PART 19

Piping Systems

19.01 Water (Hydronic) Piping Systems

A. Pipe Sizing (See Appendix B):

1. 4 Ft./100 Ft. Maximum Pressure Drop.
2. 8 FPS Maximum Velocity Occupied Areas.
3. 10 FPS Maximum Velocity Unoccupied Areas.
4. Minimum pipe velocity 1.5 Fps, even under low load/flow conditions.
5. *ASHRAE Standard 90.1:* 4 Ft./100 Ft. Maximum Pressure Drop.
6. Standard Steel Pipe Sizes. ½″, ¾″, 1″, 1¼″, 1½″, 2″, 2½″, 3″, 4″, 6″, 8″, 10″, 12″, 14″, 16″, 18″, 20″, 24″, 30″, 36″, 42″, 48″, 54″, 60″, 72″, 84″, 96″.
7. Standard Copper Pipe Sizes. ½″, ¾″, 1″, 1¼″, 1½″, 2″, 2½″, 3″, 4″, 6″, 8″, 10″, 12″.
8. Standard Stainless Steel Pipe Sizes. ½″, ¾″, 1″, 1¼″, 1½″, 2″, 2½″, 3″, 4″, 6″, 8″, 10″, 12″, 14″, 16″, 18″, 20″, 24″.

B. Friction Loss Estimate

1. 1.5 × System Length (Ft.) × Friction Rate (Ft./100 Ft.).
2. Pipe Friction Estimate: 3.0–3.5 Ft./100 Ft.

C. Hydronic System Design and Piping Installation Guidelines:

1. Hydronic Systems Design Principle and Goal. Provide the correct water flow at the correct water temperature to the terminal users.
2. Common Design Errors:
   a. Differential pressure control valves are installed in pump discharge bypasses.
   b. Control valves not selected to provide control with system design pressure differentials at maximum and minimum flows.
   c. Control valves are selected with improper pressure drop.
   d. Incorrect primary/secondary/tertiary system design.
   e. Constant flow secondary or tertiary systems connected to variable flow primary or secondary systems, respectively.
   f. Check valves are not provided in pump discharges when pumps are operating in parallel.
   g. Automatic relief valves are oversized which result in quick, sudden, and sometimes violent system pressure fluctuations.
3. Piping System Arrangements:
   a. When designing pumping systems for chillers, boilers, and cooling towers, provide either a unitized pumping arrangement (each pump piped directly to each piece of central plant equipment) or provide a headered system.
   b. Unitized System:
      1) A unitized system should only be used when all the equipment in the system is the same capacity (chillers, boilers, cooling towers, and associated pumps).
   c. Headered System:
      1) A true headered system is preferred especially when chillers, cooling towers, boilers, and associated pumps are of unequal capacity.
      2) **DO NOT USE A MODIFIED HEADERED SYSTEM.** A modified headered system causes major operational problems; it does not work.
      3) When designing a headered system, Griswold Valves (flow control device) must be installed in the supply piping to each piece of equipment to obtain the proper flow through each piece of equipment. In addition to Griswold Valves, control valves must be installed to isolate equipment not in service if system is to be fully

automatic. These control valves should be provided with manual means of opening and closing in case of control system malfunction or failure.

4) Provide adequate provisions for expansion and contraction of piping in boiler, chiller, cooling tower, and pump headered systems. Provide U-shaped header connections for all equipment to accommodate expansion and contraction (first route piping away from header, then route parallel to the header, and finally route back toward header; size of U-shape will depend on the temperature of the system).

4. Minimum recommended hydronic system pipe size should be ¾ inch.
5. In general, noise generation, in hydronic systems, indicates erosion is occurring.
6. Large system diversities:
   a. Campus Heating. 80%.
   b. Campus Cooling. 65%.
   c. Constant Flow. Load is diversified only; flow is not diversified resulting in temperature changes.
   d. Variable Flow. Load and flow are both diversified.
7. When designing a campus or district type heating or cooling system, the controls at the interface between the central system and the building system should be secured so that access is limited to the personnel responsible for operating the central plant and not accessible to the building operators. Building operators may not fully understand the central plant operation and may unknowingly disrupt the central plant operation with system interface tinkering.
8. Differential pressure control of the system pumps should never be accomplished at the pump. The pressure bypass should be provided at the end of the system or the end each of the subsystems regardless of whether the system is a bypass flow system or a variable speed pumping system. Bypass flow need not exceed 20 percent of the pump design flow.
9. Central plant equipment (chillers, boilers, cooling towers, and associated pumps) should be of equal size units; however, system design may include ½ size units or ⅓ size units with full size equipment. For example, a chiller system may be made up of 1,200 ton, 600 ton, and 400 ton chillers. However, ⅓ sized units have limited application. This permits providing multiple units to achieve the capacity of a single unit and having two or three pumps operate to replace the one larger pump.
10. Pump Discharge Check Valves:
    a. Pump discharge check valves should be center guided, spring loaded, disc type check valves.
    b. Pump discharge check valves should be sized so that the check valve is full open at design flow rate. Generally this will require the check valve to be one pipe size smaller than the connecting piping.
    c. Condenser water system and other open piping system check valves should have globe style bodies to prevent flow reversal and slamming.
    d. Install check valves with 4 to 5 pipe diameters upstream of flow disturbances is recommended by most manufacturers.
11. Install air vents at all high points in water systems. Install drains at all low points in water systems. All automatic air vents, manual air vents, and drains in hydronic systems should be piped to a safe location within 6 inches of the floor, preferably over a floor drain, especially heating water systems.
12. Thermometers should be installed in both the supply and return piping to all water coils, chillers, boilers, heat exchangers, and other similar equipment. Thermometers should also be installed at each location where major return streams mix at a location approximately 10 pipe diameters downstream of the mixing point. Placing thermometers upstream of this point is not required, but often desirable, because the other return

