, non-drip, non-volatile adhesive. 20 gauge galvanized steel holding frame. Nominal size 24 inches by 24 inches. Pre-filters shall have slide-in frames, which shall be sealed to prevent bypass.

b. Rating: 500 FPM face velocity, 0.15 inches w.g. initial resistance, 0.5 inches w.g. final resistance.

2. Extended Surface Retained Media Filters:

Effective media area of 50 square feet per 1000 CFM. Nominal size 24 inches by 24 inches by 12 inches deep.

b. Rating: ASHRAE 52; 60 percent dust spot efficiency, 96 percent average weight arrestance. 500 FPM face velocity, 0.5 inches w.g. initial resistance, 1.2 inches w.g. final resistance.

3. Extended Surface High Efficiency Media Filters:

a. Media: Pleated, water resistant glass fiber with aluminum or kraft separators. 16 gauge galvanized steel holding frame with corrosion resistant coating. Effective media area of 50 square feet per 1000 CFM. Nominal size 24 inches by 24 inches by 12 inches deep.

b. Rating: ASHRAE 52; 95 percent dust spot efficiency. 500 FPM face velocity, 0.65 inches w.g. initial resistance, 1.0 inches w.g. final resistance.

4. High Efficiency Particulate (HEPA) Filters:

a. Media: Pleated, water-resistant glass fiber with aluminum separators; ANSI/UL 586. 16 gauge galvanized steel holding frame with corrosion resistant coating. Nominal size 24 inches by 24 inches by 12 inches deep.

b. Rating: 0.3 micron DOP to 99.97 percent efficiency in accordance with MI-STD-282 thermal DOP penetration test method. 250 FPM face velocity, 1.0 inches w.g. initial resistance, 3.0 inches w.g. final resistance.

5. Activated Carbon Filters:

a. Assembly: Galvanized steel unit with extruded aluminum tracks to accommodate filter servicing trays in deep V arrangement for upstream/downstream side servicing with disposable panel pre-filter.

b. Media: Activated carbon density 34 lb./cu ft pelletized or granular to 6 by 10 Tyler mesh screen. Minimum carbon tetrachloride activity of 60 percent. Nominal size 24 inches by 24 inches by 1 inch thick. 9 pounds of carbon per 2000 CRM air flow.

c. Rating: 500 FPM face velocity, 0.45 inches w.g. initial resistance.

D. Air Terminals:

1. General: Air terminals shall not exceed sound ratings as scheduled in accordance with AMCA 301 and tested according to AMCA 300.

2. Single-Duct Variable Air Volume:

b. Insulation: Minimum 1-inch, 1.5 pound density fiberglass, neoprene or vinyl coated insulation complying with NFPA 90A and UL 181. Exposed edges of insulation coated with NFPA 90A approved sealant.

c. Air Valve/Damper: Extruded or cast aluminum, automatic pressure compensating. Air valve/damper to seal 100% shut off. Maximum leakage not to exceed 2% of rated airflow at 3 inches inlet static pressure. Valve/Damper to be (normally open)(normally closed). Capable of operating with pressure drop across the unit as low as 0.4 inch w.g.

d. Airflow Sensor: Multi-point, averaging type.

e. Heating Coil:

1) 1 row or 2 row as scheduled, copper tube mechanically bonded to aluminum fins. Leak tested underwater to 200 psig.

f. Controls: Devices compatible with temperature controls specified in Section 15950.

3. Dual-Duct Variable Air Volume Terminal:

a. Casing: Minimum 22 gauge galvanized steel with 2 volume dampers inside casing with mixing attenuator section. Access panel in bottom of unit for access to air valve/damper.

b. Insulation: Minimum 1-inch, 1.5 pound density fiberglass, neoprene or vinyl coated insulation complying with NFPA 90A and UL 181. Exposed edges of insulation coated with NFPA 90A approved sealant.

c. Air Valve/Damper: Extruded or cast aluminum, automatic pressure compensating flow devices. Air valve/dampers to seal 100% shut off. Maximum leakage not to exceed 2% of rated airflow at 3 inches inlet static pressure. Valve/Dampers to be (normally open)(normally closed). Capable of operating with pressure drop across the unit as low as 0.4 inch w.g. Separate cooling and heating air valve/damper assemblies. Factory calibrated, field adjustable set points to set maximum, minimum, and crossover CFM.

d. Airflow Sensor: Multi-point, averaging type.

e. Controls: Devices compatible with temperature controls specified in Section 15950.

E. Air Inlets and Outlets:

1. Louvers:

a. Test and rate performance in accordance with AMCA 500.

b. Stationary Steel Louver: 16 gauge galvanized steel louver with 4-inch storm proof and drainable blades on 4-inch centers at 45 degree angle and channel mounted in extruded aluminum rewireable frame. Frame construction with storm proof blades. Provide aluminum bird screen...
c. Stationary Aluminum Louver: Extruded aluminum, 0.081 inch thick louver with 4-inch storm type blades with 5-inch spacing at 45 degree angle with storm proof and drainable blades. Head, sills, and jambs to be one piece extruded structural members. Fastenings shall be either stainless steel or aluminum. Fixed blade accurately fitted and firmly secured to frames. Provide aluminum bird screen mounted in extruded aluminum rewireable frame.

F. Grilles, Registers, and Diffusers:

1. General:
   a. Test and rate performance in accordance with ARI 880 and ASHRAE 70.
   b. Coordinate borders and mounting frames with ceiling and wall finish.
   c. Provide airflow capacity and throw patterns as shown. Pressure drops of diffusers and supply registers shall not exceed 0.1 inch w.g. and pressure drops for return and exhaust grilles shall not exceed 0.05 inch w.g. unless otherwise shown.
   d. Dampers shall be opposed blade type; key or standard blade screwdriver operated from the face of the unit.
   e. Provide opposed blade damper keys.

2. Diffusers:
   a. Louvered Face: Square, louvered face steel diffuser with movable blades accessible from face for adjustable discharge and volume damper. Border style compatible with ceiling system. Finish shall be white. Face size shall equal ceiling module size when mounted in ceiling grid; i.e., a diffuser with 24-inch x 24-inch face would be provided for a 24 x 48 ceiling grid.
   b. Linear bar diffuser with deflection bars fixed and parallel to long dimension with opposed blade damper. Finish shall be white. Provide alignment strips to join sections together end-to-end for continuous appearance.
   c. Slot: Aluminum linear slot diffuser with direction and volume adjustable by 180 degree controller. Number of slots shall be as shown. Finish shall be white. Diffuser shall be capable of being joined end-to-end for continuous appearance. Provide steel blankoffs, alignment pins, end caps, and borders.
   d. Round: Round diffuser constructed of 18 gauge steel with four round cones and round inlet neck. Field adjustable airflow discharge pattern from horizontal to vertical. Finish shall be white. Provide with round steel damper and safety chain.

3. Registers:
   a. Supply Register: Double deflection, 3/4-inch blade spacing, 1-1/4-inch steel border with extruded aluminum airfoil blades and steel opposed
blade damper. Front blades parallel to long dimension. Blades individually adjustable and securely held in place. Provide gasket between the frame and surface. Register finish shall be white.

4. Grilles:
   a. Perforated steel ceiling grille with 3/16-inch diameter holes on 1/4-inch staggered centers. Finish shall be white.
   b. Wall Grilles: 45-degree deflection, 3/4-inch blade spacing, steel grille with front blades parallel to long dimension. Grille finish shall be white.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL:

A. Accessories

   1. Install access doors of sufficient size at all fire damper, filter, or coil location to provide for cleaning and inspection.

   2. Where fire dampers are installed, paint duct red at damper, provide tight fitting access doors sealed with gaskets for inspection and replacement of fusible links. Doors shall be installed, so access is unobstructed. Where these doors occur on concealed ducts, provide access doors in walls or ceiling properly aligned to permit the servicing of the fusible links. Mark ceiling or walls according to accepted identification.

B. Ductwork:

   1. Maximum flexible ductwork length shall be 6 feet. Secure flexible ductwork to collars with metal bands. Support at least every 3 feet.

   2. General: Assemble and install ductwork in accordance with recognized industry practices which will achieve air-tight and noiseless (no objectionable noise) systems, capable of performing each indicated service. Install each run with minimum number of joints. Align ductwork accurately at connections, within 1/8-inch misalignment tolerance and with internal surfaces smooth. Support ducts rigidly with suitable ties, braces, hangers and anchors of type that will hold ducts true to shape and to prevent buckling, popping or compressing. Support vertical ducts at every floor.

   3. Construct ductwork to schedule of operating pressures as shown on drawings.

   4. Inserts: Install concrete inserts for support of ductwork in coordination with form work, as required to avoid delays in work.

   5. Field Fabrication: Complete fabrication of work at project as necessary to match shop fabricated work and accommodate installation requirements.

   6. Routing: Locate ductwork runs, except as otherwise indicated, vertically and horizontally and avoid diagonal runs. Locate runs as indicated by diagrams, details and notations or, if not otherwise indicated, run ductwork in shortest
route that does not obstruct useable space or lock access for servicing building and its equipment. Hold ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of the building. Limit clearance to 1/2 inch where during is shown for enclosure or concealment of ducts, but allow for insulation thickness. Locate insulated ductwork for 1 inch clearance outside of insulation. In finished and occupied spaces, conceal ductwork from view, by locating in mechanical shafts, hollow wall construction or above suspended ceilings, Do not encase horizontal runs in solid partitions, except as specifically shown. Coordinate layout with suspended ceiling and lighting layouts and similar finished work.

7. Electrical Equipment Spaces: Do not route ductwork through transformer vaults and their electrical equipment spaces and enclosures.

8. Transitions: Diverging transitions shall not exceed 15 degrees per side. Converging transitions shall not exceed 30 degrees per side.

9. Elbows: Use radius elbows with throat radius equal to duct depth wherever possible.

10. Flexible Duct Fan Connections: Install flexible duct with at least one inch slack to insure that no vibration is transmitted from fan to ductwork.

11. Penetrations: Where ducts pass through interior partitions and exterior walls, and are exposed to view, conceal space between construction opening and duct or duct insulation with sheet metal flanges of same gage as the duct. Overlap opening on all four sides by at least 1-1/2 inch. Fasten to duct only.

12. Coordination: Coordinate duct installations with installation of accessories, dampers, coil frames, equipment controls and other associated work of ductwork system.

13. Temporary Closure: At ends of ducts which are not connected to equipment or air distribution devices at the time of the ductwork installation, provide temporary closure of polyethylene film or other covering which will prevent entrance of dust and debris until time connections are to be completed.

C. Sealing of Ducts:

1. General:
   a. All ducts, seams, and joints (lateral and horizontal) shall be sealed with sealant.
   b. Metal surfaces to be joined shall be clean, dry, and grease free.
   c. Apply a heavy brush coat of sealant to the interior metal surface of the duct slip joint, then interlock securely the duct sections and position into place.
   d. Apply a heavy brush coat finish of sealant to the exterior metal surface duct joint or seam covering heads of lock joint screws. Ensure that all voids are completely filled to provide a continuous air pressure seal.
   e. Where ducts are subject to excessive vibration or mechanical abuse, the exterior joint finish shall consist of a heavy coat of brush applied
2. Low pressure ducts:
   a. Seal in accordance with SMACNA standards for Class B seals.

3. Medium and high pressure ducts:
   a. Seal in accordance with SMACNA standards for Class A seals.

D. Fire and Smoke Dampers:
   1. Install dampers with code approved sleeves.
   2. Install in accordance with UL requirements. Provide access door in duct.

E. Grilles, Registers, and Diffuser Installation:
   1. In moist areas, install grilles, registers, and diffuser with stainless steel fasteners.
   2. When installing grilles, registers, and diffusers in existing drop ceilings provide additional T-sections as required for a finished opening for the grille, register, or diffuser.

F. Air Pressure Gauges:
   1. Provide magnehelic gauges at all air handling unit filter housings.
   2. Provide an engraved nameplate on each magnehelic gauge indicating the normal operating pressure.

G. Access Panels:
   1. Install access panels for inspection, maintenance, and cleaning of all automatic dampers, fire and smoke dampers, duct turning vanes, before and after all coils, and at other locations where equipment will require service.
   2. Access panels to fire dampers shall be labeled with letters not less than 1/2-inch in height reading "Fire Damper." For locations where access panels are insulated, provide identifying labels on the exterior of the insulation.

H. Filters:
   1. Install bag-in/bag-out filters at location shown on drawings. Housing shall be labeled "Danger, Hazardous Material." Install housing in accordance with manufacturer’s instructions and allow a minimum 36” clearance for access.

3.3 TESTING, CLEANING, AND CERTIFICATION

A. Air Cleaning Devices: Systems shall not be operated during construction.
B. Leakage Tests: Conduct duct leakage test in accordance with SMACNA HVAC Air Duct Leakage Test Manual. Repair leaks and repeat tests until total leakage is less than the maximum permissible leakage as specified below.

C. General:

1. Ductwork pressure tests shall be observed by Architect/Engineer prior to installation of insulation.

2. Ductwork systems in the three-inch W.G. pressure class and higher shall be tested in their entirety for leaks. Arbitrary sections of ductwork in the two inch W.G. and lower pressure class shall be tested as required by the Engineer.

3. Test Failures: Duct systems shall be repaired if test pressure and leakage requirements are not met or if air noise condition is encountered. Repairs and sealing shall be done with sheet metal, tape, sealant, or a combination thereof.

D. Fire and Smoke Damper:

1. Dampers shall be tested and accepted in accordance with NFPA prior to project closeout.

E. All tests shall be witnessed by the UC Denver’s representative and approved by Architect/Engineer and the UC Denver representative, coordinated through the Project Manager.

3.4 COMMISSIONING (DEMONSTRATION)

3.5 SCHEDULE

END OF SECTION
SECTION 15900
BUILDING AUTOMATION SYSTEM FIELD DEVICES

PART 1 -- GENERAL
1.1. SUMMARY

A. The devices listed in this section are control system field devices generally connected to the Building Automation System. These devices have been placed in a separate section for clarity. See Section 15950 for system standard and for items not clarified in this section.

B. Include all required factory and field calibration of each instrumentation device to accurately measure and control the desired variable.

C. Steam and chilled water connections and parameters from the Central Utilities Plant (CUP) to the individual buildings are further defined in Part 3 of the Manual of Guidelines and Standards for Design and Construction Projects and in the UC Denver Metering Standard.

D. All wiring requirements in this section shall be considered in addition to the requirements in Division 16 not in place of Division 16.

1.2. SUBMITTALS

A. See Section 15950

1.3. WARRANTY

A. See Section 15950

PART 2 -- PRODUCTS

2.1. GENERAL

A. All input and output devices will be of the type which are universally accepted in the industry, can easily be second sourced and are fully compatible with the BAS.

