## SECTION 231000 - HVAC PIPING SYSTEMS

1.0 ASHRAE 90.1 Compliance: University of Pennsylvania buildings shall comply with the Commercial Energy Efficiency Requirements of ASHRAE Standard 90.1-2016. The ASHRAE 90.1-2016 compliance paths shall be followed instead of the International Energy Conservation Code (IECC) requirements as permitted by 2018 IECC Section 401.2 Application.

2.0 This section is intended to define the general installation requirements for the numerous piping systems installed at the University of Pennsylvania. Codes which govern the actual sizing and installation of piping should be used during the design process. Welding shall conform to current standards and recommendations of the National Certified Pipe Welding Bureau and all OSHA, State and City fire protection, NFPA Standards 241 and 51B, and the University's Office of Fire and Safety requirements.

3.0 Pipe and fittings shall be specified to meet one of the numerous industry standards such as ANSI, ASTM, AWWA, etc. and shall be suitable for the operating temperatures and pressures to be encountered on the project. Pipe stress analysis shall be provided when deemed necessary by the University Representative or the Project Engineer. Mechanically coupled, grooved pipe connections are permitted only for fire protection systems.

4.0 Piping and conduits shall be designed to run parallel with the lines of the building. Electrical conduits shall not be hung on hangers with any other service pipes. The different service pipes, valves, and fittings shall be installed so that after the covering is applied, there will not be less than 1 inch clear space between the finished covering and other work and between the finished covering or parallel adjacent pipes. Hangers on different service lines, running parallel with each other and nearly together shall be in line with each other and parallel to the lines of the building.

5.0 The minimum pipe shall be ¾ inch for HVAC systems. Size reductions may only occur immediately adjacent to equipment connections. Valves and specialties serving equipment shall be full pipe size, not the reduced equipment connection size.

6.0 Hangers shall be spaced to prevent sag and permit proper drainage of piping. A hanger shall be placed within 1 ft. of each horizontal elbow or valve.

7.0 Vertical runs of pipe and conduit less than 10 ft. long shall be supported by hangers placed one (1) foot or less from the elbows on the connecting horizontal runs. Vertical runs of pipe and conduit over 10 ft. long, but not over 30 ft. long, and not over 6 inches in size, shall be supported by heavy metal clamps. Clamps shall be bolted tightly around the pipes and conduits and shall rest securely on the building structure without blocking. When run in a shaft, support riser clamps on both sides of clamp. For pipes over 30 feet long or over 6 inches in size, support base of all vertical pipe stacks (except soil pipe stacks, generator exhaust stacks and copper water pipe risers) with a base leg. Cut top of base leg to shape and completely weld to heel of base elbow. Weld leg support to a bearing plate and bolt to floor. Locate base leg on vertical pipe centerline. All vent stack piping shall be supported from below roof. Provide springs for vibration isolation where piping system movement, expansion, or noise criteria dictate. Clamps may be welded to the pipes and placed below couplings.

8.0 In lieu of individual hangers, multiple (trapeze) hangers should be considered for water pipes having the same elevation and slope and for electrical conduits. Each multiple hanger shall be

designed to support a load equal to the sum of the weights of the pipes, conduits, wire, and water, the weight of the hanger itself, plus 200 lbs. The size of the hanger rods shall be such that the stress at the root of the thread will not be over 10,000 PSI at the design load. No rod shall be smaller than 3/8 inches. The size of the horizontal members shall be such that the maximum stress will not be over 15,000 PSI design load. A structural engineer shall review all loads imposed upon the structure.

9.0 Steam, condensate, and other hot service piping shall be designed with loops, bends, and offsets to allow for thermal expansion and keep stresses within the allowable limits of the piping material.

Expansion joints or ball joints should be avoided if possible.

10.0 Roller-type pipe supports shall be specified where significant horizontal pipe movement will occur due to thermal expansion, and spring-type supports shall be specified where significant vertical movement will occur and where vibration isolation is needed due to building usage and program requirements.