thermometers located upstream will provide the water temperatures coming into this junction point. Placing thermometers in these locations will provide assistance in troubleshooting system problems. Liquid filled type thermometers are more accurate than the dial type thermometers.

13. Select water coils with tube velocities high enough at design flow so that tube velocities do not end up in the laminar flow region when the flow is reduced in response to low load conditions. Tube velocities become critical with units designed for 100 percent outside air at low loads near 32°F. Higher tube velocity selection results in a higher water pressure drop for the water coil. Sometimes a trade-off between pressure drop and low load flows must be evaluated.
14. Install manual air vent and drain on coupon rack to relieve pressure from coupon rack to facilitate removing coupons. Pipe drain to floor drain.
15. Install manual air vent on chemical feed tank and also pipe drain to floor drain.
16. Provide water meters on all makeup water and all blowdown water connections to hydronic systems (heating water, chilled water, condenser water, and steam systems). System water usage is critical in operating the systems, maintaining chemical levels, and troubleshooting the systems. If project budget permits, these meter readings should be logged and recorded at the building facilities management and control system.
17. Locate all valves, strainers, unions, and flanges so that they are accessible. All valves (except control valves) and strainers should be full size of pipe before reducing size to make connections to equipment and controls. Union and/or flanges should be installed at each piece of equipment, in bypasses and in long piping runs (100 feet or more) to permit disassembly for alteration and repairs.
18. Provide chainwheel operators for all valves in equipment rooms mounted greater than 7′-0″ above floor level, and chain should extend to 5′-0″ to 7′-0″ above floor level.
19. All balancing valves should be provided with position indicators and maximum adjustable stops (memory stops).
20. All valves should be installed so that valve remains in service when equipment or piping on equipment side of valve is removed.
21. Locate all flow measuring devices in accessible locations with straight section of pipe upstream (10 pipe diameters) and downstream (5 pipe diameters) of device or as recommended by manufacturer.
22. Provide a bypass around the water filters and water softeners. Show water filters and water softener feeding hydronic or steam systems on schematic drawings and plans.
23. Provide vibration isolators for all piping supports connected to and within 50 feet of isolated equipment and throughout mechanical equipment rooms, except at base elbow supports and anchor points.
24. Glycol systems do not use malleable iron fittings.
25. Water in a system should be maintained at a pH of approximately 8 to 9. A pH of 7 is neutral; below 7 is acid; above 7 is alkaline. Closed system water treatment should be 1600 to 2000 ppm Borax-Nitrite additive.
26. Terminal Systems:
    a. Design for the largest possible system delta T.
    b. Better to have terminal coils *slightly* oversized than undersized. Increasing flow rates in terminal coils to twice the design flow rate only increases coil capacity 5 to 16 percent, and tripling the flow rate only increases coil capacity 7 to 22 percent. Grossly oversized terminal unit coils can lead to serious control problems, so care must be taken in properly sizing coils.
27. Terminal Unit Control Methods:
    a. Constant Supply Temperature, Variable Flow.
    b. Variable Supply Temperature, Constant Flow.

c. Flow Modulation to a minimum value at constant supply temperature, at minimum flow a pump or fan, is started to maintain constant minimum flow at a variable supply temperature.
d. No primary system control, secondary system control accomplished by blending or face and bypass control.