B. Required components:

1. All components shall be included to meet the intent of sections 15950 and 15970

2. Pilot positioners shall be included where necessary to assure smooth operation of all analog pneumatic outputs.

2.2. SYSTEM INPUTS OR MEASUREMENT DEVICES

A. General

1. All sensor and signal conditioning equipment will be of the type which are universally accepted in the industry, can easily be second sourced and are compatible with all of the manufacturer’s equipment.

2. See section 15970 for required points.
3. Provide components that are fully compatible with the Building Automation System (BAS). Include all required factory and field calibration of each instrumentation device to accurately measure the desired variable.

B. Temperature Transmitters:

1. General: Temperature sensor/transmitters shall have ranges appropriate for applications, input resolution of 0.2 Deg. F, accuracy of .4 degree F and stability of .3 degree F over the entire span. Pneumatic sensors are not allowed.

2. Space:
   a. Space (room) sensors in non-public areas (offices, etc.) shall be provided with a set-point adjustment and a portable service tool jack.
   b. Sensors shall be capable of providing temporary zone or building controls override.

3. Duct Averaging:
   a. Duct mounted averaging sensors shall utilize a sensing element incorporated in a copper capillary.
   b. If the cross section of the duct where the sensor is located is larger that 24 inches long by 24 inches wide, averaging sensors of adequate length shall be specified to assure accurate temperature. Provide averaging sensors in all mixed air applications.

4. Outside Air: Sunshields shall be provided for outside air sensors.

5. Liquids
   a. Temperature sensors for liquids and steam shall have wells of appropriate type for the application and separable from the sensing element. Strap on sensors will not be accepted.

C. Differential Pressure Transmitters – Air and Water:

1. General: The differential pressure transmitters shall be temperature compensated.

2. Performance:
   a. Sensing range shall be suitable for the application with accuracy of +/- 1% including hysteresis and non-linearity of range and repeatability of +/- 0.2% of range.
   b. The sensor element shall be capable of withstanding up to 800% of rated pressure without damage.
   c. The sensor range shall be selected such that the anticipated set-point is approximately mid-range. Range may be larger if necessary to keep all anticipated measurements within the range.

3. Air Application:
   a. The sensor element shall be capable of withstanding at least 5 psi differential pressure.
b. For applications referencing outdoor air, provide an outdoor static reference enclosure that eliminates wind effects.

c. Provide a metal pitot tube for all duct static measurements.

d. Provide a recessed housing with metal fittings designed for space static measurements.

4. Water Application: For all water measurements, provide an isolation valve manifold and a permanently installed local visual gauge. The sensor element shall be capable of withstanding a pressure of twice the full scale pressure.

D. Humidity Transmitters:

1. General:
   a. Humidity sensing elements shall be of the solid-state type.

2. Performance:
   a. The sensing element shall have a minimum range of 10% - 99%, with an accuracy of +/- 2% of range.
   b. Provide lockable metal guards for all sensors located in public areas.

E. Air Velocity Sensors For VAV Box Control:

1. General:
   a. The sensor shall sense a velocity range that is appropriate for each box.
   b. Repeatability including transmitter shall be +/- 5% of the CFM reading across the range of flow required by the application.
   c. The consultant shall determine if the airflow transmitter included in the controller will meet the above accuracy and specify an external transmitter where necessary.

2. Performance:
   a. Thermal anemometer sensors shall use constant temperature differential technology and operate from 30°F degree F to 120 F. degrees F
   b. Differential pressure sensors shall provide periodic auto-calibrate to insure accurate velocity pressure measurement at low flows.

F. Refrigerant Gas Monitoring:

1. General:
   a. Provide an alarm light, horn, local digital LED readout, and a 4-20mA analog output to the BAS.

2. Performance: Provide a halogen refrigerant gas monitoring system for the chiller room that shall specifically sense the type of refrigeration utilized in the chillers.
a. The sensing range shall be such that the alarm level is approximately mid range of the full sensing range, with accuracy of +/- 3% of full scale.

b. Sample each point a minimum of once every minute.

3. The alarm levels shall be as follows:
   a. 10ppm for HCFC-123.
   b. 100ppm for HFC-134A and R-22.

G. Flow Sensor – Air:
   1. General:
      a. The sensor shall utilize a multi-point airflow measuring array with a minimum of one sensing point for every two square feet of area (rounded down).

   2. The accuracy of the flow measurement shall be +/- 3% of full scale.

   3. Airflow measuring element accuracy shall be +/- 2% of the actual airflow span.

   4. Differential Pressure Sensor/Transducer Performance: Refer to Differential Pressure Transmitter specification above.

H. Flow Sensor – Steam Meter (see UC Denver Metering Standard for more information):
   1. Vortex Type: Piping location for meter must meet the manufacturer’s recommendation for minimum specified length of straight pipe. Meter sizing must consider maximum peak steam load and minimum steam flow during low load conditions (125 psi saturated steam). Dual station metering arrangement may be required to capture both peak flows and low-load off-season flow. Meter data communication must be coordinated with Building Automation System (BAS) interface requirements provided by Siemens.

      a. Temperature and pressure compensated vortex-shedding mass flow meter.
      b. Flanged, in-line body, flow element with electronic transmitter producing a linear flow signal.
      c. High precision (0.4% of full scale) pressure transducer.
      d. 20:1 turndown ratio or better, accuracy better than 1% of span.
      e. 4-20 mA output signal sent to the BAS panel for interpretation.
      f. Pulsed lb/hr totalizer output signal sent to the BAS panel for interpretation.
      g. NEMA 4X enclosure.
      h. Alphanumeric LCD display with user selectable display options.
      i. Totalizer with reset possible only with security code or non-resetable.
      j. High / low limit alarm relays.
k. Mounting hardware.

l. Calibration certification.

2. Acceptable Manufacturers: EMCO, Sierra Instruments

I. Flow Sensor – Chilled Water Meter (see UC Denver Metering Standard for more information):

1. Ultrasonic Type: Piping location for meter must meet the manufacturer’s recommendation for minimum specified length of straight pipe. The metering of the cooling energy (chilled water) is based on the total BTU (British Thermal Units) of cooling delivered to the building. Determination of BTUs of energy requires a minimum of two temperature sensors (one on the supply line, one on the return line) and a flow sensor/transmitter, preferably on the supply line (building chilled water design conditions are CHWS=41 degree F and CHWR=56 degree F). Meter data communication must be coordinated with Building Automation System (BAS) interface requirements provided by Siemens. The BAS will perform BTU calculations.

a. Transit time flow and energy meter.

b. High precision clamp-on flow transducers.

c. Insertion (wetted) type RTDs w/ 4 wire output (balanced) individually accurate to within 0.1 degree F and provided as a matched pair.

d. NEMA 4X enclosure.

e. Alphanumeric LCD display with user selectable display options.

f. Totalizer with reset possible only with security code or non-resetable.

g. Pulsed BTU totalizer output signal sent to the BAS panel for interpretation.

h. High / low limit alarm relays.

i. Mounting hardware.

j. RTD and flow transducer cables.

k. Calibration certification.

l. Acceptable Manufacturers: Panametrics, Controlotron, Sono-Trak, Polysonics

J. Carbon Dioxide Sensor:


2. Performance:

   a. The sensor shall have a range of 0-2000 ppm

   b. Accuracy +/- 50 ppm
c. Repeatability +/- 10 ppm.
d. Drift less than 20 ppm/yr

K. Current Transducer:

1. General:
   a. Rated for 120% of maximum amperage of monitored system with 4-20 mA output.
   b. Provide matched removable clamp-on type current transformer.

2. Performance:
   a. Accuracy: +/- 0.5% of full scale
   b. Repeatability/Linearity: +/- 0.1% of full scale.

L. Level Transmitter:

1. Capacitance Type: PTFE coated 316 SS probe with ¾ inch NPT or 150 LB connection, 4-20mA output.

2. Displacement Type: C-Iron or steel case with 316 SS displacer, specific gravity adjustment, 4-20mA output.

3. Ultrasonic Type:
   a. Two-inch NPT connection, CPVC material, auto temperature compensation, NEMA-4X housing, 120 VAC power mA isolated output.
   b. Provide two adjustable relay contacts which may be set to alarm at particular level values, an electronic transmitter corresponding to 0-100% of level span, self-testing and calibrating and adjustable noise/echo filters.

M. kWh Meter:

1. Metering of electrical power is done on the basis of total kW (kilowatt-hours) of consumption and peak demand kW (kilowatts). The campus distribution voltage is 13.2 kV and each building service has a supply transformer with a secondary voltage of 480 volts (208 V is some existing buildings). Primary side metering would be nice in that losses through the transformer would not be an issue, but service and cost considerations preclude this method. UC Denver will meter electrical power on the secondary side of the transformer for each building, with the meter located at the main distribution panel. Projects may have unique design considerations that will require discussions with Facilities Operations Department engineering staff. Meter data communication must be coordinated with Building Automation System (BAS) – interface requirements provided by Siemens.

   a. Electrical metering must include both total energy use and demand values.
   b. Composite accuracy of +/- 0.5% of energy consumed.
   c. CT’s and PT’s installed on services greater than 200 amps.
d. Socket metering is applicable for smaller, low amperage installations.
e. Panel / Substation metering is desired for larger, high amperage installations.
f. Pulsed output will be received at a local controller and sent to the BAS panel for interpretation.
g. Provide reset button on meter.
h. UL listed/CSA certified.
i. Maintain reading in the event of power failure.
j. LCD display.

2.3. SYSTEM OUTPUTS OR CONTROL DEVICES

A. Electro-Pneumatic Transducers (I/P):
   1. General: Shall accept industry standard electronic signals and provide standardized pneumatic outputs.
   2. Performance:
      a. The accuracy of conversion shall be 4% of full scale, linearity +/- 1% of full range at ambient temperatures of 40 to 120F.

B. Control Relays:
   1. Shall be UL listed plug-in type with dust cover and LED “energized” indicator or RIB with indicator.
   2. Contact rating, configuration and coil voltage shall be suitable for the application.

C. Manual Control Switches:
   1. Shall be UL listed for use in NEMA 1 enclosures with contact arrangement and rating suitable for the application.
   2. Bat handle or knob actuator with nameplate clearly identifying function of each switch position.

D. Low Temperature Protection Thermostats:
   1. General:
      a. Shall be the manual reset type.
      b. The element shall be properly supported to cover the entire downstream side of the heating coil with a minimum of three loops.
      c. Separate thermostats shall be provided for each 25 square feet of coil face area or fraction thereof.
   2. Performance:
      a. The set point shall be adjustable with a minimum range of 34 F to 50 F.
b. The thermostat shall operate in response to the coldest one foot length of the 20 sensing element regardless of the temperature at other parts of the element.

E. Differential Pressure Switches:

1. Pressure differential switches (air or water service) shall be UL listed, Snap-acting, pilot duty rated (125 VA minimum), NEMA enclosure appropriate for the application, with scale range such that an adjustable set point is approximately at the mid-point of the device span.

2. Provide metal pitot tubes for airside differential pressure switches measuring duct static.

F. High/Low Static Pressure Limit Switches:

1. Shall be UL listed line voltage snap-acting pilot duty rated (125 VA minimum), NEMA 1 enclosure.

2. Provide manual reset unless otherwise required by the application.

3. Provide metal pitot tubes for airside differential pressure switches measuring duct static.

G. Current Sensing Switches:

1. Shall be UL listed for line voltage with SPDT snap-acting, pilot duty rated (125 VA minimum) with range such that the set-point is at approximately the mid-point of span of the device.

2. Provide a maximum switching differential of 0.5 amps.

H. Valve or Damper Limit (End) Switches:

1. 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.

2. Provide end open and closed status switches as a minimum on all motorized valves utilized for equipment isolation. Provide end switches on all isolation dampers.

I. Positive Positioners:

1. General: Shall be high capacity force balance relay type with suitable mounting provisions and position feedback linkage tailored for particular actuator.

2. Performance:

   a. The positioner shall reposition the actuator on an input (pilot) signal change or 1/8 PSI or less.

   b. The repeatability shall be +/- 2%.

J. Electro-Pneumatic (EP) Solenoid Air Valves:

1. Shall be UL listed, snap-acting, 3 way air valve with 3-port (common, N.O, & N.C.).
2. Provide bronze or plastic body with stainless steel trim. Minimum safe pressure shall be 30 PSIG at 130 F ambient and/or control air temperature.

3. Provide coil voltages as required up to 460 VAC. Provide an open type for panel mounting or enclosed type with a NEMA 1 housing for remote installation.

K. Control Valves – Globe:

1. General: All control valves, unless otherwise required by application, shall meet the following:
   a. All modulating valve/actuator combinations for water application shall have linear flow or equal percentage characteristics in relationship to valve actuator input.
   b. The minimum close-off rating of any-two valve/actuator combination shall be 110% of the total system (pump) head for water application or 50 psid, whichever is greater.
   c. Valves shall have valve position indication on the valve.
   d. Water valves utilized in modulating applications shall be sized for a 4 to 6 psi drop with a maximum of 7 psi and a minimum of 3 psi. Application with flows less than 2 gpm may utilize pressure drops less than 3 psi.
   e. The valves shall be rated to 240 deg. F and 125 psig, two-way or three-way as required.

2. Valves ½” to 1”:
   a. The valve body shall be nickel plated brass or bronze and provided with sweat or screwed fittings as required.
   b. Provide a screwed type with NPT fittings. Provide valves with equal percentage or linear flow characteristics.

3. Valves 1” to 6”:
   a. The valve body shall be cast iron with a chrome nickel steel or stainless steel seat and inner valve material.
   b. Valves 1” to 2” shall be screwed type with NPT fittings.
   c. Valves 2-1/2” and larger shall be flanged.
   d. Provide linear flow characteristics.

4. Valves 6” and Greater: Provide one of the following types:
   a. Rotary globe valves equal to Masonelian Camflex II. Provide equal percentage or linear flow characteristics.
   b. Linear globe valves equal to Fisher. Provide equal percentage or linear flow characteristics.
c. High performance butterfly valves/actuator combination that shall provide equal percentage flow characteristics at low flow. Provide Keystone K-Loc or equal.

L. Control Valves – Butterfly:

1. General:
   a. Butterfly valves shall not be utilized for any modulating applications with valve sizes of six inches and under.
   b. Butterfly valves utilized for two-position control shall be line-sized.
   c. The minimum close-off rating for any two-way valve/actuator combination shall be 110% of the total system (pump) head for water application or 50 psid, whichever is greater.
   d. All valves shall have valve position indication on the valve.