11.0 Piping shall be designed and installed without undue stress or strain and run parallel to the lines of the building, except to grade them as specified in a neat and workmanlike manner using a minimum of fittings. Fittings, valves, and accessories shall be designed as may be required to meet the conditions of installation and accommodate service. Piping shall be designed to suit the necessities of clearance with ducts, conduits, and other work and so as not to interfere with any passages or doorways and allow sufficient headroom at all places.

12.0 Hazardous services piping shall be designed in strict compliance with applicable codes and/or relevant NFPA Standards.

13.0 System vents, relief valves, rupture disc, etc., shall be piped safely outdoors. Overflow pipes, system drains, and relief devices shall be piped to suitable drainage facilities and indirectly connected. Certain pieces of equipment may have high discharge rates that can quickly result in flooding; drains, sumps, or other receiving devices must have the storage volume required. The discharge piping from all steam safety valves shall be piped to a drip pan elbow and then to a safe discharge point on the exterior of the building at a minimum height of 10 feet above roof level. The drain connections from each drip pan elbow shall be piped to a floor drain.

14.0 Unions and flanges on each side of all pieces of equipment and other similar items shall be designed in such a manner that they can be readily disconnected. Unions and flanges shall not be placed in a location which will be inaccessible after completion of the project.

15.0 The project engineer shall specify testing and flushing procedures for each piping service installed on the project. Test procedures shall include all items required by code and be sufficient to prove all systems tight at conditions which exceed the maximum design conditions. Water sampling to establish a treatment plan, pipeline sterilization, positive pressure, and vacuum testing must be included as part of the procedures.

16.0 All piping systems shall be designed to meet seismic codes if required.

17.0 Underground Chilled Water Piping:

A. Underground piping systems shall be US Pipe TR-FLEX, ductile iron, class 250 with factory cut and fabricated joints with welded bead. Gripper rings, field lock gaskets or

any other method of restrained joint shall not be permitted. The minimum thickness of the cement lining shall be as follows:

Up to 12" – 1/16".

14" to 24" – 3/32".

Above 24" – 1/8".

The ductile pipe dimensions and tolerances shall conform to ANSI/AWWA C151/A21.51 Class 56 standards. The piping will be factory coated with an asphaltic coating. The contractor must be directed not to field apply any coating to the pipe. All underground piping must be cathodically protected. Pipe bedding shall be equal to Type 1 through 5 per ANSI/AWWA Standards. A holiday detector shall be used during the installation to determine if any faults exist in the asphaltic coating.

B. Provide air vents and hydrants at all high points.

C. Transition from ductile iron (TR-Flex) to building piping (steel) shall be made by a spun ductile iron flange (by US-pipe) to steel flange connection. Connection shall comply with ANSI / AWWA C151 / A21.51 "Class 250#". The use of mechanical fittings is prohibited. Consider piping restraining systems as required. Ductile iron connections shall not project more than 3' into building. Site work contractor shall be responsible for all DI piping systems. Building mechanical contractor is responsible for making the DI to steel connection. Pressure test laterals to determine supply and return before making final connections.

D. Laterals from mains through the building foundation shall be run straight with NO offsets.

E. Protection of the valves and valve boxes during construction is paramount. Avoid heavy loads directly on piping systems!

18.0 Underground Steam Piping:

A. Cellular glass insulated steel carrier pipe (steam-schedule 40 for pipes that are 10" and below and standard weight for 12" and above, condensate-schedule 80) inside insulated outer steel conduit and jacketed with extruded high-density polyethylene (HDPE). System needs to be drainable, dryable and testable. Outer casing field joints shall be wrapped with a shrink sleeve seal.

B. The design shall specify and indicate all thrust blocks, anchors, moment guides, oversized elbows and expansion loops necessary for a complete system. Include all end seals, gland seals and pipe supports. A holiday detector shall be used during the installation to determine if any faults exist in the conduit coating.

C. Manufacturers and models: Multi-Therm 500 with HDPE Jacket (By Permapipe-Ricwil), Duo-Therm 505 (By Thermacor), or Insul-800 (by Rovanco). No exceptions.