28. Terminal Unit Design:
    a. Terminal unit design should be designed for the largest possible system delta T.
    b. Terminal unit design should be designed for the closest approach of primary return water temperature and secondary return temperature.
    c. Terminals must be selected for full load and for partial load performance.
    d. Select coils with high water velocities at full load, larger pressure drop. This will result in increased performance at partial loads.
29. Thermal Storage:
    a. Peak shaving. Constant supply with variable demand.
    b. Space heating/cooling. Variable supply with constant demand, waste heat recovery.
    c. Variable supply with variable demand.
30. Provide stop check valves (located closest to the boiler) and isolation valves with a drain between these valves on both the supply and return connections to all heating water boilers.
31. Boiler warming pumps should be piped to both the system header and to the boiler supply piping, thus allowing the boiler to be kept warm (in standby mode) from the system water flow or to warm the boiler when is has been out of service for repairs without the risk of shocking the boiler with system water temperature. Boiler warming pumps should be selected for 0.1 gpm/BHP (range 0.05 to 0.1 gpm/BHP). At 0.1 gpm/BHP, it takes 45 to 75 minutes to completely exchange the water in the boiler. This flow rate is sufficient to offset the heat loss by radiation and stack losses on boilers when in standby mode of operation. In addition, this flow rate allows the system to keep the boiler warm without firing the boiler, thus allowing for more efficient system operation. For example, it takes 8 to 16 hours to bring a bring a boiler on-line from a cold start. Therefore, the standby boiler must be kept warm to enable immediate start-up of the boiler upon failure of an operating boiler.
32. To provide fully automatic heating water system controls, the controls must look at and evaluate the boiler metal temperature (water temperature) and the refractory temperature prior to starting the primary pumps or enabling the boiler to fire. First, the boiler system design must circulate system water through the boilers to keep the boiler water temperature at system temperature when the boiler is in standby mode as discussed for boiler warming pump arrangements. Second, the design must look at the water temperature prior to starting the primary pumps to verify that the boiler is ready for service. And third, the design must look at refractory temperature to prevent boiler from going to high fire if the refractory is not at the appropriate temperature. However, the refractory temperature is usually handled by the boiler control package.
33. Heating Water System Warm-Up Procedure:
    a. Heating water system start-up should not exceed 120°F. temperature rise per hour, but boiler or heat exchanger manufacture limitations should be consulted.
    b. It is recommended that no more than a 25°F. temperature rise per hour be used when warming heating water systems. Slow warming of the heating water system allows for system piping, supports, hangers, and anchors to keep up with system expansion.
    c. Low temperature heating water systems (250°F and less) should be warmed slowly at 25°F. temperature rise per hour until system design temperature is reached.

d. Medium and high temperature heating water systems (above 250°F) should be warmed slowly at 25°F. temperature rise per hour until 250°F system temperature is reached. At this temperature the system should be permitted to settle for at least 8 hours or more (preferably overnight). The temperature and pressure maintenance time gives the system piping, hangers, supports, and anchors a chance to catch up with the system expansion. After allowing the system to settle, the system can be warmed up to 350°F or system design temperature in 25°F temperature increments and 25 psig pressure increments, semi-alternating between temperature and pressure increases, and allowing the system to settle for an hour before increasing the temperature or pressure to the next increment. When the system reaches 350°F and the design temperature is above 350°F. the system should be allowed to settle for at least 8 hours or more (preferably overnight). The temperature and pressure maintenance time gives the system piping, hangers, supports, and anchors a chance to catch up with the system expansion. After allowing the system to settle, the system can be warmed up to 455°F or system design temperature in 25°F temperature increments and 25 psig pressure increments, semi-alternating between temperature and pressure increases, and allowing the system to settle for an hour before increasing the temperature or pressure to the next increment.

34. Provide heating water systems with warm-up valves for in service startup as shown in the table on page 159. This will allow operators to warm these systems slowly and to prevent a sudden shock or catastrophic system failure when large system valves are opened. Providing warming valves also reduces wear on large system valves when they are only opened a small amount in an attempt to control system warm-up speed.
35. Heating Water System Warming Valve Procedure:
    a. First, open warming return valve slowly to pressurize the equipment without flow.
    b. Once the system pressure has stabilized, then slowly open the warming supply valve to establish flow and to warm the system.
    c. Once the system pressure and temperature have stabilized, then proceed with the following items listed below, one at a time:
        1) Slowly open the main return valve.
        2) Close the warming return valve.
        3) Slowly open the main supply valve.
        4) Close the warming supply valve.

D. Chilled Water Systems:

1. Leaving Water Temperature (LWT): 40–48°F. (60°F. Maximum)
2. ΔT Range 10–20°F.
3. Chiller Start-up and Shutdown Bypass: When starting a chiller, it takes 5 to 15 minutes from the time the chiller start sequence is initiated until the time the chiller starts to provide chilled water at the design temperature. During this time the chilled water supply temperature rises above the desired set point. If chilled water temperature is critical and this deviation unacceptable, the method to correct this problem is to provide the chillers with a bypass which runs from the chiller discharge to the primary pump suction header return. The common pipe only needs to be sized for the flow of one chiller because it is unlikely that more than one chiller will be started at the same time. Chiller system operation with a bypass should be as follows:
    a. On chiller start sequence, the primary chilled water pump is started, the bypass valve is opened, and the supply header valve is closed. When the chilled water supply temperature is reached, as sensed in the bypass, the supply header valve is slowly opened. When the supply header valve is fully opened, the bypass valve is slowly closed.