2. Construction:
   a. Two-way and three-way butterfly valves shall have:
      1) a cast iron valve body
      2) aluminized bronze disc
      3) stainless steel stem
      4) disc seal suitable for bubble-tight shut off

M. Control Valves – Ball:

1. General:
   a. Ball valves shall not be utilized for modulating control unless approved by the engineer prior to bid. Exception: Only characterized ball valves providing equal percentage flow characteristics will be considered for modulating control applications.
   b. The minimum close-off rating for any two-way valves/actuator combination shall be 110% of the total system (pump) head for water applications or 50 psid, whichever is greater.
   c. All valves shall have position indication on the valve.
   d. The pressure drop calculations shall include the pressure drops of the fittings required to install a valves several sizes smaller than the pipe it is being installed in.

2. Ball Valves (2” or less):
   a. Valves shall utilize bronze bodies with female NPT threads. Valve bodies may also be stainless steel, titanium or nickel with operating pressure up to 2000 psi.
b. Provide a blowout proof stem design, glass-reinforced Teflon thrust seal washer and stuffing box ring with minimum 600 psi rating. Stem packing gland screw shall be adjustable for wear.

c. Standard chromium plated bronze ball or where specified, stainless steel ball and stem, shall be rated at a minimum of 600 psi water, cold, non-shock service, and 150 psi for saturated steam service. All valves shall be provided with reinforced Teflon seats.

3. Ball Valves (2-1/2” to 6”):

   a. Valves shall have flanged carbon steel or stainless steel bodies rated at 150 psi working pressure.

   b. Provide a blowout stem design and reinforced PTFE thrust seal washer.

   c. Provide a stainless steel ball and stem and reinforced PTFE seats, packing and o-ring.

N. Control Valves – Low Pressure Steam:

1. General:

   a. Low pressure steam valves shall be sized for a maximum 42% pressure drop of inlet pressure.

   b. The minimum close-off rating any two-way valve/actuator combination shall be inlet pressure for steam applications.

   c. All valves shall have valve position indication on the valve.

   d. All modulating valve/actuator combination for steam applications shall have equal percentage flow characteristic in relation to valve actuator signal input.

2. Construction:

   a. The valves shall be two-way with a rating to 360 deg. F up to 230 psig.

   b. The valve body shall be cast iron with a chrome nickel steel or stainless steel seat and inner valve material.

O. Control Dampers:

1. Motorized dampers, unless otherwise required by the application, shall meet the following:

   a. Damper frames shall use 12 or 13 gauge galvanized steel channel or 1/8” extruded aluminum with reinforced corner bracing.

   b. The damper blades shall not exceed eight (6) inches in width or 48” in length.

   c. Damper bearings shall be oil-impregnated sintered bronze or bearing grade nylon. Bushings that turn in the bearing are to be oil impregnated sintered metal.
d. All blade edges and top and bottom of the frame shall be provided with replaceable, butyl rubber or neoprene seals. Side seals shall be spring-loaded stainless steel, synthetic elastomer, or combinations of both. The seals shall provide a maximum leakage rate of \( \frac{1}{2}\% \) of maximum flow or 10 CFM/SF leakage at 4” W.C. close-off pressure.

e. The damper linkage shall be concealed and provide a linear flow or equal percentage characteristic as required.

f. Airfoil type dampers shall be used for any modulating air volume applications, pressure control applications, or air velocities greater than 1500 FPM.

g. Provide a minimum of one damper actuator per damper section.

2. Blade Arrangement:

a. Unless parallel blade dampers are necessary for mixing outdoor/return air streams, dampers other than fire dampers shall be opposed blade type.

P. Electronic Actuators:

1. Value Actuators for Primary HVAC Equipment:

a. Shall provide tight close-off at design system pressure and shall provide smooth modulation at design flow and pressure conditions.

b. The valve actuators shall be electrically actuated with proportional modulation and spring return.

c. Provide a hand wheel at the valve or manual position dial mounted in the BAS panel to allow manual positioning of valve.

2. Valve Actuators for Butterfly Valves:

a. Shall provide tight close-off at design system pressure and shall provide smooth modulation over the full range of expected flow and pressure conditions.

b. Provide actuators with internal heaters if installed outdoors.

c. Provide 2 sets of end switches, one set for limiting of the stroke, the other set for open/closed position indication feedback.

d. Provide a hand wheel at the valve or manual position dial mounted in the BAS panel to allow manual positioning of valve.

3. Valve Actuators for VAV Terminal Units:

a. The valve actuator shall be electrically actuated with proportional or 3 point floating modulation.

b. Thermally actuated valve actuators are not acceptable.

4. Damper Actuators for Primary Equipment:
a. Shall be selected per manufacturer’s recommendations to provide sufficient close-off force to effectively seal damper and to provide smooth modulating control over the full range of expected flow and pressure conditions.

b. Shall be proportional modulating or 2-position as required by the application and have a position indicator for external indication of damper position.

c. Provide modulating actuators with manual override release to manually position the actuator without disconnecting damper linkage.

d. Provide adjustable stops for both open and closed positions.

e. Provide spring return to the closed position on all dampers that open to the outdoors.

5. Damper Actuators for VAV Box Terminal Unit Control:

a. Provide a rotary type capable of permanent stall operation without damage.

b. Provide adjustable stop pins on the actuator for stroke limit.

c. The actuator shall fit directly over the damper shaft.

Q. Pneumatic Actuators:

1. General:

a. Pneumatic actuators shall be piston-rolling diaphragm type with easily replaceable beaded, molded neoprene diaphragm.

b. Actuator size and spring ranges selected shall be suitable for intended application.

c. Provide a manual position dial mounted in the BAS panel to allow manual positioning of each actuator or group of actuators utilized for a modulating control application.

d. All modulating valve applications shall be provided with spring return to the normal position.

e. All damper applications with outdoor air openings shall be provided with spring return to the closed position.

f. All actuator torque rating shall be 150% of the requirements of the application.

2. Damper Actuators:

a. Shall be selected per manufacturer’s recommendations to provide sufficient close-off force to effectively seal damper and to provide smooth modulating control under design flow and pressure conditions.

b. The actuator body shall be cast aluminum.

3. Valve Actuator:
a. Shall provide tight close-off at design system pressure and shall provide smooth modulation over the full range of expected flow and pressure conditions.

b. The actuator body shall be cast aluminum.

4. Positive Positioners: Shall be provided on actuators for inlet vane control, modulating dampers, and modulating valves to provide smooth modulation or proper sequencing.

2.4. AUXILIARY EQUIPMENT

A. Building Automation System (BAS) Controls Transformers:

1. Shall be UL listed Class 2 current limiting type, or shall be furnished with over-current protection in both primary and secondary circuits for Class 2 service.

B. Pneumatic Indicating Gauges and Test Ports:

1. Control signal indicating and test gauges shall be 1-1/2”, back-connected, 0 to 30 PSIG.

2. Test ports shall be quick-disconnect type using needle probe or threaded pin valve type.

3. Permanent indicating gauges shall be furnished for all pneumatic transducer and relay outputs used to position actuators or PE switches.

4. Gauges shall be in local control panels when applicable.

5. Test ports shall be provided for all EP, relay and signal conditioning inputs which do not directly signal actuators.

6. One main (supply) air pressure gage shall be installed in each local control panel.

C. Enclosures:

1. General:

   a. Mounting: All Controllers, Relays, Transducers, transmitters, relays, etc. shall be housed in a NEMA enclosure rated for the installed conditions.

   b. Panels shall be NEMA type suitable for applications as required with hinged door and key-lock latch.

2. Terminations and Connections:

   a. Interconnections between internal and face-mounted devices pre-piped and wired with color-coded tubing/conductors shall be neatly installed in plastic tray and/or tie-wrapped.

   b. All wiring within the panel shall be shall be run in wiring tray in accordance with NEMA and UL standards, and shall meet all local codes.

   c. Terminals for field connections shall be UL listed for 600V service, individually identified per control shop drawings, with adequate clearance for field wiring.

   d. Control air terminations for field connection shall be individually identified as per control shop drawings.
3. General Application Controller Panel Enclosures

a. Provide a 120 VAC receptacle in each panel, and a fused on/off power switch for the panel power supply. Where ganged together panels within 8 feet of each other may be served by the same convenience 120 VAC receptacles.

b. Provide a main air gauge for control power sources to each local panel containing pneumatic controls. Provide air gages for each pneumatic output. Indicator lights on BAS outputs similar to Siemens module PTM6.1 do not meet this standard.

c. Provide a final as-built control drawing of panel and related devices, reduced, laminated, and mounted inside of the panel door.

d. Use of existing control panels to house new controllers is discouraged. Use of existing control panels for junction panels is acceptable under the following conditions.

1) All excess devices, wiring and tubing shall be removed.

2) All remaining devices, wiring and tubing shall be tagged and neatly revised.

D. Wiring and Conduit:

1. All wire will be copper and meet the minimum wire size for the application.

2. Input wiring shall not be in the same conduit as power wiring. Communication wiring shall not be in the same conduit as power or output wiring.

3. Where different wiring classes terminate within the same enclosure, maintain clearances and install barriers per the National Electric Code.

4. Where wiring is required to be installed in conduit, EMT shall be used. Conduit shall be minimum ½ inch galvanized EMT. Compression fittings shall be used for interior locations and watertight compression fittings for exterior locations. Provide conduit seal off fitting where exterior conduits enter the building or between areas of high temperature/moisture differential.

5. Flexible metallic conduit (max. 3 feet) shall be used for connections to motors, actuator controllers, and sensors mounted on vibration producing equipment. Liquid-tight flexible conduit shall be use in exterior locations and interior locations subject to moisture.

6. Junction boxes shall be provided at all cable splices, equipment terminations, and transitions from EMT to flexible conduit. Interior dry location J-boxes shall be galvanized pressed steel, nominal four-inch square with cover. Exterior and damp location J-boxes shall be cast alloy FS boxes with threaded hubs and gasket sealed covers.

7. Wire inside walls should be in conduit, low voltage wire in ceilings should be ran in the information system cable tray and should enter room along with other low voltage wiring through a 2” conduit from the cable tray to a point of penetration in the adjacent room and run on J Hooks or bridle rings in the ceiling space of a room.
8. Low Voltage/Wire and Cable: All LV/W&C shall be run in conduit in floors and walls spaces. In hallways LV/W&C shall be run in the common telecom and other low voltage system cable tray. LV/W&C must be run in a conduit sleeve, minimum 2” dia. with plastic bushings, from the point it leaves the cable tray to the interior side of a room. Once the LV/W&C enters the room it can be supported from bridle rings or j-hooks. Wiring shall comply with Section 16720 and approved NEC.

9. Low Voltage/Wire and Cable and Hallway Devices: LV/W&C running from the cable tray to devices in the hallway shall be protected by plenum rated flexible sleeving or flexible metal conduit. LV/W&C in sleeving or flexible metal conduit shall be supported per NEC and installed with UL approved connectors and plastic bushings on both ends.

10. Low Voltage/Wire and Cable Insulation Sleeve Color: BAS conductor insulation colors allowed are:
   a. Points Blue Jacket
   b. BLN Orange Jacket
   c. FLN Orange with blue stripe jacket
   d. Power Dark blue or black jacket

11. Where the space above a suspended ceiling is a supply or return air plenum, any wiring not run in conduit shall be plenum rated. EXCEPTION: Any wire run in suspended ceiling that is used to control outside air dampers, provide smoke control functions or to connect the system to the fire management system shall be in conduit.

E. Pneumatic Tubing:

1. All pneumatic tubing will be FR rated polyethylene instrumentation tubing, type M, hard copper tubing, or soft copper tubing.

PART 3 -- EXECUTION

3.1. INSTALLATION, GENERAL

A. Remote control devices not in local panels shall be accessible for adjustment and service below 7’ above finished floor whenever possible.

B. All transducers, transmitters, relays, etc., shall be mounted in a panel with hinged doors in an orderly manner and shall be properly labeled with permanent labels to identify the parts of the system being served.

C. Component panels shall be mounted at eye level for accessibility and service, and located within 50 feet of the system served, unless otherwise shown on the plans.

3.2. SYSTEM INPUTS OR MEASUREMENT DEVICES

A. Temperature Sensors:

1. Space: Mount room temperature sensors 60 inches above finished floor.
2. Outside Air:
   a. The contractor is responsible for providing a sensor that accurately reflects outdoor air temperature throughout the year in any weather conditions.
   b. The outside air temperature sensor shall be located on a northern exposure away from any heat sinks or sources.
   c. Sunshields shall be provided such that the sensor is shaded for all possible solar angles.

3. Duct Averaging
   a. The sensor shall be installed according to manufacturer’s recommendation and looped and fastened at a minimum of every 36 inches. Firmly supported ½’ EMT is acceptable.
   b. The sensor shall be thermally isolated from the unit.

4. Water:
   a. Temperature sensors for liquids and steam shall be installed in wells of appropriate type for the application. Strap on sensors will not be accepted.
   b. Coordinate the locations of all thermo wells to provide for accurate and reliable temperature readings.
   c. Provide heat conductive compound between the well and sensor element.

B. Low Temperature Protection Thermostats:
   a. All low limit thermostats shall be firmly supported in the ductwork or air handling unit using ½” EMT or other auxiliary support.

C. Humidity Transmitters: Duct mounted sensors shall be mounted a minimum of 20 duct diameters downstream of any type of humidifiers or evaporative cooling equipment.

D. Differential Pressure Transmitters:
   1. Coordinate the locations of all water pressure differential transmitters such that the transmitter is located in the hydronically furthest lines. Confirm that there are no automatic modulating or two position valves between the transmitter taps and the pump.
   2. Locate the air pressure differential transmitter for VAV fan control approximately 2/3rd of the distance down the furthest duct. A location at or near the air handling system supply fan discharge is unacceptable.

E. Flow Meters
   1. All weld-o-lets for flow meters must be installed in a manner that no lip is in the pipe.

F. Airflow Stations
   1. The installation shall be a minimum of 10 duct diameters below and 5 duct diameters above any tees or elbows in the ductwork or in the inlet cone for each supply and return
fan. If the fans are double wheel double inlet (DWDI) fans, provide a flow sensor at each fan inlet.

G. Air Velocity Sensors for Terminal Box Control
1. The terminal box air flow measurement needs to be installed with the minimum duct diameters to assure accurate measurement of minimum ventilation air flow.

H. Differential pressure Switches
1. All differential pressure switches shall be calibrated to specifications provided by the mechanical engineer.

3.3. AUXILIARY EQUIPMENT

A. Wiring Installation Methods:
1. General:
   a. At a minimum, install systems and materials in accordance with manufacturer’s instructions, rough in drawings and equipment details.
   b. Install electrical components in compliance with requirements of applicable Sections of Division 16.
   c. Install all control wiring 50 volts and above in conduit.
2. Installation:
   a. All control wiring shall be installed in a neat and workmanlike manner parallel to building lines, with adequate support and shall be supported from or anchored to structural members.
   b. Conduit supported from or anchored to piping, duct supports, the ceiling suspension system, or other electrical conduits are not acceptable.
   c. Wiring buried in slab on grade concrete or explosion proof areas shall be in rigid metal conduit.
   d. Provide adequate strain relief for all field terminations.
   e. Varistors shall be installed on the control side of all output relays and on both sides of the transformers.
   f. All terminations shall be neat with no stray strands.
   g. An additional number of spare wires shall be included in each run as determined by UC Denver for future use.