D. Threaded joints are permitted up to a 2" nominal pipe size. Above 2 inches, all joints must be flanged or welded.

E. Thermal PAK flexible ball and slip joints.

Ball joint shall be of integral design. Series P-2 Ductile iron seats with injectable packing cylinder while under full line pressure. Packing cylinder shall be a Type B (400H) packing cylinder. Type B contains an integral stainless steel safety valve to supplement the discharge tip design and provide a positive shut off when the plunger is used. Note: Specify removable and resilient insulation blanket.

Manufacturers: Advanced Thermal Systems, Inc. or Barco (600 Series / Style III)

19.0 General Underground Piping Considerations:

A. Typically, the University owns and maintains the Campus steam distribution piping after service from the local provider (Veolia Philadelphia).

B. All underground utility work within the right-of-way must follow the GPIS permitting system process. The A/E is responsible for entering the appropriate information in the system in a timely fashion to concur with the project schedule requirements.

C. All restoration by permit tee to be in accordance with the Streets Department Standard Construction Item publication.

D. A/E shall coordinate the termination of services with the Utility Companies.

20.0 Provide isolation valves outside buildings (not in the street – just inside the curb line preferred) as near to the connection to utility main and inside buildings

21.0 Piping System Pressure Loss Limitations:

All HVAC hot water, chilled water and condenser water piping systems shall be designed such that the fluid flow in gpm in each pipe segment shall not exceed the values listed in the table below for the appropriate total annual hours of operation. Pipe size selections for systems that operate under variable flow conditions and that contain variable frequency drive pump motors are allowed to be made from the "Variable Flow/Variable Speed" columns. All others shall be made from the "Other" columns Piping System Design Maximum Flow Rate in GPM

Piping System Design Maximum Flow Rate in GPM

ASHRAE 90.1 Compliance: Maximum flows (From Table 6.5.4.6).

| <=2000 hours/yr | | | | <=4400 hours/yr | | | <=8760 hours/yr | | |
|---|---|---|---|---|---|---|---|---|---|
| Pipe Size (in.) | Other | | Variable Flow/ Variable Speed | Other | | Variable Flow/ Variable Speed | Other | | Variable Flow/ Variable Speed |
| 1/2 | 4 | | 6.2 | 3 | | 4.7 | 2.4 | | 3.6 |
| 3/4 | 8.9 | | 14 | 6.7 | | 10 | 5.3 | | 8.1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 15 | | 23 | 12 | | 18 | 9.2 | | 14 |
| 1 1/4 | 22 | | 34 | 17 | | 26 | 13 | | 20 |
| 1 1/2 | 35 | | 52 | 26 | | 40 | 21 | | 32 |
| 2 | 77 | | 120 | 58 | | 89 | 46 | | 70 |
| 2 1/2 | 88 | | 140 | 67 | | 110 | 52 | | 80 |
| 3 | 180 | | 270 | 140 | | 210 | 110 | | 170 |
| 4 | 350 | | 530 | 260 | | 400 | 210 | | 320 |

| | <=2000 hours/yr | | | <=4400 hours/yr | | | <=8760 hours/yr | | |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 410 | | 620 | 310 | | 470 | 250 | | 370 |
| 6 | 740 | | 1100 | 570 | | 860 | 440 | | 670 |
| 8 | 1200 | | 1400 | 700 | | 1100 | 700 | | 830 |
| 10 | 1800 | | 2700 | 1300 | | 2000 | 1000 | | 1600 |
| 12 | 2500 | | 3800 | 1900 | | 2900 | 1500 | | 2300 |
| 14 | 3350 | | 5450 | 2700 | | 4000 | 2100 | | 3150 |
| 16 | 4400 | | 7100 | 3550 | | 5200 | 2750 | | 4100 |
| 18 | 5550 | | 9050 | 4500 | | 6600 | 3450 | | 5200 |
| 20 | 6900 | | 11000 | 5400 | | 8100 | 4300 | | 6400 |
| 24 | 10000 | | 16000 | 8150 | | 11900 | 6250 | | 9400 |
| 26 | 14000 | | 20000 | 10000 | | 16000 | 8200 | | 12000 |
| 30 | 17200 | | 26300 | 13100 | | 19000 | 10100 | | 15000 |

Exceptions:

1) Design flow rates exceeding the values in the Table above are allowed in specific sections of piping if the piping in question is not in the critical circuit at design conditions and is not predicted to be in the critical circuit during more than 30% of operating hours.
2) Piping systems that have equivalent or lower total pressure drop than the same system constructed with the standard weight steel pipe with piing and fittings sized per the Table above.