Bypass and Warming Valves

MAIN VALVE NOMINAL PIPE SIZE	NOMINAL PIPE SIZE	
	SERIES A WARMING VALVES	SERIES B BYPASS VALVES
4	1/2	1
5	3/4	1-1/4
6	3/4	1-1/4
8	3/4	1-1/2
10	1	1-1/2
12	1	2
14	1	2
16	1	3
18	1	3
20	1	3
24	1	4
30	1	4
36	1	6
42	1	6
48	1	8
54	1	8
60	1	10
72	1	10
84	1	12
96	1	12

Notes:
1. **Series A covers steam service for warming up before the main line is opened and for balancing pressures where lines are of limited volume.**
2. **Series B covers lines conveying gases or liquids where bypassing may facilitate the operation of the main valve through balancing the pressures on both sides of the disc or discs thereof. The valves in the larger sizes may be of the bolted on type.**

   b. On chiller stop sequence, the bypass valve is slowly opened. When the bypass valve is fully opened, the supply header valve is slowly closed. When the primary chilled water pump stops, the bypass valve is closed.
4. Large and campus chilled water systems should be designed for large delta T's and for variable flow secondary and tertiary systems.
5. Chilled water pump energy must be accounted for in the chiller capacity because they add heat load to the system.
6. Methods of Maintaining Constant Chilled Water Flow:
   a. Primary/Secondary Systems.
   b. Bypassing-Control.
   c. Constant volume flow only applicable to two chillers in series flow or single chiller applications.
7. It is best to design chilled water and condenser water systems to pump through the chiller.
8. When combining independent chilled water systems into a central plant,
   a. Create a central system concept, control scheme, and flow schematics.

b. The system shall only have a single expansion tank connection point sized to handle entire system expansion and contraction.
c. All systems must be altered, if necessary, to be compatible with central system concept (temperatures, pressures, flow concepts, variable or constant, control concepts).
d. For constant flow and variable flow systems, the secondary chillers are tied into the main chiller plant return main. Chilled water is pumped from the return main through the chiller and back to the return main.
e. District chilled water systems, due to their size, extensiveness, or both, may require that independent plants feed into the supply main at different points. If this is required, design and layout must enable isolating the plant; provide start-up and shutdown bypasses; and provide adequate flow, temperature, pressure, and other control parameter readings and indicators for proper plant operation, and other design issues which affect plant operation and optimization.

9. In large systems, it may be beneficial to install a steam-to-water or water-to-water heat exchanger to place an artificial load on the chilled water system to test individual chillers or groups of chillers during plant start-up, after repairs, or for troubleshooting chiller or system problems.

E. Low Temperature Chilled Water Systems (Glycol or Ice Water Systems)

1. Leaving Water Temperature (LWT): 20–40°F. (0°F. minimum)
2. ΔT Range 20–40°F.

F. Heating Water Systems General:

1. From a design and practical standpoint, low temperature heating water systems are often defined as systems with water temperatures 210°F. and less, and high temperature heating water systems are defined as systems with water temperatures 211°F. and higher.
2. Provide manual vent on top of heating water boiler to vent air from top of boiler during filling and system operation. Pipe manual vent discharge to floor drain.
3. Blowdown separators are not required for hot water boilers, but desirable for maintenance purposes. Install the blowdown separator so that the inlet to the separator is at or below the boiler drain to enable the use of the blowdown separator during boiler draining for emergency repairs.
4. Safety: High temperature hydronic systems when operated at higher system temperatures and higher system pressures will result in lower chance of water hammer and the damaging effects of pipe leaks. These high temperature heating water systems are also safer than lower temperature heating water systems because system leaks subcool to temperatures below scalding due to the sudden decrease in pressure and the production of water vapor.
5. Outside air temperature reset of low temperature heating water systems is recommended for energy savings and controllability of terminal units at low load conditions. However, care must be taken with boiler design to prevent thermal shock by low return water temperatures or to prevent condensation in the boiler due to low supply water temperatures and, therefore, lower combustion stack discharge temperature.
6. Circulating hot water through a boiler which is not operating, to keep it hot for standby purposes, creates a natural draft of heated air through the boiler and up the stack, especially in natural draft boilers. Forced draft or induced draft boilers have combustion dampers which close when not firing and therefore reduce, but not eliminate, this heat loss. Although this heat loss is undesirable for standby boilers, circulating hot water through the boiler is more energy efficient than firing the boiler. Operating a standby boiler may be in violation of air permit regulations in many jurisdictions today.