B. Control Air Piping Installation Methods:
1. General:
   a. All control air piping shall be installed in a neat and workmanlike manner parallel to building lines with adequate support.
2. Installation:
   a. Piping above suspended ceilings shall be supported from or anchored to structural members.
   b. Tubing shall not be supported by or anchored to electrical conduits or the ceiling suspension system.
   c. Sleeve through concrete surfaces in minimum one inch (25 mm) sleeves, extended 6 inches (150 mm) above floors and one inch (25 mm) below bottom surface of slabs.
   d. Isolate air supply with wire-braid reinforced rubber hose or polyethylene tubing.
   e. Purge tubing with dry, oil-free compressed air before connecting control instruments.
   f. Lines buried in slab on grade concrete shall be in rigid metal conduit. Lines in concrete or masonry walls shall be in EMT.
   g. All pneumatic piping that penetrates metal shall be protected with grommets from wear from the metal.

C. Identification:
   1. General
      a. Verify label nomenclature with UC Denver before engraving or printing.
      b. All control equipment shall be individually and clearly identified by control shop drawing designation:
      c. Paper labels are not acceptable.
   2. Control Panels
      a. Provide engraved Bakelite or lithographed metal nameplates with panel number and system served
      b. Utilize white ½ inch high letters on a black background.
      c. Embossed labels are not acceptable
   3. Component sub-panels – metal tags or laser printed, adhesive backed, metallized polyester film labels.
   4. Control valves and damper actuators – brass tags or engraved Bakelite tags.
   5. Other remote control devices – metal tags or laser printed, adhesive backed, metallized polyester film labels.
   7. Label room temperature sensors with point name and address of the terminal controller served by the sensor.
8. For all control devices located above the ceiling attach an additional label to the ceiling “T” frame with pop rivets. Use engraved nameplates, 3”x1”, black lettering on white background.

9. Number-code conductors and pneumatic tubing appropriately for future identification and servicing of control system. Reflect this tagging or color coding system on the Project Record Documents

D. VFD interface wiring.

1. All safety circuit and BAS control wiring to VFDs shall be connected to a terminal strip in a NEMA enclosure external to the drive before entering the drive. This is to allow servicing these circuits without opening the drive.

END OF SECTION
SECTION 15950
BUILDING AUTOMATION SYSTEM

PART 1 -- GENERAL

1.1. SUMMARY

A. These standards are minimum UC Denver requirements only. They are designed to clarify UC Denver needs. They are not intended as a substitute for design services. Consultant shall provide a complete design and specification for the Building Automation Systems (BAS). This section may be referenced or portions copied and inserted into the specifications to clarify owner requirements. However, the design and specifications are the responsibility of the consultant not UC Denver.

B. The Building Automation System (BAS) shall be a complete and fully integrated, microprocessor based BAS for control of HVAC and Building Environmental Processes.

C. The BAS shall have full control of the lighting control system.

1.2. RELATED WORK SPECIFIED ELSEWHERE:

A. The engineer shall clearly specify responsibilities between the BAS contractor, the TAB contractor the terminal box manufacturer and all other sections to provide a complete system that is installed without overlap.

1.3. SUBMITTALS

A. General:

1. All submittal items in this section are in addition to Section 15000.

2. Submittals shall be complete, with detailed information on all items provided.

3. All submittal requirements specified shall be provide as a single bound package. Provide six (6) submittal copies or the amount specified in Division 1, whichever is greater.

B. Submit AutoCAD (or AutoCAD compatible through DXF conversion) generated schematic in hardcopy and electronic media for the entire control system, for review and approval before work shall begin. The hardcopy drawings shall be submitted on 8-1/2” x 11” or 11” x 17” sheet with drawings information sized such that all drawing information is legible. The submittal drawings shall include the following:

1. Communications:

a. Provide a one-line diagram depicting the system architecture complete with a communication riser and peripheral devices.

b. Provide a tabular listing of locations of controlled equipment, communications and network wiring layout, and panel locations with unit communication address identifiers.

2. Point-to-point wiring diagrams for each HVAC system accurately depicting:
a. complete termination and configuration of all wiring and pneumatics. (This includes termination points for wires that are terminated on equipment supplied by others.)

b. all temperature controls located on a schematic diagram of the controlled HVAC system

c. start-stop wiring for each piece of equipment
d. equipment interlocks
e. wiring terminal numbers
f. any special connection information required for properly controlling the mechanical equipment.

3. Panel interior and panel face layouts.

C. A bill of material reference list with drawing tag identifiers, application description, manufacturer, complete model number, and quantity.

D. Identify all deviations from this standard and project documents.

E. Provide written sequences of operation which shall define all modes control strategies.

F. The submittals shall include manufacturers catalog data describing each item of control equipment or component provided and installed for the project.

1.4. WARRANTY

A. The BAS shall be warranted to be free from defects in both material and workmanship for a period of one (1) year of normal use and service. This warranty shall become effective the date the owner accepts the system. The warranty shall include 24 hour per day, 7 day per week emergency problem response and all standard service contract preventative maintenance items (i.e. sensor calibration, linkage adjustment, etc.). An emergency service number shall be provided to the owner. Response shall be within four (4) hours to the phone call.

B. Provide factory trained technicians familiar with the installation for emergency warranty service.

C. Upgrades: Include all controller firmware and software updates for the installed system version at no additional cost to the system owner during the warranty period.

D. Tuning: Include seasonal fine-tuning of PID loop parameters and other control parameters to provide an optimized control system to the owner.

1.5. QUALITY ASSURANCE

A. Installation:

1. The control system shall be furnished, engineered, and installed by the BAS manufacturer’s local office.
2. Certain wiring and pneumatic installation may be performed by the BAS installer/manufacturer’s approved subcontractor under the direct supervision of the BAS installer/manufacturer’s field management.

B. Control system components shall be new and in conformance with the following applicable standards for products specified.

1. American Society for testing and materials, ASTM
2. Institute of Electrical and Electronic Engineers, IEEE
3. National Electrical Manufacturers Association, NEMA
4. Underwriters Laboratory, UL 916
5. Underwriters Laboratory, UL 855 (Smoke Control Only)
6. FCC Regulation, Part 15, Section 156
7. National Fire Protection Association, NFPA
8. Applicable Building Codes

1.6. SYSTEM PERFORMANCE REQUIREMENTS

A. Campus Building Automation System Design Intent.

1. Provide a single vendor, stand-alone Building Automation System (BAS) within each new or retrofitted building. Integrate the stand alone systems via the campus BAS data network.

2. Systems shall be designed to be BACnet compatible.

3. System shall be designed as an effective easy to use tool to operate, control, monitor and alarm mechanical equipment.

4. The system shall include all DDC controllers, sensors, valves, actuators, dampers, transmission equipment, software, local workstations, local panels, installation, setup, engineering, supervision, acceptance testing, training, and warranty necessary for a complete operable system.

5. The BAS shall be a full control system designed to control terminal equipment as well as main systems.

6. Each building and or renovation project shall provide adequate devices for monitoring and operating the BAS.

7. Each building shall include one or more BAS workstations to, based on password, allow full access to system configuration and monitoring.

B. System Architecture:

1. The BAS control system architecture shall be comprised of four levels of DDC controls devices.
a. Level 1: The first level is the system instrumentation component devices that includes but is not limited to sensors, valves, actuators, switches, relays, and transducers.

b. Level 2: The second level includes the terminal equipment DDC controllers with specific applications for control of terminal units such as VAV boxes, fan coils and unit heaters.

c. Level 3: The third level is comprised of general application DDC controllers for control of large primary mechanical systems such as air handling systems, heating hot water systems and chilled water systems. This level also performs system networking functions.

d. Level 4: The fourth level consists of a file server, workstations and other devices that provide access, programming and setup tools, database management and other functions.

e. Provisions for expansion of all levels of the DDC system shall be provided with each project such that a need for future “gateway” or “repeater” expansion hardware and software is not required.

2. Alternates:

a. Variations from this general outline should meet the following functionality and be approved by UC Denver

b. Non-intelligent slave panels may be utilized only to expand the controller point capacity for control of a single HVAC system, or specified monitoring not requiring control logic.

PART 2 -- PRODUCTS

2.1. MANUFACTURERS

A. Approved BAS Installers/Manufacturers:

1. Siemens Building Technologies

2. Alternative manufacturers must be approved by Owner.

2.2. SYSTEM AND CONTROLLERS

A. All systems shall be configured and designed to be stand-alone.

B. All outputs including all outputs attached to terminal equipment controllers and special applications shall be directly commandable by the system operator. Any application that has outputs that can not be commanded by the operator shall not be accepted.

2.3. Terminal Equipment Controllers

A. Terminal Equipment Controller Hardware

1. General:
a. Each terminal equipment controller shall be a stand-alone DDC controller designed specifically for terminal unit control such as VAV boxes, fan coil units, heat pump units or similar application.

b. The controller shall execute local control sequences, independent of a network controller or workstation.

c. All controllers shall preserve setup and programming from a loss of power for a minimum of 7 days.

2. Programs:

   a. The control program shall reside in the terminal equipment controller.

   b. The default data base, i.e. setpoints and configuration information, shall be stored in EEPROM or other non-volatile memory.

3. Stand-Alone:

   a. Controllers that share processing with a “master controller” shall not be acceptable.

   b. After a power failure the terminal equipment controller must run the control application without having to contact another controller.

4. Communications:

   a. Communications to the general application controller shall maintain the specified network throughput speed specified in the network controller hardware section.

5. Isolation:

   a. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 watts at 3 feet.

6. Connections:

   a. All electrical connections shall be made to a combination terminal strip and base assembly.

   b. To insure long term reliability, all electrical terminations shall be screw type.

B. Terminal Equipment Controller Software:

1. Controllers shall be provided with the capabilities required by the application.

2. Each input, output or calculation result shall accessible from the terminal equipment controller communication port, application controllers and workstations.

3. Controllers that require an EPROM burn to make permanent changes to the software configuration shall not be acceptable.

4. All outputs for all controlled devices shall be directly commandable from the general application or network controller and from any workstation.
5. Global commanding of outputs and setpoints shall be available to command any number of similar terminal equipment controller outputs to the same position with a single command.

6. Terminal device controllers that do not allow separate space heating and space cooling setpoints to be configured shall not be accepted. This includes setpoint dial applications.

2.4. General Application Controllers

A. Hardware

1. General

a. The controller shall support all of the standards for the front-end software such as trending, alarming, etc.

b. The general application controllers shall be a local control loop microprocessor-based controllers installed at each mechanical system; (i.e., air handling units, heating plants, chiller plants, etc.).

c. The controller provides uplink and downlink communications, polling and other supervisory functions for terminal equipment controllers.

d. Mechanical systems in close proximity with a small number of physical inputs and outputs may be combined in controllers with modular input output layouts.

e. The controller shall be a true no-host system that does not require a PC or “Host” computer to perform any control functions or communication.

f. Each controller shall be addressable by a workstation or a portable service tool.

g. Non-intelligent slave panels may be utilize only to expand the controller point capacity for control of a single HVAC system, or monitoring without control logic.

h. Self Diagnostics: The controller shall contain in its program, a self-test procedure for checking communications and, verify the functionality of the CPU memory.

2. Each controller shall be provided with the memory capacity to store 1000 data samples for each physical analog point and 100 data samples for each physical digital point, attached to it (including all expansion boards) and 400 data samples for each terminal equipment controller attached. This shall be in addition to the memory needed for all other functions of the panel.

3. Power Loss/Restart: The controller shall be tolerant of power failures. The memory shall be nonvolatile or unit shall hold memory for a minimum of four hours.

a. Automatically and without operator intervention, the controller shall execute these restart procedures:

1) Come on line

2) Update all monitored functions
3) Implement special building start-ups strategies as required
4) Resume operation based on current time and status

b. Controllers with batteries shall provide an alarmable point to the front end workstations when the batteries need to be replaced.

4. Network:
   a. Each general application controller shall connect to the campus Ethernet system.
   b. Multiple system workstation operators shall be able to access the controller simultaneously. Systems which do not provide multi-tasking, multi-user operating systems shall not be acceptable.
   c. Communication speed of each network shall have a maximum 10 second end-to-end throughput from a Level 1 device input to a Level 1 device output, anywhere in the system. Provide a system configuration that will maintain this minimum throughput speed during trend collection, recovery from power outages, and monitoring of multiple mechanical systems. Strategies to limit traffic shall not interfere with control or system monitoring.
   d. Uploading trends shall not interfere with control or monitoring operations

5. Isolation
   a. Control, communication and power circuits for each controller shall be individually electrically isolated to protect against transients, spikes, and power surges.
   b. The ports shall be optically and/or electrically isolated from each other, the controller circuit board and from power wiring.
   c. The controller shall be able to operate at 90% to 110% of nominal voltage rating.
   d. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 watts at 3 feet.

6. Servicing:
   a. For ease of servicing, each controller shall consist of a removable plug-in circuit board.
   b. Products which require disconnection of wiring from the general application controller logic card before removal shall supply and install a quick disconnect type interconnection.

7. Input/Output Modules:
   a. Analog inputs shall accept industry standard analog signals such as 4-20 mA, 0-5 VDC, and 0-10 VDC.
   b. Digital inputs shall accept binary contact closures.
c. Digital outputs may be form C, latched or momentary contact type as required by the application.

1) Digital output pairs controlling a tri-state motor/transducer or pulse width modulation shall not be utilized by general application controllers.

2) Provide all digital outputs with hand/off/auto switches and LED status indication.

d. Analog outputs shall have a 1% resolution over total output span of 0 to 100%.

1) Provide all analog outputs with manual override switches and pot adjustments.

e. Provide each control panel with a minimum 10% spare of each input and output type.

B. General Application Controller Software:

1. Provide complete controller software to execute all mechanical system local loop controls functions.

2. Controllers that require an EPROM burn to make permanent changes to the software configuration shall not be acceptable.

3. Each input, output, or calculation result shall be capable of being assigned to the network controller for system networking.

4. Each controller shall be fully programmable both from a portable service tool at the controller and through the network communication system from the front-end workstation. Programs shall be able to be changed online without effecting other programs or point monitoring.

2.5. Front-end Software

A. BAS Seat License

1. Licenses shall be by concurrent user. Software shall be able to be installed on as many computers as necessary without additional licenses.

2. Each building shall provide a minimum of one seat license.

3. Additional licenses required are one seat license per 200,000 sq. ft. of lab or animal space and one seat license for every 400,000 sq. ft. of office and education space. No individual building shall be required to provide more than two seat licenses.