Notes:

- 26" Diameter Pipe is not a standard size. 24" ≤ Pipe Size Dia. ≤ 60", sizes increase in increments of 6".
- Maximum flows in pipe sizes less than 2-1/2 are not defined in ASHRAE 90.1-2016.

22.0 Pipe and fittings for all buildings shall be as defined as follows:

| | Service | Abbreviation | Color Code | Pipe | Fitting | Joints |
|---|---|---|---|---|---|---|
| 1. | Primary Building Chilled Water Supply and Return | CHS/CHR | Green | | | |
| a | 2-1/2" and larger | | | M | XIII | m |
| b | 2" and smaller | | | M | XV | j |
| c | 2" and smaller (optional) | | | J | XI | c |
| 2. | Secondary Chilled Water Supply and Return | SCHS/ SCHR | Green | | | |
| a | 5" and larger | | | M | XIII | m |
| b | 4" and smaller | | | J | XI | c |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3. | Glycol Water Supply and Return | GWS/ GWR | Green | | | |
| a | 2-1/2” and larger | | | M | XIII | m |
| b | 2” and smaller | | | M | XV | j |
| c | 2: and smaller (optional) | | | J | XI | c |
| 4. | Condenser Water Supply and Return | CWS/ CWR | Green | | | |
| a | 2-1/2” and larger | | | M | XIII | m |
| b | 2-1/2” and larger (optional) | | | M | XIV | h |
| 5. | Heating Water Supply and Return | HS/HR | Yellow | | | |
| a | 2-1/2” and larger | | | M | XIII | m |
| b | 2” and smaller | | | M | XV | j |
| c | 2” and smaller (optional) | | | J | XI | c |
| 6. | Reheat/Chilled Beam Water Supply and Return | RHS/RHR | Yellow | | | |
| a | 2-1/2” and larger | CHBS/CHBR | | M | XIII | m |

| Service | | Abbreviation | Color Code | Pipe | Fitting | Joints |
|---|---|---|---|---|---|---|
| b | 2” and smaller | | | M | XV | j |
| c | 2” and smaller (optional) | | | J | XI | c |
| 7. | Heat Recovery Supply and Return | HRS/HRR | Yellow | | | |
| a | 2-1/2” and larger | | | M | XIII | m |
| b | 2” and smaller | | | M | XV | j |
| c | 2” and smaller (optional) | | | J | XI | c |
| 8. | Secondary Heating Water Supply and Return | SHS/SHR | Yellow | | | |
| a | 5” and larger | | | M | XIII | m |
| b | 5” to larger (optional) | | | M | XIV | h |
| c | 4” and smaller | | | J | XI | c |
| 9. | Steam Supply 250 psi Maximum | HPS/ MPS/LPS | Yellow | | | |
| a | 2-1/2” and larger | | | M | XIII | m |
| b | 2” and smaller | | | M | XVI | j |
| c | 2” and smaller (optional) | | | M | XVII | m |
| 10. | Steam Relief | SR | Yellow | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| a | 2-1/2” and larger | | | M | XIII | m |
| b | 2” and smaller | | | M | XVI | j |
| c | 2” and smaller (optional) | | | M | XVII | m |
| 11. | Steam Vents | SV | Yellow | | | |
| a | 2-1/2” and larger | | | M | XIII | m |
| b | 2” and smaller | | | M | XVI | ~~l~~ j |
| c | 2” and smaller (optional) | | | M | XVII | m |
| 12. | Steam Condensate | HPR/ | Yellow | | | |
| | | | | | | |
| **Service** | | **Abbreviation** | **Color Code** | **Pipe** | **Fitting** | **Joints** |
| | | MPR/LPR | | | | |
| a | 2-1/2” and larger | | | N | XIII | m |
| b | 2” and smaller | | | N | XVI | j |
| c | 2” and smaller (optional) | | | N | XVII | m |
| 13. | Pump Condensate | PC | Yellow | | | |
| a | 2-1/2” and larger | | | N | XIII | m |