G. Low Temperature Heating Water Systems:

1. Leaving Water Temperature (LWT):	180–200°F.
2. ΔT Range	20–40°F.
3. Low Temperature Water	250°F. and less; 160 psig maximum

H. Medium and High Temperature Heating Water Systems:

1. Leaving Water Temperature (LWT):	350–450°F.
2. ΔT Range	20–100°F.
3. Medium Temperature Water	251–350°F.; 160 psig maximum
4. High Temperature Water	351–450°F.; 300 psig maximum

5. Submergence or antiflash margin is the difference between the actual system operating pressure and the vapor pressure of water at the system operating temperature. However, submergence or antiflash margin is often expressed in degrees Fahrenheit—the difference between the temperature corresponding to the vapor pressure equal to the actual system pressure and the system operating temperature.
6. Provide operators on valves on the discharge of the feed water pumps for medium and high temperature systems to provide positive shutoff because the check valves sometimes leak with the large pressure differential. Interlock the valves to open when the pumps operate. Verify that valve is open with an end switch or with a valve positioner.
7. Provide space and racks for spare nitrogen bottles in mechanically pressurized medium and high temperature heating water systems.
8. Medium and High Temperature Heating Water System Design Principles:
   a. System pressure must exceed the vapor pressure at the design temperature in all locations in the system. Verify this pressure requirement at the highest location in the system, at the pump suction, and at the control valve when at minimum flow or part load conditions. The greater the elevation difference, above the pressure source (in most cases the expansion tank), the higher the selected operating temperature in the medium and high temperature heating water system should be.
   b. Medium and high temperature water systems are unforgiving to system design errors in capacity or flow rates.
   c. Conversion factors in standard HVAC equations must be adjusted for specific gravity and specific heat at the design temperatures.
   d. Thermal expansion and contraction of piping must be considered and are critical in system design.
   e. Medium and high temperature heating water systems can be transported over essentially unlimited distances.
   f. The greater the system delta T, the more economical the system becomes.
   g. Use medium and high temperature heating water systems when required for process applications, because it produces precise temperature control and more uniform surface temperatures in heat transfer devices.
   h. The net positive suction head requirements of the medium and high temperature system pumps are critical and must be checked for adequate pressure. It is best to locate and design the pumps so that cavitation does not occur as follows:
      1) Oversize the pump suction line to reduce resistance.
      2) Locate the pump at a lower level than the expansion tank to take advantage of the static pressure gain.
      3) Elevate the expansion tank above the pumps.
      4) Locate the pumps in the return piping circuit and pump through the boilers, thus reducing the system temperature at the pumps, which reduces the vapor pressure requirements.

i. Either blending fittings or properly designed pipe fittings must be used when blending return water with supply water in large delta T systems or injecting medium and high temperature primary supply water into low temperature secondary circuits. When connecting piping to create a blending tee, the hotter water must always flow downward and the colder water must always flow upward. The blending pipe must remain vertical for a short length equal to a few pipe diameters on either side of the tee. Since turbulence is required for mixing action, it is not desirable to have straight piping for any great distance (a minimum of 10 pipe diameters is adequate).

9. Above approximately 300°F., the bearings and gland seals of a pump must be cooled. Consult factory representatives for all pumps for systems above 250°F. to determine specification requirements. Cooling water leaving the pump cooling jacket should not fall below 100°F. The best method for cooling seals is to provide a separate heat exchanger (one at each pump or one for a group of pumps) and circulate the water through the seal chamber. The heat exchanger should be constructed of stainless steel. Another method to cool the seals is to take a side stream flow off of the pump discharge, cool the flow, and inject it into the end face. This is not recommended because the amount of energy wasted is quite substantial.
10. Medium and high temperature heating water systems work well for radiant heating systems.
11. Control valves should be placed in the supply to heat exchangers with a check valve in the return. This practice provides a safety shutoff in case of a major leak in the heat exchanger. By placing the control valve in the supply when a leak occurs, the temperature or pressure increases on the secondary side causing the control valve to close while the check valve prevents back flow or pressure from the return. Flashing may occur with the control valve in the supply when a large pressure differential exists or when the system is operated without an antiflash margin. To correct this flashing, control must be split with one control valve in the supply and one control valve in the return.
12. If using medium or high temperature heating water systems to produce steam, the steam pressure dictates the delta T and thus the return water temperature.
13. Medium and High Temperature Heating Water Systems in Frequent Use:
    a. Cascade Systems with integral expansion space:
        1) Type 1. Feedwater pump piped to steam boiler.
        2) Type 2. Feedwater pump piped to medium or high temperature heating water system with steam boiler feedwater provided by medium and high temperature heating water system.
    b. Flooded generators with external expansion/pressurization provisions.
14. Medium and High Temperature Water System Boiler Types:
    a. Natural Circulators, Fire Tube and Water Tube Boilers.
    b. Controlled (Forced) Circulation.
    c. Combustion (Natural and Forced), Corner Tube Boilers.
15. Design Requirements:
    a. Settling camber to remove any foreign matter, dirt, and debris; oversized header with flanged openings for cleanout.
    b. Generator must never be blown down. Blowdown should only be done at the expansion tank or piping system.
    c. Boiler safety relief valves should only be tested when water content is cold; otherwise, flashing water-to-steam mixture will erode valve seat and after opening once or twice the safety relief valves will leak constantly.
    d. Boiler safety relief valves must only be considered protection for the boilers. Another safety relief valve must be provided on the expansion tank.
    e. Relief valves should be piped to a blowdown tank.