B. Software shall be a complete package including report management, alarm management, sequence programming language, live and historical data plotting capability, complete graphics with a library of HVAC symbols and animation capabilities.

C. Software shall allow operator configurable reports that list in columns points chosen by the operator and attributes chosen by the operator.

D. Amount of trend data stored on the file server shall be limited only by the file server disk size and the discretion of the system administrator. Uploading data shall not effect the operation of the system.
E. Trend data shall be stored in an ASCI file for retrieval by standard “off-the-shelf” software programs.

2.6. Workstation

A. Provide a minimum of one desktop workstation per building.

1. Newest version of Windows approved by UC Denver ITS department
2. Processor speed, memory, should meet specifications necessary to run front-end BAS software without delays
3. Minimum RAM: one Gigabyte
4. CD reader/writer: DVD ROM/CD-RW
5. Ports: USB
6. Monitor: Minimum 17” flat panel LCD
7. Network: Provide an ethernet PC Card compatible with the campus BAS network.
8. Printer: Color Inkjet

B. The server-client workstations shall communicate via a campus-wide ethernet.

C. Perform all administrative tasks including but not limited to control program editing, graphics setup, alarm management, trend management, point setup, point commanding, report management and system setup.

2.7. Portable Service Tool:

A. General:

1. The portable service tool shall be a PDA device that can communicate with terminal equipment controllers and general application controllers.
2. Each building, or BAS controls replacement as part of renovation, shall provide a minimum of one (1) palmtop sized portable service tool(s) per 200,000 sq. ft. of lab or animal space and one service tool for every 400,000 sq. ft. of office and education space. No individual building shall be required to provide more than three service tools with the system

B. The portable service tool shall have the following capabilities:

1. Readout of each input, output and virtual value.
2. Manual override of all digital outputs, analog outputs, and application modes (occupied / unoccupied / standby) and control modes (heating / cooling / deadband).

2.8. Portable Operation Workstation Hardware:

A. Provide one (1) portable operator workstation (this is in addition to the “Portable Service Tool” specification requirements) which shall run the workstation software and includes the following minimum hardware configuration:
1. Newest version of windows approved by UC Denver ITS department
2. Processor speed, memory, should meet specifications necessary to run front-end BAS software without delays
3. CD reader/writer
4. Ports: Serial and USB
5. Monitor: Minimum 13” active matrix color LCD, Resolution sufficient to run BAS graphics without scrolling.
6. Power: Battery Life – 3 hours minimum. Provide Lithium-Ion type. Include (2) AC adaptors and (2) batteries.
7. Network: Provide an ethernet PC Card compatible with the campus BAS network.
8. Weight: 7.0 lbs. Maximum

PART 3 -- EXECUTION

3.1. INSTALLATION, GENERAL

A. Provide a project manager who shall, as part of his duties, be responsible for the following
   1. Coordination between the Contractor and all other trades, UC Denver, local authorities, and the design team.
   2. Scheduling of manpower, material delivery, equipment installation and checkout.
   3. Maintenance of construction records such as project scheduling and manpower planning and AutoCAD for project co-ordination and project record drawings.

B. Mount all panels at eye level in a workmanlike manor.

3.2. SYSTEM SETUP

A. Nomenclature: All point names shall comply with the existing point naming conventions. See Section 15190 and the standard points list.

B. Point Setup
   1. See section 15970 for a list of required points.
   2. All physical analog outputs shall be setup to be commandable from the graphics with units of percent open to the energy source. This means mixed air dampers will be in percent open to outside air. The value of the physical units of the output shall also be available as live data.
   3. Points shall be setup so they read on reports and graphics with standard engineering units and without decimal places that exceed point updating or sensor accuracy.
   4. A graphic link will be installed for all points that are alarmed to allow drag and drop of alarms from the alarm status application to the appropriate graphic panel.

C. Trends
1. All general application controller physical points, setpoints, and points on graphics shall be trended.

2. All trends shall be scheduled for data transfer from the field panels to the database without data loss and without interfering with system operation.

3. For archiving purposes, trends shall be setup to automatically transfer from the system database to files that can be easily used by standard spreadsheets.

4. Analog points should have an interval trend of 15 minutes, 200 samples at the panel, and 45 days in the database.
   a. A change of value style of trend will be setup to record significant changes between the fifteen minute intervals.

5. Digital inputs shall have change of value trends with a minimum of 25 changes from on to off or off to on stored in the panel, and 100 at the database or as needed for 45 days of data.

6. For archiving purposes, fifteen minute interval reports should be setup for each mechanical system. Once a month they should automatically export last months data to a csv file on the file server. File names will be organized logically and include the date and system.

D. Locations

1. The room number for the mechanical system needs to be on the graphic. Where points on the graphic are not in the same room as the system, the location shall be in the point setup that can not be accidentally deleted during manual manipulation of the point or on the graphic.

E. Graphics

1. The graphics should include all devices used by the control system and all controlled equipment.

2. UC Denver must approve all graphic panels before they are copied.

3. All physical IO shall be on a graphic that enlightens the user to its function. All systems shall have graphics that convey accurate and complete schematic information about the equipment.

4. Graphics shall be clear and readable. Misleading details like construction room numbers and fonts that are too small to read shall not be used.

5. Use typical graphic developed by UC Denver when available otherwise match existing style.

6. Each building will have a Building Chart that lists major AHU and building system parameters. It should be linked to each system graphic and the main graphic.

7. AHU graphics must contain utility and general information on the graphic. An air handler graphic shall have outside air and the properties of any chilled water, heating water, or steam supplied to the air handler.
8. The graphics shall either have links to all relevant graphics or be setup such that the operator will be able to navigate from the terminal box graphic to the relevant air handler graphic and back in less than three double clicks. The same shall be true between the terminal graphic and the related floor plan.

9. Each system graphic shall have a link to the sequence and a link to a maintenance log file.

10. Equipment references on the graphics will be compatible with the campus database naming conventions.

11. Controllers and miscellaneous alarm points will be located on the floor plan graphic.

12. Terminal equipment controller graphics shall be schematically correct, clear to read and have points arranged in a logical pattern to help viewer find information.
   a. All terminal box controllers, fan coils, unit heaters, exhaust boxes, etc. shall be located on a floor plan with a link to the relevant graphic.
   b. Terminal device graphics must contain utility and general information on the graphic. This would include supply air temperature, heating water supply temperature or chilled water supply temperature as applicable.
   c. Terminal device graphics shall distinguish graphically between the type of equipment controlled such as VAV boxes, fan coils, hoods, general exhaust boxes etc.
   d. Points on the graphics that indicate position of terminal equipment controller outputs will read in percent open to energy source. All points necessary to command the outputs will be included on the graphics.

13. Room numbers shall be included on the floor plans and shall be the UC Denver room numbers not the construction room numbers.

14. The operator shall be able to print any graphic including the live data.

F. Alarms

1. Point alarms should follow the Standard Points List.

2. All general application controller and network controller communication failures shall be annunciated at the applicable system workstations as an alarm.

3. Priority 3 alarms shall be setup for failed batteries at the field panels.

4. All specified I/O device alarms shall be annunciated at the system workstation with alarm messages that clearly identify the type of alarm, the point in alarm and the value of the point in alarm.

5. All alarms shall be assigned priority levels with different notification strategies attached to each level. These alarm levels shall conform to the standards points list (see Section 15970). The system administrator shall have complete control over notification strategies and alarm levels.

6. All alarms with high priority shall be annunciated on alphanumeric pagers.
a. Pager messages shall be fully changeable by the system administrator. They shall clearly identify the type of alarm, the building, the point in alarm and the value of the point in alarm.

b. Critical alarms shall be sent to the paging system within 10 seconds.

7. The alarm logic shall include adjustable high and low alarm limits, mixed mode expressions, and equipment interlocks.

8. Unique high and low limits shall be supplied for each analog alarm point in the system.

9. The system shall be programmed to suppress alarm reporting on primary equipment that is in the inactive state.

10. All alarmed points where the location is not obvious must have the location of the point in the point informational text or graphics.

11. Nuisance alarm suppression
   a. Alarms shall have an adjustment delay for the alarm condition to clear before the alarm is sent to workstations or pagers. If the condition clears before the delay is over the alarm shall not be sent.
   b. When the alarm conditions clears there shall be an adjustable time delay before an alarm clear is sent. If the alarm condition clears before the delay is over then no alarm clear shall be sent and the point shall remain in alarm.

12. All alarmed points where the location is not obvious must have the location of the point in the point informational text or graphics.

3.3. COMMISSIONING

A. Engineer shall include a complete specification for testing all BAS components as part of division 15995. Final testing shall not begin until after system is connected to the campus system and accessible from existing workstations.

B. Project Record Documentation:

1. At least 3 working days before final acceptance demonstration, the contractor shall submit project record drawings of the BAS for approval by UC Denver. If more than three errors or omissions are found during UC Denver review or during the acceptance procedure the acceptance procedure will be cancelled and rescheduled when accurate and complete drawings are received.

2. Project Record Documents shall include all the information in the submittal drawings plus:
   a. All communication wiring shall have the exact route shown on a floor plan.
   b. Exact locations of all devices including panels, communication devices, IO devices, etc. shall be shown. Construction room numbers if different from UC Denver room numbers do not meet this requirement.
   c. All changes made during installation shall be shown.
d. The electrical circuits used by the BAS should be clearly indicated as panel and circuit number.

e. Unit communication address identifiers shall be shown.

f. Conductor and pneumatic tubing identifier numbers.

3. After receiving final approval, supply six (or as specified on Division 1) complete project record drawing sets (maximum ANSI “D” size), together with an electronic copy to the owner. The project is not considered complete until record documents have been received and certified complete and accurate by UC Denver.

4. O&M manuals shall be provided that detail any maintenance required for any device in the system.

3.4. TRAINING

A. Contractor shall provide to the engineer and UC Denver a training class outline prior to any schedule training.

B. The control contractor shall conduct on-site training courses for designated UC Denver personnel in the maintenance and operation of the control system.

1. A minimum of one class shall be given upon system acceptance. Classes shall be no longer than four hours in duration and budgeted at 1 hour of training time per 4000 sq. ft. of controlled area in labs and 1 hour per 7500 sq. ft. in office space. A minimum of one four hour class shall be provided.

2. Before training begins the O&Ms shall be complete the project BAS shall be communicating to the campus BAS.

3. Training sessions shall be provided for the UC Denver’s personnel by factory trained personnel knowledgeable about all aspects of the installation.

4. Training outline shall be coordinated with UC Denver Engineering and shall include as a minimum.

a. Instruction on specific systems and instructions for operating the installed system

b. A tour of the installation to show the location of all system components

c. A review of the project documentation.

d. A review of the sequences of operation.

e. A review of graphical commanding and alarming.

C. The BAS contractor will provide, at no cost to the owner, standard training for the operations staff. Such training shall be adequate to fully enable the student to perform any required operating procedures in the BAS.

D. Forty hours of factory training shall be provided for any Lab building over 80,000 sq. ft. Eighty hours of factory training shall be provided for any lab building over 300,000 sq. ft.

3.5. DEMOLITION:
A. Demolition of an existing control system will include removal of controls which do not remain as part of the BAS, all associated abandoned wiring and conduit, and all associated pneumatic tubing.

B. The UC Denver Project Manager will inform the BAS Contractor of any equipment which is to be moved that will remain the property of UC Denver. All other equipment which is removed will be disposed of by the BAS Contractor.

C. Existing controls which are to be reused must each be tested and calibrated for proper operation.

D. Existing controls which are specified to be reused and are found to be defective requiring replacement will be noted to the UC Denver Project Manager. If necessary a change order will be issued to the contractor for repair or replacement of the defective device.

END OF SECTION
SECTION 15970
BUILDING AUTOMATION SYSTEM
SEQUENCES OF OPERATION & POINTS LIST

PART 1 -- GENERAL

1.1. SUMMARY

A. The Engineer shall submit to UC Denver for review and comment a complete sequence of operations two weeks before final documents are sent out to bid.

1.2. SYSTEM PERFORMANCE REQUIREMENTS

A. All sequences shall be written to maximize energy conservation

B. All units that can be placed on a schedule shall have complete schedule control including optimum start and an optimized unoccupied turn on for unoccupied space heating and cooling.

C. Separate supply air temperature setpoints for heating components and cooling components in air handling unit shall be specified unless application makes impractical

D. Complete schedule control shall be included for terminal devices such as baseboard heating, VAV boxes that auditoriums, classrooms, conference rooms and other scheduled areas irregardless of whether they are served by a dedicated air handler.

E. Separate room heating and room cooling setpoints shall be included for space comfort except where prohibited by space design parameters.

F. All conference rooms, class rooms, and other rooms of over 50 person occupancy shall have demand controlled ventilation designed by the engineer using carbon dioxide sensing in the space. Areas served by economizer systems that are not practical for complete coverage with space CO2 sensors shall have CO2 sensors in the return duct.

G. Sequences for the chilled water system shall conform to the UC Denver Metering Standard.

H. Normal (Power Fail) positions for dampers and valves are as follows:

1. Outside air damper: Closed (NC)
2. Exhaust air damper: Closed (NC)
3. Return air damper: Open (NO)
4. Primary AHU HW Valves: Open (NO)
5. Primary AHU CHW Valves: Closed (NC)
6. Terminal Unit Reheat Valves: Closed (NC) or Fail to Last Position (FLP)
7. Chiller – Chilled Water Isolation Valves: Fail to Last Position (FLP)
8. Chiller – Condenser Water Isolation Valves: Fail to Last Position (FLP)
9. Cooling Tower Isolation Valves: Fail to Last Position (FLP)
10. Boiler Isolation Valves: Fail to Last Position (FLP)

11. Heating Water Mixing Valve: Fail to Heat

12. Steam Valves: Closed (NC)

1.3. STANDARD POINTS LIST

A. General

1. Simulated analog outputs such as tri-state digital output pairs or pulse width modulation shall not be allowed except in dedicated controllers.

2. Fan and pump status inputs shall be independent current switches, not contacts, on any VFD.

3. Alarm priorities are a starting point and can be adjusted by UC Denver after project commissioning.

4. All VFDs shall have an RS485 communications port compatible with the BAS. Speed control, VFD speed, Fan start/stop, and VFD alarm points can be through this port.

5. Priorities 1 or 2 shall be set up to call the alpha numeric pagers.

6. This standard points list is a minimum only. The Engineer and BAS controls contractor are responsible for providing a complete BAS system.