| | | | | | | |
|---|---|---|---|---|---|---|
| b | 2” and smaller | | | N | XVI | j |
| c | 2” and smaller (optional) | | | N | XVII | m |
| 14. | Steam Instrumentation | SI | Yellow | | | |
| a | 2” and smaller | | | M | XVI | j |
| b | 2” and smaller (optional) | | | M | XVII | m |
| 15. | Fuel Supply | FOS/FOR | Yellow | | | |
| a | 2-1/2” and larger | | | M | XIII | m |
| b | 2” and smaller | | | M | XV | j |
| 16. | Fuel Oil Vent | FOV | Yellow | M | XIII | m |
| 17. | Control Air | CA | Blue | J | XI | c |
| 18. | Refrigerant Piping | RS/RL<br>HG | Yellow | | XI | r |
| 19. | Refrigerant Relief | RR | Yellow | M | XIII | m |
| 20. | Generator Exhaust | GE | N/A | M | XIII | m |

23.0 Pipe Material indicated in the Table below shall be as follows:

| Pipe Specification | | Designation |
|---|---|---|
| 1. | Seamless copper water tube, ASTM B 88, Type K, hard | J |
| 2. | Black steel pipe, ASTM A 53/106 Grade B, seamless Schedule 40. Pipes >20" shall be electric resistance weld. | M |
| 3. | Black steel pipe, ASTM A 53/106 Grade B, seamless Schedule 80 | N |

24.0 Fitting materials indicated in the Table below shall be as follows:

| Fitting Specification | | Designation |
|---|---|---|
| 1. | Wrought-copper solder joint fittings, 68 kg, ANSI Standard B 16.18 or ASME/ANSI B<br><br>16.22 and ASTM B 4 copper pipe nipples with threaded end connections | XI |
| 2. | Steel butt-welding fittings, ANSI<br><br>Standard B 16.9 using long-turn ells, ANSI Standard B 16.5 weld-neck or slip-on flanges and Bonney Forge Woodlets and threadolets, wall thickness to match pipe | XIII |
| 3. | Black, malleable iron-grooved fittings and couplings, ASTM A47. | XIV |
| 4. | Black, malleable iron-screwed fittings, 68 kg, ANSI Standard B 16.3 for less than 517 kPa and 136 kg for 517 kPa or more | XV |
| 5. | Black, cast-iron screwed fittings, ANSI Standard B16.4, 57 kPa less than 517 kPa and 113 kg for 517 kPa and more. Steam and condensate piping shall be 113 kg for all operating pressures | XVI |
| 6. | Black steel socket welded fittings, ASNI Standard B 16.11 wall thickness to match pipe | XVII |

25.0 Joint materials indicated in the Table below shall be as follows:

| Joint Specification | | Designation |
|---|---|---|
| 1. | Soldered using ASTM B 32, 95-5 tin-antimony or Grade Sn 96 tin-silver and flux containing not more than 0.2% lead | c |
| 2. | ASME B 18.2.1 coupling nuts and bolts, ASTM D 2000 rubber gaskets for water service | h |
| 3. | Threaded using American Standard for pipe threads, ANSI Standard B 2.1 | j |
| 4. | Welded engineering standards of the Mechanical Contractors Association of America, Inc. Part VII, Standard Procedure Specifications 1 | m |
| **Joint Specification** | | **Designation** |
| | & 2 | |
| 5. | Brazed: AWS A5.8 BcuP (brazing-copper-phosphorus) series, greater than 538°C melting temperature, cadmium-free brazing filler; the use of flux is prohibited | r |

Methods and materials for wet taps, where permitted by the Office of the University Engineer, shall be submitted for approval by the A/E. Submittals shall include documentation on the products to be used with complete instructions and procedures to ensure successful wet taps.

26.0 Capping of Lines: Whenever demolition of existing piping systems occurs, no lines shall be left open ended. All lines shall be terminated with either a valve and a cap or plug, or with just a cap or plug. The cap or plug shall be installed to withstand the flow and pressure of the line that it is terminating in the event that the line is reenergized.