16. Medium and high temperature heating water systems may be pressurized by steam systems on the generator discharge or by pump or mechanical means on the suction side of the primary pumps pumping through the boilers.
17. Steam pressurized system characteristics are listed below:
    a. Steam pressurized systems are generally continuously operated with rare shutdowns.
    b. System expansion tank is pressurized with steam and contains a large volume of water at a high temperature, resulting in a considerable ability to absorb load fluctuations.
    c. Steam pressurized systems improve operation of combustion control.
    d. Steam pressurized system reduces the need to anticipate load changes.
    e. System is closed and the entry of air or gas is prevented, thus reducing or eliminating corrosion or flow restricting accumulations.
    f. Generally these systems can operate at a lower pressure than pump or mechanical pressurized systems.
    g. Steam pressurized systems have a higher first cost.
    h. These systems require greater space requirements.
    i. The large pressurization tank must be located above and over generators.
    j. Pipe discharges into a steam pressurized expansion tank should be vertically upward or should not exceed an angle greater than 45 degrees with respect to the vertical.
18. Mechanically pressurized system characteristics are listed below:
    a. Mechanically pressurized systems have flexibility in expansion tank location.
    b. Mechanically pressurized systems should be designed to pump through the generator; place the expansion and pressurization means at the pump suction inlet.
    c. Mechanically pressurized systems are best suited for intermittently operated systems.
    d. A submergence or antiflash margin must be provided.
    e. Nitrogen supply must be kept on hand. System cannot operate without nitrogen.
    f. Mechanically pressurized systems have a lower first cost.
    g. Mechanically pressurized systems require less expansion tank space.
    h. Start-up and shutdown of these systems simplified.
19. Pumps in medium and high temperature heating water systems should be provided with ½ to ¾ inch bypasses around the check valve and shutoff valves on the pump discharge:
    a. To refill the pump piping after repairs have been made.
    b. To allow for opening the system shutoff valve (often gate valve) which becomes difficult to open against the pressure differentials experienced.
    c. To allow for a slow warming of the pump and pump seals, and for letting sealing surfaces to seat properly.
20. Double valves should be installed on both the supply and return side of equipment for isolation on heating water systems, above 250°F. with a drain between these valves to visually confirm isolation. The double valving of systems ensures isolation because of the large pressure differentials which occur when the system is opened for repairs. Double valve all the following:
    a. Equipment.
    b. Drains.
    c. Vents.
    d. Gauges.
    e. Instrumentation.
    f. Double drain and vent valve operation: Fully open the valve closest to the system piping first. Then open the second valve modulating the second valve to control

flow to the desired discharge rate. Close second valve first when finished draining or venting. Operating in this fashion keeps the valve closest to the system from being eroded and thus allowing for the valve to provide tight shutoff when needed. In addition, this operation allows for replacement of the second valve with the system in operation since this valve receives most of the wear and tear during operation.

21. Do not use screw fittings because high and medium temperature water is very penetrating. Use welded or flanged fittings in lieu of screwed fittings. Do not use union joints.
22. Use of dissimilar metals must be avoided. Use only steel pipe, fittings, valves, flanges, and other devices.
23. Do not use cast iron or bronze body valves.
24. Use valves with metal to metal seats.
25. Do not use lubricated plug valves.

I. Dual Temperature Water System Types:

1. Leaving Cooling Water Temperature 40–48°F.
2. Cooling ΔT Range 10–20°F.
3. Leaving Heating Water Temperature: 180–200°F.
4. Heating ΔT Range 20–40°F.
5. 2-Pipe Switch-over Systems provide heating or cooling but not both.
6. 3-Pipe Systems provide heating and cooling at the same time with a blended return water temperature causing energy waste.
7. 4-Pipe Systems:
   a. Hydraulically joined at the terminal user (most common with fan coil systems with a single coil). Must design the heating and cooling systems with a common and single expansion tank connected at the generating end. At the terminal units the heating and cooling supplies should be connected and the heating and cooling returns should be connected.
   b. Hydraulically joined at the generator end (most common with condenser water heat recovery systems).
   c. Hydraulically joined at both ends.