B. AHU Point Lists

Typical Physical Points -- Mixed Air, VAV, Heating Water Preheat

<table>
<thead>
<tr>
<th>Subpoint Name</th>
<th>Type</th>
<th>Description</th>
<th>Alarm Priority</th>
<th>Alarm Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAD</td>
<td>AO</td>
<td>Mixed air dampers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCV</td>
<td>AO</td>
<td>Heating coil valve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCV</td>
<td>AO</td>
<td>Cooling coil valve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAT</td>
<td>AI</td>
<td>Return air temperature</td>
<td>3</td>
<td>Low or high temperature. High temperature should not alarm if fan status is off.</td>
</tr>
<tr>
<td>RSD</td>
<td>DI</td>
<td>Return air smoke detector</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>AI</td>
<td>Carbon dioxide sensor</td>
<td>2</td>
<td>High or low CO2 levels</td>
</tr>
<tr>
<td>FAN</td>
<td>L2SL</td>
<td>Return fan output and status</td>
<td></td>
<td>Should not alarm if supply fan is off.</td>
</tr>
<tr>
<td>RCF</td>
<td>AI</td>
<td>Return air volume</td>
<td>2</td>
<td>Low volume. Should not alarm if return fan off.</td>
</tr>
<tr>
<td>MAT</td>
<td>AI</td>
<td>Mixed air temperature</td>
<td>2</td>
<td>Low temperature</td>
</tr>
<tr>
<td>HCT</td>
<td>AI</td>
<td>Heating coil temperature</td>
<td>2</td>
<td>Low temperature</td>
</tr>
<tr>
<td>LTD</td>
<td>DI</td>
<td>Low temperature alarm</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>FAN</td>
<td>L2SL</td>
<td>Supply fan output and status</td>
<td>2</td>
<td>Should not alarm if freezestat or high static pressure alarms have tripped.</td>
</tr>
<tr>
<td>SCF</td>
<td>AI</td>
<td>Supply air volume</td>
<td>2</td>
<td>Low volume. Should not alarm if supply fan is off.</td>
</tr>
<tr>
<td>HSPA</td>
<td>DI</td>
<td>High static pressure alarm</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>CHWR</td>
<td>AI</td>
<td>Chilled water return temperature</td>
<td></td>
<td>Low temperature</td>
</tr>
<tr>
<td>SAT</td>
<td>AI</td>
<td>Supply air temperature</td>
<td>2</td>
<td>Alarm setpoint should vary with discharge air setpoint. Should not alarm if supply fan is off.</td>
</tr>
<tr>
<td>SSD</td>
<td>DI</td>
<td>Supply air smoke detector</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>FILTER</td>
<td>AI</td>
<td>Filter differential pressure</td>
<td>3</td>
<td>Dirty filter. Setpoint should vary with supply air velocity.</td>
</tr>
</tbody>
</table>
### SSP AI Supply air static pressure 2 Low or high pressure. Low pressure should not alarm if return fan is off.

#### Typical Physical Points – 100% Outside Air, VAV, Steam Preheat

<table>
<thead>
<tr>
<th>Subpoint Name</th>
<th>Type</th>
<th>Description</th>
<th>Alarm Priority</th>
<th>Alarm Notes</th>
</tr>
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<tbody>
<tr>
<td>HRV</td>
<td>AO</td>
<td>Heat recovery coil valve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCV</td>
<td>AO</td>
<td>Heating coil valve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FBD</td>
<td>AO</td>
<td>Face and bypass dampers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCV</td>
<td>AO</td>
<td>Cooling coil valve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HRT</td>
<td>AI</td>
<td>Heat recovery coil discharge air temperature</td>
<td>4</td>
<td>Low or high temperature. Alarm setpoint should vary with outside air temperature and only alarm when heat recovery pumps are on.</td>
</tr>
<tr>
<td>HCT</td>
<td>AI</td>
<td>Heating coil discharge air temperature</td>
<td>2</td>
<td>Low temperature.</td>
</tr>
<tr>
<td>LTD</td>
<td>DI</td>
<td>Low temperature alarm</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>TRP</td>
<td>AI</td>
<td>Trap monitor</td>
<td>3</td>
<td>Should alarm leaking steam but not cold trap</td>
</tr>
<tr>
<td>FAN</td>
<td>L2SL</td>
<td>Supply fan output and status</td>
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C. Chilled water systems

1. See metering standard

**PART 2 -- EXECUTION**

2.1. **SEQUENCE PROGRAMMING**

A. Sequence logic shall be installed in a professional manor that demonstrates a full understanding of the sequence and maximizes energy conservation and smooth operation in strategies and techniques not covered by the sequence.

B. All setpoints and control parameters shall be adjustable

C. All control loops shall utilize PID control algorithms unless application dictates otherwise.

1. The proportional and integral values which make up the PID output value shall be readable and modifiable to facilitate tuning of control loops.

2. All PID loops serving critical equipment shall provide for operator control of loop starting point without program editing when control is returned to program control after being in operator control.

3. All loops shall have a virtual output in the loop statement to allow knowledge of loop performance before changing output from manual to program control.

D. The outside air temperature sensor and other inputs that are used in multiple programs shall be attached to a single virtual point, which is used in the programs.

E. Mode changes shall be stable. Abrupt changes that cause unnecessary opening of valves should not be used. Example: Do not abruptly change the supply air temperature setpoint when going from warmup mode to occupied mode.

F. All logic statements or blocks shall be input with consistent naming conventions.

G. The logic for separate DDC controllers serving AHUs with identical sequences of operation, shall also be identical.

2.2. **INSTALLATION GENERAL**

A. All HVAC safeties shall be hardwired such that the shutdown will occur both in Automatic and Hand modes at the BAS system and the starter.

B. Software safeties are not acceptable (exception: smoke control may be done through software if the control system is UL listed for smoke control).

END OF SECTION
SECTION 15990  
TESTING, ADJUSTING AND BALANCING

PART 1- GENERAL

1.1 SUMMARY
A. This section includes standards for testing, adjusting and balancing air, fluid, mechanical, control, and electrical systems associated with HVAC systems to optimum performance.

1.2 REFERENCE
A. All Section of Division 15.

1.3 SYSTEM PERFORMANCE REQUIREMENTS
A. Require general, mechanical and electrical contractors to coordinate and cooperate with the TAB contractors as necessary to allow them to perform work.
B. Items such as start-up, initial testing, cleaning, calibration of controls, electrical testing, etc., are to be completed prior to the commencement of TAB work.

1.4 DEFINITIONS

1.5 SUBMITTALS
A. Submit name of balancing and testing agency with resume of the agency, including qualifications of personnel to be used and authority and responsibilities of personnel.
B. Product data shall be submitted, in accordance with Section 15000, for each of the following:
   1. Procedure Submittal: Prior to commencing work, submit, for approval, a written procedure of how balance will be performed and a description and manufacturer’s name of equipment and instruments to be used. The submittal shall include, but not necessarily be limited to the following:
      a. List of preliminary checks to be performed at the job site such as confirmation that manual volume dampers are present, filters are installed, frequency drive units operational, location of control sensors, etc.
      b. Identify how the air outlets will be measured and the type of instruments to be used.
      c. Locations of pilot traverses and the type of instruments to be used.
      d. Modes of operation that the system will be placed in during balancing and testing, i.e., full cooling and heating, maximum and minimum outside air flows, maximum and minimum sash positions for fume hoods, toilet fans on or off, etc.
      e. Position of doors and windows during balance, i.e., some labs should be balanced with doors shut.
f. Operating static pressures for terminal devices and pressure sensors for controlled devices.
g. Method of adjusting outside and return air quantities at air handling units.
h. Initial test procedures for preliminary balance.
i. Final test procedures.
j. List of deficiencies in mechanical system that could hinder the balance work such as missing or leaky dampers, incomplete systems, inadequate fans, etc.
k. Sample of data sheets and test forms to be used in final report.
l. Identification and manufacturer’s name of equipment to be used on project and proof of last calibration on each piece.

2. Progress Report(s) – Report, in writing, any deficiencies or problems with air or water systems that have affected balance work. Include items that affect system performance such as broken thermostats, damaged ductwork, excessive noise, etc.

1.6 QUALITY ASSURANCE


B. TAB contractors shall present to the UC Denver Project Manager and general contractor, proof of current equipment certification approved by National Institute of Standards and Technology.

C. Testing Agency Qualifications: Agency shall be NEBB or AABC certified in testing and balancing disciplines required for this project. Work shall be performed under direct supervision of professional engineer, NEBB, or AABC certified supervisor.

1.7 DELIVERY, STORAGE AND HANDLING

1.8 WARRANTY

A. Guarantee of Work: TAB contractor shall guarantee the balancing for a period of 90 days from date of acceptance of final report. During this period, the TAB contractor shall make personnel available at no cost to the UC Denver to verify measurements and/or correct deficiencies in the balance. During this period, emergency adjustments shall not void this warranty.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

2.2 MATERIALS, GENERAL
A. Provide all test instruments, meters, gauges, power-measuring instruments, pumping equipment, temporary piping and miscellaneous items necessary to perform required testing procedures.

B. Provide necessary dampers, thermometer wells, gauge cocks, balancing valves, and other appurtenances as required. Coordinate locations of these items as construction progresses to avoid disturbance of finished complete systems. Provide new sheaves and belts for air moving equipment, if required, to attain desired air quantities.

PART 3 - EXECUTION

3.1 EXAMINATION

3.2 INSTALLATION, GENERAL

A. Pre-Balancing Conference: Before beginning testing, adjusting, and balancing procedures, schedule and conduct a conference with UC Denver Project Manager, Facilities Operations Representative(s) and representatives of installers of mechanical and control systems. Conference objective is final coordination and verification of system operation and readiness for testing, adjusting, and balancing, and assigning testing responsibilities of each installer.

B. Systems shall be complete and fully operational prior to beginning procedures. Insure all items such as thermometer wells, pressure test-cocks, access doors, etc., are installed to facilitate tests and adjustments.

C. Put all heating, ventilating, and air conditioning systems and equipment into full operation and continue operation during testing and balancing.

D. Before air balance work is started, check system for duct leakage, install a complete set of clean filters, check for correct fan rotation and equipment vibration, and check automatic dampers for proper operation. Set volume control dampers and outlets in wide open position. Ensure fire dampers are open and that return air paths are not obstructed.

E. Prior to performing hydronic balance work; check system for plugged strainers, proper pump rotation, and proper control valve installation and operation. Check air vents at high points of systems to ensure all are installed and operating freely (automatic type) or bleed air completely (manual type); and verify proper flow meter and check valve installation and proper system pressure.

F. All throttling devices and control valves shall be set open.

G. Performing Testing, Adjusting, and Balancing:

1. Cut insulation, ductwork, and piping for installation of test probes to minimum extent necessary to allow adequate performance of procedures.

2. Patch insulation, ductwork, and housings, using materials identical to those removed.

3. Reseal ducts and piping, and test for and repair leaks.

4. Reseal insulation to re-establish integrity of the vapor barrier.
5. Mark equipment settings, including damper control positions, valve indicators, fan speed control levers, and similar controls and devices, to show final settings. Mark with paint or other permanent identification materials.

6. Retest, adjust, and balance systems subsequent to significant system modifications, and resubmit test results.

H. Sequencing and Scheduling:

1. Systems shall be fully operational before beginning procedures.

1. Conduct tests in the presence of the UC Denver Project Manager after providing 7-day notice before any test is to be conducted. Provide water and electricity required for tests. Determine that all dampers, registers, and valves are in a set or full open position.

I. Balancing:

1. Water Balance:

a. Balance water piping and snow melt systems to produce water quantities within 5 percent of design flow rates for cooling water systems and within 10 percent of design flow rates for heating water systems.

b. Hydronic systems shall be proportionally balanced, ensuring the path to one terminal is fully open. Total system flow shall be adjusted at pump by restricting discharge balancing valve.

c. Indicate and record final position of balancing valves.

d. Primary-Secondary Flow Systems: Balance primary system crossover flow first, then balance secondary system.

e. Pumps:

1) Verify pump impeller size and pump rotation.

2) Measure flow.

3) Measure inlet and outlet pressures.

4) Measure motor full load amperage at design flow and shut-off condition.

f. Heat Exchangers:

1) Measure water flow through all circuits.

2) Measure inlet and outlet water temperatures.

3) Calculate capacity in btu-h.

4) Measure inlet steam pressure. Check setting and operation of automatic temperature-control valves and pressure reducing valves.
5) Record safety valve settings.

6) Verify operation of steam traps.

g. Chillers:

1) Balance water flow through each evaporator and condenser with all pumps operating. With only one chiller operating in a multiple chiller installation, do not exceed flow for maximum tube velocity recommended by chiller manufacturer. Perform tests and record data with each chiller operating at design conditions for:

   a) Evaporator and condenser water entering and exiting temperatures, pressure drop, and water flow.

   a) Evaporator and condenser refrigerant temperature and pressures.

   b) Calculate capacity in tons.

2) For air cooled chillers, verify condenser fan rotation and record fan data, including number of fans and entering and exiting air temperatures.

h. Cooling Towers:

1) Shut off makeup water for duration of test and ensure makeup and blow-down systems are fully operational after tests. Perform tests and record data for:

   a) Condenser water flow to each cell of cooling tower.

   b) Entering and exiting water temperatures.

   c) Wet, and dry, bulb temperatures of entering and exiting air.

   d) Condenser water flow rate recirculating through cooling tower.

   e) Cooling tower pump discharge pressure.

   f) Fan cfm and static pressure for each cell.

i. Heat Transfer:

1) Measure entering and exiting water temperatures and pressures.

2) Measure gas flow rate.

3) Measure water flow.

4) Calculate capacity in btu-h.
a. Water Coils:

1) Measure entering and exiting water temperatures and pressures.

2) Measure water flow rate.

3) Measure entering and exiting dry, and wet, bulb air temperatures.

4) Measure airflow. Measure air pressure drop. Calculate capacity in btu-h.

k. Finned Tube Radiation:

1) Measure entering and exiting water temperatures.

2) Measure water flow rate.

3) Calculate capacity in btu-h.

2. Air Balance:

a. Balance duct system to produce air quantities within 10 percent of indicated value.

b. Dampers: Adjust automatic damper linkages to provide air flow quantities shown. Check all automatic dampers in normal operation to verify proper operation. Verify return, relief air, and fresh air intake dampers operate as designed to produce desired room comfort.

c. Place all fans (supply, return, and exhaust) in operation. Load or restrict filters to increase pressure drop to 50% of span between initial pressure drop and final recommended pressure drop for setting final air flows for fans. Check the following:

1) Motor amperage and voltage to guard against overload.

2) Fan rotation.

3) Operability of static pressure limit switch.

4) Automatic dampers for proper position.

5) Air and water resets operating to deliver required temperatures.

6) Air leaks in casing and in safing around coils and filter frames.

d. Traverse Main and Branch Ducts: Perform pitot traverses for fan total air flows including traverses for hot and cold decks, for each zone in multi-zone systems and for each floor. Mark locations of pitot traverses on reduced drawings in final report.