J. Condenser Water Systems:

1. Entering Water Temperature (EWT): 85°F.
2. ΔT Range 10–20°F.
3. Normal ΔT 10°F.

K. Water Source Heat Pump Loop

1. Range: 60–90°F.
2. ΔT Range 10–15°F.

Water Equation Factors

SYSTEM TYPE	SYSTEM TEMPERATURE RANGE °F.	EQUATION FACTOR
LOW TEMPERATURE (GLYCOL) CHILLED WATER	0 - 40	SEE NOTE 2
CHILLED WATER	40 - 60	500
CONDENSER WATER HEAT PUMP LOOP	60 - 110	500
LOW TEMPERATURE HEATING WATER	110 - 150	490
	151 - 200	485
	201 - 250	480
MEDIUM TEMPERATURE HEATING WATER	251 - 300	475
	301 - 350	470
HIGH TEMPERATURE HEATING WATER	351 - 400	470
	401 - 450	470

Notes:
1. Water equation corrections for temperature, density and specific heat.
2. For glycol system equation factors, see paragraph 19.04, Glycol Solution Systems, below.

Hydronic System Design Temperaturers and Pressures

WATER TEMPERATURE °F.	VAPOR PRESSURE PSIG	SYSTEM OPERATING PRESSURE ANTIFLASH MARGIN						
		10 °F.	20 °F.	30 °F.	40 °F.	50 °F.	60 °F.	70 °F.
200	-3.2	-0.6	2.5	6	10	15	21	27
210	-0.6	2.5	6	10	15	21	27	35
212	0.0	3	7	11	16	22	29	36
215	0.9	4	8	13	18	24	31	39
220	2.5	6	10	15	21	27	35	43
225	4.2	8	13	18	24	30	39	48
230	6.1	10	15	21	27	35	43	52
240	10.3	15	21	27	34	43	52	63
250	15.1	21	27	34	43	52	63	75
260	20.7	27	34	43	52	63	75	88
270	27.2	34	43	52	63	75	88	103
275	30.7	39	47	58	69	81	96	111
280	34.5	43	52	63	75	88	103	120
290	42.8	52	63	75	88	103	120	138
300	52.3	63	75	88	103	120	138	159
310	62.9	75	88	103	120	138	159	181
320	74.9	88	103	120	138	159	181	206
325	81.4	96	111	129	148	170	193	219
330	88.3	103	120	138	159	181	206	232
340	103.2	120	138	159	181	206	232	262
350	119.8	138	159	181	206	232	262	294
360	138.2	159	181	206	232	262	294	329
370	158.5	181	206	232	262	294	329	367
375	169.5	193	219	247	277	311	347	387
380	180.9	206	232	262	294	329	367	407
390	205.5	232	262	294	329	367	407	452
400	232.4	262	294	329	367	407	452	500
410	261.8	294	329	367	407	452	500	551
420	293.8	329	367	407	452	500	551	606
425	310.9	347	387	429	475	524	578	635
430	328.6	367	407	452	500	551	606	665
440	366.5	407	452	500	551	606	665	729
450	407.4	452	500	551	606	665	729	797
455	429.1	475	525	578	635	697	762	832

Notes:

1. **Safety: High temperature hydronic systems when operated at higher system temperatures and higher system pressures will result in lower chance of water hammer and the damaging effects of pipe leaks. These high temperature heating water systems are also safer than lower temperature heating water systems because system leaks subcool to temperatures below scalding due to the sudden decrease in pressure and the production of water vapor.**
2. **The antiflash margin of 40°F. minimum is recommended for nitrogen or mechanically pressurized systems.**

L. Piping Materials:

1. 125 Psi (289 Ft.) and Less:
   a. 2″ and Smaller:
      1) Pipe: Black Steel Pipe, *ASTM A53, Schedule 40,* Type E or S, Grade B.
         Fittings: Black Malleable Iron Screw Fittings, 150 lb. *ANSI/ASME B16.3.*
         Joints: Pipe Threads, General Purpose (American) *ANSI/ASME B1.20.1.*
      2) Pipe: Black Steel Pipe, *ASTM A53, Schedule 40,* Type E or S, Grade B.
         Fittings: Cast Iron Threaded Fittings, 150 lb. *ANSI/ASME B16.4.*
         Joints: Pipe Threads, General Purpose (American) *ANSI/ASME B1.20.1.*