1) Note temperature and barometric pressure. Corrections should be made for systems for 5200-foot elevation.
2) After establishing total air being delivered, adjust fan speed to obtain design airflow. Check power and speed to see that motor power and critical fan speed have not been exceeded.

3) Proportionally adjust branch dampers until each has proper air volume.

4) With all dampers and registers in system open and with supply, return, and exhaust fans operating at design cfm or speed, set minimum outdoor and return air ratio.

5) After minimum outside air damper has been set for proper percentage of outside air, take another traverse of mixture temperatures. Notify UC Denver Project Manager and note in balancing report if variation from average is more than 5 percent.

e. Adjust system with mixing dampers positioned for minimum outside air.

f. Balance terminal outlets in each control zone in proportion to each other. Use branch dampers for major adjusting and terminal dampers for trim or minor adjustment only.

g. Balance constant volume reheat systems in one mode, namely design airflow.

h. Balance constant volume dual duct systems at the boxes for full cooling and full heating air flows. Balance the fan with all the boxes on full cooling. Record the total fan supply with the boxes on full cooling.

i. Balance VAV fans by placing a certain number of the VAV boxes in full cooling mode. This number shall be equal to the system diversity and shall include boxes that are at the end of the system, that are on duct branches with high static loss and serve critical areas. With the system in this mode the fan shall be sheaved to maintain the static pressure required to control the worst case VAV box.

j. Once total design air has been balanced in branches and at outlets, verify and record the following:

1) Fan motor amperage.
2) Fan speed
3) Fan cfm.
4) Fan outlet velocity.
5) External and total static pressure.
6) Supply, return, mixed, and outside air temperatures.
7) Percent outside air under minimum damper position.
8) Static pressure across each component (intake, filters, coils, and mixing dampers).

9) Take a final duct traverse.

k. Final adjustments shall include, but not be limited to the following:

1) Adjust RPM on belt drive fans. Include sheave and belt exchange to deliver air flow within limits of installed motor horsepower and mechanical stress limits of the fan. Determine limiting fan tip speed before increasing RPM. Final fan speed setting shall allow for filter loading and shall establish proper duct pressures for operation of zone cfm regulators.

2) Adjust rpm on Direct Drive Fans:

   a) For motors with speed taps, set fan speed on tap which most closely approaches design cfm. Report tap setting on equipment data sheet as high, medium, or low.

   b) For motors with speed control, set output of fan at design cfm by adjusting control. Ensure the fans restart after shut down. Increase setting as required for proper setting. Mark control to indicate final setting position.

3) Terminal Boxes:

   a) For variable air volume (VAV), constant volume boxes, or dual duct boxes, set regulators to provide design minimum and maximum airflow rates. Adjust thermostat to assure proper damper operation.

   b) For VAV, or constant volume boxes with reheat, set regulators to provide design minimum and maximum airflow rates. Check control sequence operation to assure proper sequencing.

   c) Air flow performance of boxes for both primary and secondary balance settings shall be verified by flow measuring hood measurements at diffuser outlets.

3. Fume Hood Balancing:

   a. Balance fume hood exhaust fans to meet face velocity requirements. The face velocity shall be maintained at a minimum of 100 fpm.

   b. Balance hoods with the building supply and exhaust systems in normal operation, with doors and windows in typical position and hoods empty and clean. Record these conditions in report.

   c. Set horizontal sash hoods at 12 inches or greater. Adjust the fan to provide the required face velocity measured at a minimum of nine centerline measurements equally spaced at sash plane using a hot wire anemometer. The average of the nine measurements shall be corrected.
for temperature and altitude and recorded. Place a sticker furnished by the UC Denver Project Manager at the approved sash height.

Raise the sash to find the height where 100 fpm face velocity is achieved. Mark this height with a second sticker furnished by the UC Denver Project Manager. If the sash height is below the acceptable working height, the hood will not pass acceptance.

d. Set vertical sash hoods with a 12-inch or greater space centered in front of the hood. If an odd number of sashes exist, the opening shall be the most distant from the exhaust point inside the hood. Adjust the fan to provide the required face velocity measured at a minimum of nine centerline measurements equally spaced at sash plane using a hot wire anemometer. The average of the nine measurements shall be corrected for temperature and altitude and recorded.

Move the sash to find the position where 100 fpm face velocity is achieved. Mark this position with a second sticker furnished by the Project Manager.

e. Adjust spaces with pressure gradients or directional air flow requirements to meet standards as well as designated air flows. Verification of performance shall be made with pressure gradient measurements, smoke tests in presence of the UC Denver Facilities Operations representative, or hot wire anemometer across door cracks etc. Pressure differential measurements are preferred unless gradient is too small (under 0.01 inches w.c.) by standard.

4. Smoke Systems: Test smoke management systems per NFPA 92A.

5. Equipment Motors: Record the following information for every motor and include information with the appropriate equipment.

   a. Motor horsepower and rpm.
   b. Nameplate and measured voltage and amperage, each phase.


   a. Verify proper operation of devices. Verify that all controllers are calibrated and operational.
   b. Check location of transmitters and controllers. Note adverse conditions that would affect control and suggest relocation as necessary to UC Denver Project Manager.
   c. Note settings on controllers. Note discrepancies between set point for controller and actual measured variable.
d. Verify operation of all limiting controllers, positioners, and relays (e.g., high and low temperature thermostats, high and low differential pressure switches, etc.).

e. Activate controlled devices, checking for free travel and proper operation of stroke for dampers and valves. Verify and note normally open (NO) or normally closed (NC) operation.

f. Verify sequence of operation of controlled devices. Note line pressures and controlled device positions. Correlate to air or water flow measurements. Note speed of response to step change.

g. Confirm interaction of interlock and lockout systems.

7. Sound and Vibration Levels: Test and adjust mechanical systems for sound and vibration in accordance with instructions of referenced standards.

8. After deficiencies are corrected, retest the systems until acceptable values are obtained.

9. Permanently mark balancing devices spray paint indicating final position. Grease markers are not permitted.

J. Report:

1. Report Format: Standard forms prepared by the referenced standard for each respective item and system to be tested, adjusted, and balanced. Include information indicated on standard report forms prepared by AABC or NEBB for each respective item and system, and schematic diagrams for each system or piece of equipment to accompany each respective report form. Bind report forms complete with schematic systems diagrams and other data in reinforced vinyl three-ring binders. Provide binding edge labels with project identification and a title descriptive of contents. Divide contents of binder into following divisions, separated by divider tabs:

   a. General Information and Summary

   b. Air Systems

   c. Hydronic Systems

   d. Temperature Control Systems

   e. Special Systems such as fume hood exhaust systems.

   f. Sound and Vibration Systems

   g. Recommendations.

2. Report Contents: Provide following minimum information, forms, and data:

   a. General Information and Summary:

      1) Inside cover sheet to identify testing, adjusting, and balancing agency, contractor, and project name. Include contact names, addresses, and telephone numbers.
2) Certification sheet containing seal, address, telephone number, and signature of Certified Test and Balance Engineer.

3) Listing of instrumentation used for procedures along with proof of calibration.

b. Test Data: Report shall include the following data, in addition to certified field report readings taken during the balancing and testing operations. Include required or specified reading, first reading taken, and final balanced reading.

1) Air Handling Units and Fans: Air handling unit, fan and motor nameplate information, type, drive sheave information (as installed and changed), and final belt number and size.

2) Air Balance for Supply, Return, Relief, and Exhaust Systems:

   a) Outlets, Inlets, Diffusers, Registers, and Grilles: Size, reading orifice size, velocity in fpm, and design and final balanced air quantity in cfm.

   b) Terminal Boxes: Design and final minimum and maximum cfm settings including fan cfm on fan powered terminal boxes.

   c) Ducts: Size, velocity in fpm, and air quantity in cfm.

3) Hydronic Balance:

   a) Water coil size and manufacturer.

   b) Boiler and burner nameplate information and flue gas analysis. Flue gas analysis shall be copy of manufacturer's analysis report.

   c) Chiller and motor nameplate information.

   d) Cooling tower and fan motor nameplate information.

   e) Pump and motor nameplate information. Include manufacturer's pump curves.

   f) Heat exchanger nameplate information.

   g) Snow melt circuits.

4) Record thermal protection for all motors. Starter brand, model, enclosure type, installed thermal heaters and rating of heaters, required thermal heaters and rating of heaters if different from installed shall be recorded.

5) Include sheet that reports method of balance, project altitude, and any correction factors used in calculations.
6) Include a reduced set of contract drawings with all terminals (VAV boxes, outlets, inlets, coils, unit heaters, fans, etc.) clearly marked and all equipment designated.

7) Prepare list of recommendations for correcting unsatisfactory mechanical performances when system cannot be successfully balanced.

3.3 TESTING, CLEANING AND CERTIFICATION

A. After cleaning, pressure tests, adjusting, and balancing are complete, each system shall be performance tested as a whole to verify that all items perform as integral parts of system, and temperatures and conditions are evenly controlled throughout building. Make corrections and adjustments as required to produce conditions indicated.

B. Provide four (4) copies of testing, adjusting, and balancing report bearing seal and signature of the TAB Engineer. The report shall be certification that systems have been tested, adjusted, and balanced in accordance with referenced standards; accurate representation of how systems have been installed; and accurate record of all final quantities measured.

C. Final Report:

1. Submit a preliminary report within 30 days of completed TAB work. Report shall include the following information.
   a. A general discussion preface section. This section shall summarize all abnormalities or problems encountered during the project and what course of action was taken. This summary should be assembled from the written progress reports described earlier, except that it will be expanded to include responses from the Engineer, UC Denver Project Manager and Contractor regarding each problem indicated in the progress reports.
   b. Copies of correspondence if related to the performance and balance of the systems.
   c. Status of doors, windows and equipment static pressures during balance work.
   d. Reduced 11” x 17”, readable, as-built drawings obtained from the UC Denver Project Manager. All devices and equipment shall be clearly labeled.
   e. Belt and sheave information, fan and motor nameplates information, full load operating voltage and amperage indicate sheave diameter as pitch diameter.
   f. Design and final actual cfm at each system terminal unit. Include terminal/size, inlet static pressure, temperature and velocities read to attain the design cfm.
   g. Overload protection for all motors shall be recorded. Starter and brand model, enclosure type, installed overload devices, original ratings, and set points (and revised device ratings and set points when application) shall be recorded.
2. Any corrective action shall be completed and the systems re-tested. The corrected system information shall be provided in the final report.

3. Final Report shall be completed within 30 days of preliminary report.

3.4 COMMISSIONING (DEMONSTRATION

A. Upon request of the UC Denver Facilities Operations Representative, through the UC Denver Project Manager, the balancing firm shall demonstrate measured quantities of randomly selected equipment. The number of readings verified will not exceed 10 percent of the total in the report.

3.5 SCHEDULES

END OF SECTION
PART 1 – GENERAL

1.1 SUMMARY

A. Description

1. This section covers the commissioning process for facilities. Commissioning is intended to enhance the quality of system start-up and aid in the orderly transfer of systems to UC Denver.

2. Commissioning is required on all projects. Utilization of outside resources will be decided on a project-by-project basis with approval of UC Denver Facilities Operations through the UC Denver Project Manager.

3. Systems should be commissioning should include LEED Energy and Atmosphere minimum of fundamental commission prerequisite and should consider LEED Enhanced Commissioning work with UC Denver Project Manager and LEED rating for new building, addition or major renovation.

1.2 REFERENCES

A. Related Documents

1. Division 1

2. Division 15

3. Division 16

1.3 SYSTEM PERFORMANCE REQUIREMENTS

A. Commissioning Authority

1. Coordinating and directing each step of the commissioning process, and for recommending acceptance or non-acceptance to the UC Denver’s representative.

2. Assisting in clearly identifying problems encountered in testing the functional performance of the mechanical system and cooperatively assisting in the development of the solutions to those problems. These potential problems may include mechanical design, mechanical installation, mechanical equipment, controls devices, controls installation, controls software, etc.

3. Coordinate directly with each sub contractor with respect to their responsibility and contractual obligations.

4. Obtain, assemble and submit commissioning documentation.

5. Attend periodic on-site commissioning activities.

6. Develop the commissioning plan and schedule.
7. Development of the commissioning checklists and functional performance test plans. If there is a conflict between the requirements of the engineer and those of the Commissioning Authority, and the conflict cannot be resolved, the requirements of the Engineer shall have precedence.

8. Coordinate the installation verification inspections.

9. Review the control documentation and interface with other systems.

10. Review the operation and maintenance information and as-built drawings provided by the various sub-contractors and vendors.

11. Note any inconsistencies or deficiencies in the system.

12. Enforce system compliance and recommend modifications to the system design that will correct or enhance the system performance.

13. Coordinate the UC Denver’s representative for witnessing of the tests.

14. Be present during start-up activities to assist and witness the execution of start-up.

15. Monitor the performance of the Test, Adjust and Balance contractor.

16. Review the accuracy and calibration of any instrumentation utilized for the functional performance testing.

17. Direct the functional performance testing.

18. Track commissioning deficiencies until correction.

19. Prepare and submit the commissioning reports.

20. Provide a three to five day training class for up to six maintenance personnel.

21. The Commissioning Authority shall include in the commissioning bid.

   a. All required costs to identify the design and construction problems as they relate to the mechanical system functional performance and acceptance.

   b. Assistance in the process of proposing solutions to mechanical system functional performance and acceptance problems.

   c. Assistance in implementing the solution for a mechanical system functional performance and acceptance problem.

22. In the event that any one of the contractors or engineers are unwilling or unable to participate in the commissioning process and/or the resolution of problems identified in the commissioning process, that portion of the commissioning process shall be discontinued until such time that contractor/designer participation and problem resolution is resumed. The Commissioning Authority shall notify the UC Denver’s representative in writing of:

   a. The portion of the commissioning process in question.
b. The problem being encountered with the system.

c. The problem being encountered with the contractor/designer.

d. The approximate costs encountered in attempting to get cooperation and projected costs in completing that portion of the commissioning process.

B. Smoke Management System Commissioning Authority:

1. Inspect the following:

   a. Automatic dampers
   
   b. Fans
   
   c. Controls diagrams
   
   d. Marking & identification

2. Verify the following:

   a. Vestibules
   
   b. Fans
   
   c. Detection devices
   
   d. Dampers
   
   e. Inlets and Outlets
   
   f. Smoke barriers
   
   g. Standby power
   
   h. Control action & Priorities
   
   i. Controls
   
   j. Response time

3. Reports: Provide the following reports and forms:

   a. Verification plan
   
   b. Testing & Validation Forms
   
   c. Daily Log & Reports Forms
   
   d. Non-Compliance Forms

C. Design Engineer:

1. Provide Design Intent Document for individual systems and for overall building systems integration.
2. The design engineer shall be responsible for the observations and checklists for the Installation Verification as defined in Part 3 of this Section.

3. Additional calculation and investigation of design adjustments needs by the engineers as defined by the Commissioning Authority.

4. Participate in the resolution of potential design concerns as discovered during the commissioning process.

D. Contractor:

1. The contractor shall be responsible for the Pre-functional Testing, a start-up procedure performed prior to balancing as defined in Part 3 of this Section.

2. The contractor shall be responsible for providing any technical personnel required for physical operation, testing and simulation of control sequences for each piece of controlled equipment as required by the Commissioning Authority during the Functional Performance Testing. This shall include chiller service personnel, boiler service personnel, the temperature control engineering and technical start-up crew, mechanical contracting service personnel for miscellaneous equipment, and balancing contractor personnel. To the extent possible, these personnel will be scheduled.

3. Additional calibration and adjustment of the mechanical equipment included in each mechanical system for proper operation under actual operation as defined by the Commissioning Authority.

4. Additional testing, calibration, adjustments, tuning, and minor adjustments to the temperature controls system sequences for proper operation under actual operations defined by the Commissioning Authority.

5. Additional testing, calibration and adjustment of the mechanical water and airflow of each mechanical system for proper operation under actual operation as defined by the Commissioning Authority.

E. UC Denver:

1. Schedule UC Denver’s representatives to participate in commissioning process.

2. Advise Commissioning Authority regarding changes in building occupancy, usage, or functional requirements.

1.4 DEFINITIONS

A. Definition of Terms:

1. Installation Verification: This initial portion of the commissioning process includes observations and punch-list recorded and performed by the Engineer to ensure that all equipment is installed in accordance with the specifications and drawings. The Commissioning Authority shall overview this process.

2. Pre-functional Testing: This portion of the commissioning process involves primarily the test and balance and startup personnel to ensure that individual pieces of equipment are capable of performing in accordance with the specifications, drawings, and manufacturer’s requirements. This is documented.
with a pre-functional checklist provided and completed by the contractor. The Commissioning Authority shall overview this testing.

3. Functional Performance testing: This portion of the commissioning process involves dynamic tests that ensure all mechanical systems function in accordance with design intent. The tests are dynamic and on-line and test the systems through all possible modes of operation.

4. Calibration: To check or adjust the graduation of a quantitative measuring instrument against a known standard.

5. Adjustment: To change the speed, flow, position, signal, or level of any piece of mechanical equipment.

6. Turning: To adjust for maximum performance.

7. Minor Adjustment: To add, subtract, or change various parameters included on the operation of logic of a mechanical system or systems in order to improve or optimize operation performance. This refers only to the specified performance logic. Difficulties encountered in accomplishing a minor adjustment shall not be used to define a minor versus a major adjustment.

8. Major Adjustment: To fully change the specified operation logic of a mechanical system or systems. This refers only to the specified performance logic. Difficulties encountered in accomplishing a minor adjustment shall not be used to define a minor versus a major.

9. System Component or System Element: A single piece of mechanical equipment such as a pump, fan, chiller, boiler, coil, etc. that when combined together through piping or ductwork will comprise a “System”.

10. System: A combination of system components that allow the manufacturer or distribution of conditioned air or water from one location to another.

11. The commissioning process is a joint team effort to ensure that all mechanical equipment, controls, and systems function together properly to meet the design intent of the Engineer, and to document system performance parameters for fine-tuning of control sequences and operation procedures.

12. The commissioning process shall encompass and coordinate the traditionally separate functions of system documentation, equipment start-up, control system calibration, testing and balancing, training and performance testing. Testing and balancing, controls and training are addressed in other sections of the Specifications.

13. The commissioning described herein, is not intended to supersede or replace the normal system startup by the contracting team, observations by the design team or balancing by the test and balance contractor.

14. Commissioning Process: In as much as possible, the commissioning process shall occur during the construction of the project for all portions of the mechanical systems that are scheduled to be complete at the opening day. This is intended to:

   a. Reduce as much as possible any duplication of work or testing for the contractor.
b. Identify and solve any potential mechanical system design or construction problems as they relate to functional performance, prior to opening day.

15. The work included in the commissioning process involves a complete and through evaluation of the operation and performance of all components, systems, and sub-systems. Evaluate the following equipment and systems:

a. Hydronic distribution systems.
b. Air handling and air distribution systems.
c. Domestic hot water systems.
d. Variable frequency drives.
e. Fire protection and suppression systems.
f. Exterior switches and transformers.
g. Electrical unit sub stations, switch gear, distribution transformers, distribution panelboards, and branch panelboards.
h. Lighting systems.
i. Motor control centers.
j. Stand-by power systems.
k. Building automation systems, hardware, software, and documentation.
l. UPS systems.
m. Glazing.
n. Insulation.
o. Indoor air quality.
p. Building and special room pressurization.
q. Computer room air conditioning systems.
r. Fume hoods and special exhaust systems.
s. Security systems.
t. Fire alarm systems.
u. Lighting Protection systems.

B. Commissioning Team:

1. The commissioning team shall be made up of the:
a. Commissioning Authority  
b. Representative of the UC Denver  
c. Design Engineer  
d. Design Architect  
e. Construction Trades (specialty contractors)

2. The trades represented on the commissioning team will include:  
a. General Contractor  
b. Mechanical Contractor  
c. Electrical Contractor  
d. Building Automation System Contractor  
e. Fire Alarm System Contractor  
f. Test, Adjust and Balancing

3. The lead tradesman for each trade who will actually perform or supervise the commissioning work is to be designated as the representative to the commissioning team.

4. Responsibility for various steps of the commissioning process will be divided among the members of the commissioning team, as described in this section.

1.5 SUBMITTALS  
1.5 QUALITY ASSURANCE  
1.6 DELIVERY, STORAGE, AND HANDLING  
1.7 WARRANTY

PART 2 – PRODUCTS  
2.1 MANUFACTURERS  
2.2 MATERIALS, GENERAL

PART 3 – EXECUTION  
3.1 EXAMINATION  
3.2 INSTALLATION, GENERAL  
A. Commissioning Process:  
1. Meetings:
a. Scope Meeting: Early in the construction process, a commissioning scope meeting involving all members of the commissioning team shall be held at a time and place designated by the UC Denver Project Manager. The purpose of the meeting will be to familiarize all parties with the requirements of the commissioning process, and to ensure that the responsibilities of each party are clearly understood.

b. Progress Meetings: During the course of the project, the Commissioning Authority shall conduct monthly commissioning meetings during the initial 75% of the project. During the final 25% of the project construction, the Commissioning Authority shall conduct weekly meetings.

2. Reports:

a. General:

1) The Commissioning Authority shall record and maintain detailed testing data. The data record shall be comprehensive and concise.

2) All data must be recorded as soon as possible during the course of testing.

3) All documentation shall have the date, time, and names of persons participating in the inspection and testing.

4) All test instruments shall be documented for valid calibration.

5) The engineer and Commissioning Authority must approve the recording work sheets, inspection checklists, and performance testing plans. Approval must occur prior to the start of Functional Performance Testing.

b. Daily Commissioning Report Logs:

1) The Commissioning Authority shall provide daily report logs to be included in the final report.

2) The daily logs shall record the Commissioning Authority personnel and event summaries of meetings, conversations, tests, failures, solutions, procedures and successes.

c. Functional Performance Test Plans, Tables and Checklist:

1) The Commissioning Authority shall prepare detailed test plans with associated checklists to organize and document the Functional Performance Testing.

2) A separate test plan is required for each device or control sequence.

3) A separate checklist is required for each of the equipment/systems.
4) Provide testing tables for large quantities of repetitive test events such as outside air volumes, VAV box close-offs, valves, etc.

d. Final Report:

1) The Commissioning Agent shall prepare and submit to the UC Denver’s representative a final report after completion of the commissioning.

2) The report shall verify performance of HVAC equipment and systems.

3) Documentation any field modifications to the testing process and why these modifications were made.

4) The organizations of the final mechanical systems commissioning report shall be as follows:

   a) Executive Summary of each mechanical system and problems encountered and resolved.
   
   b) System Overview summarizing the system design.
   
   c) Commissioning Plan.
   
   d) Post Commissioned Controls Sequences and Points Lists.
   
   e) Prefunctional Testing Checklists.
   
   f) Functional Testing Procedures and Results.
   
   g) Smoke Control Testing Scenarios and Results.
   
   h) Appendix of letters, memo and notes occurring during the commissioning process.

3.3 TESTING, CLEANING AND CERTIFICATION

A. General Requirements:

1. All systems and system components shall be tested in presence of Commissioning Authority (and the engineer, if desired by the engineer) to demonstrate compliance with specified requirements. To minimize the time of commissioning, contracting and engineering team members, testing shall be done in seasonal single blocks of time insofar as possible.

2. The contractor shall notify the Commissioning Authority fourteen (14) days prior to scheduled Functional Performance Tests, of the scheduled completion date of the Installation Verification and Pre-functional Testing.

3. All testing shall be conducted under specified design operating conditions as approved by Commissioning Authority and engineer.
4. All elements of systems shall be tested to demonstrate that total systems satisfy all requirements of these specifications. Testing shall be accomplished on hierarchical basis. Test each piece of equipment for proper operation, followed by each subsystem, followed by entire system, followed by any inter-ties to other major systems.

5. All special testing materials and equipment shall be provided by contractor. This includes, but is not limited to balancing readout and adjustment tools.

6. Provide one copy of all test reports and records to Commissioning Authority.

B. Test Procedure and Test Documentation:

1. Within sixty (60) days prior to startup of the mechanical system, the Commissioning Authority shall prepare and submit to the UC Denver's representative and engineer for review, descriptions of the test procedures which the contractor will perform to demonstrate conformance of completed mechanical systems to the plans and specifications.

2. The decision of the Commissioning Authority and engineer upon acceptability of test procedures shall be final. In the event of an unresolved conflict between the Commissioning Authority and engineer, the engineer's decision shall have precedence. However, in no case shall such decision excuse the contractor from fulfilling the requirements of commissioning as described in this section.

C. Installation Verification Recommendations:

1. All systems and system components shall be checked and verified that they have been installed according to the drawings and specifications, and that all connections have been made correctly.

2. Each system of interactive system components shall be observed and verified that it is ready to function as specified.

3. Verification of complete and proper installation shall be completed prior to starting Component Performance Tests.

4. The Installation Verification shall be documented in a checklist format for each system/piece of equipment. Each checklist shall be dated and initialed by the engineer, mandatory.

D. Pre-functional Testing Requirements:

1. All system components shall be checked to verify that they have been installed properly and that all connections have been made correctly. Verify that each piece of equipment or system has been checked for proper lubrication, drive rotation, belt tension, calibration, control sequence or other conditions which may cause damage.

2. Verify that test, meter readings and specific electrical characteristics agree with those required by equipment or system manufacturer.

3. All discrete elements and sub-systems of system components shall be adjusted and shall be checked for proper operation. Verify wiring and support components for equipment are complete and tested.
4. The Pre-functional Tests shall be documented in a checklist format for each system and each piece of equipment. Each checklist shall be dated and initialed by the contractor, mandatory.

E. Functional Performance Testing Requirements:

1. The Functional Performance Testing portion of the commissioning process shall begin after the installation of the HVAC equipment and systems, along with related equipment, systems, structures, and areas are complete.

2. A Functional Performance Test shall be performed on each complete system. Each function shall be demonstrated to satisfaction of the Commissioning Authority on a paragraph-by-paragraph basis of the written test procedure, developed to demonstrate conformance to requirements of contract specifications and the Design Intent Document.

3. Each functional Performance Test shall be witnessed and signed off by the Commissioning Authority and contractor (and UC Denver's representative and engineer if requested) upon satisfactory completion.

4. The Functional Performance Testing Program shall be conducted in accordance with prior approved procedures and shall be documented as required hereinafter.

5. The Commissioning Authority shall notify the UC Denver's representative, the contracting team, the architect, and the engineer at least two weeks prior to date of scheduled Functional Performance Tests. Schedule each of the seasonal Functional Performance Test periods over a single block of days. The schedule seasonal Functional Performance Tests shall be based on the construction completion schedule. Further communication to the UCD DENVERHSC's representative, architect or engineer concerning the Functional Performance Testing schedule and changes to that schedule due to construction delays or coordination conflicts shall not be required unless the noted parties have expressed an interest in writing in attending the testing.

6. Mechanical System Tasks: Verify that the total HVAC mechanical system is performing to provide conditions all possible modes of operation as outlined in the Design Intent Document (provided by the engineer). The Functional Performance Testing procedures shall statistically represent all operating characteristics of all mechanical equipment and systems, including:

a. Air handling and ventilation systems operation including exhaust fans, heat pumps, and fancoils.

b. Chilled water system operation including chillers, pumps and controls.

c. Condenser water system operation including cooling towers, pumps and controls.

d. Heating water or steam system operation including boilers, pumps and controls.

e. Ventilation systems operation including air handling systems, exhaust fans, supply fans, makeup air systems and controls.
f. Terminal unit operation such as variable air boxes, fancoils, and heat pumps.

g. Pressurization system operation.

7. Building Automation System Tasks: Verify that the total building automation system control system is performing to provide conditions through all possible modes of operation as outlined in the Design Intent Document (provided by the engineer). The Functional Performance Testing procedures shall address all operating characteristics of a statistical representation of control system equipment, sequences, and instrumentation calibration. Include a point-by-point check to verify connectivity and control.

8. Test and Balance (TAB) Verification Tasks: Verify TAB readings for the approximate quantities of the following:

   a. 50% of Fan flows.
   b. 50% of Pump flows.
   c. 50% of Outside air volumes.
   d. 50% of Equipment pressure drops.
   e. 10% of the Supply (maximum and minimum primary air) return and exhaust diffusers, registers, and grilles.
   f. 10% of Hydronic flows.
   g. 10% of Balancing valve/damper settings.
   h. 10% of VAV box setups.
   i. 10% of Coil pressure drops
   j. If more than one-fifth of these readings differ from the documented TAB reading by more than 15 percent, then the TAB for the failed system shall be repeated in entirety.

3.4 COMMISSIONING (DEMONSTRATION)

   A. The Commissioning Authority shall conduct a customized three to five day training class for the UC Denver's engineering personnel in problem solving techniques with respect to the commissioned installation. This Commissioning Authority training does not reduce or exclude the training specified in other specification sections, although portions of other specification sections, although portions of other specified training may be included as a part of the Commissioning Authority training. This problem solving class shall focus on the following:

   1. Present the mechanical system design as a whole, integrated unit.
   2. Point out the unique qualities of the installed mechanical system.
   3. Provide insights into how to solve system-wide, multi-faceted problems.
4. Identify a variety of resources available to assist with problem solving.

5. The problem solving class is not intended to teach day to day maintenance of parts and/or systems, establish emergency procedures, or "quick fix" problem solving approaches.

END OF SECTION