3) Pipe: Type "L" Copper Tubing, *ASTM B88,* Hard Drawn.
Fittings: Wrought Copper Solder Joint Fittings, *ANSI/ASME B16.22.*
Joints: Solder Joint with 95-5 tin antimony solder, 96-4 tin silver solder, or 94-6 tin silver solder, *ASTM B32.*

b. 2½″ thru 10″:
1) Pipe: Black Steel Pipe, *ASTM A53, Schedule 40,* Type E or S, Grade B.
Fittings: Steel Butt-Welding Fittings *ANSI/ASME B16.9.*
Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*
2) Pipe: Black Steel Pipe, *ASTM A53, Schedule 40,* Type E or S, Grade B.
Fittings: Factory Grooved End Fittings equal to Victaulic Full-Flow. Tees shall be equal to Victaulic Style 20, 25, 27, or 29.
Joints: Mechanical Couplings equal to Victaulic couplings Style 75 or 77 with Grade H gaskets, lubricated per manufacturer's recommendation.

c. 12″ and Larger:
1) Pipe: Black Steel Pipe, *ASTM A53,* ⅜″ wall, Type E or S, Grade B.
Fittings: Steel Butt-Welding Fittings *ANSI/ASME B16.9.*
Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*
2) Pipe: Black Steel Pipe, *ASTM A53,* ⅜″ wall, Type E or S, Grade B.
Fittings: Factory Grooved End Fittings equal to Victaulic Full-Flow. Tees shall be equal to Victaulic Style 20, 25, 27, or 29.
Joints: Mechanical Couplings equal to Victaulic couplings Style 75 or 77 with Grade H gaskets, lubricated per manufacturer's recommendation.

2. 126–250 psig (290–578 Ft.):

a. 1½″ and Smaller:
1) Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B.
Fittings: Forged Steel Socket-Weld, 300 lb., *ANSI B16.11.*
Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*
2) Pipe: Carbon Steel Pipe, *ASTM A106, Schedule 80,* Grade B.
Fittings: Forged Steel Socket-Weld, 300 lb., *ANSI B16.11.*
Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*

b. 2″ and Larger:
1) Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B.
Fittings: Steel Butt-Welding Fittings, 300 lb., *ANSI/ASME B16.9.*
Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*
2) Pipe: Carbon Steel Pipe, *ASTM A106, Schedule 80,* Grade B.
Fittings: Steel Butt-Welding Fittings, 300 lb., *ANSI/ASME B16.9.*
Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*

M. Pipe Testing:

1. 1.5 × System Working Pressure.
2. 100 Psi Minimum.

N. Closed Piping Systems: Piping systems with no more than one point of interface with a compressible gas (generally air).

O. Open Piping Systems: Piping systems with more than one point of interface with a compressible gas (generally air).

P. Reverse Return Systems: Length of supply and return piping is nearly equal. Reverse return systems are nearly self-balancing.

Q. Direct Return Systems: Length of supply and return piping is unequal. Direct return systems are more difficult to balance.

R. One-Pipe Systems:

1. One-pipe systems are constant volume flow systems.
2. All Series Flow Arrangements. Total circulation flows through every terminal user with lower inlet supply temperatures with each successive terminal device.
3. Diverted Series Flow Arrangements. Part of the flow goes through the terminal unit and the remainder is diverted around the terminal unit using a resistance device (balancing valve, fixed orifice, diverting tees, or flow control devices).

S. Two-Pipe Systems:

1. Same piping used to circulate chilled water and heating water.
2. Two-pipe systems are either constant volume flow or variable volume flow systems.
3. Direct Return Systems. Critical to provide proper balancing devices (balancing valves or flow control devices).
4. Reverse Return Systems. Generally limited to small systems, simplifies balancing.

T. Three-Pipe Systems (Obsolete):

1. Separate chilled water and heating water supply piping, common return piping used to circulate chilled water and heating water.

U. Four-Pipe Systems:

1. Separate supply and return piping (2 separate systems) used to circulate chilled water and heating water.
2. Four-pipe systems are either constant volume flow or variable volume flow systems.
3. Direct Return Systems. Critical to provide proper balancing devices (balancing valves or flow control devices).
4. Reverse Return Systems. Generally limited to small systems, simplifies balancing.

V. Ring or Loop Type Systems:

1. Piping systems which are laid out to form a loop with the supply and return mains parallel to each other.
2. Constant volume flow or variable volume flow systems.
3. Provide flexibility for future additions and provide service reliability.
4. Can be designed with better diversity factors.
5. During shutdown for emergency or scheduled repairs, maintenance, or modifications, loads, especially critical loads, can be fed from other direction or leg.
6. Isolation valves must be provided at critical junctions and between all major lateral connections so mains can be isolated and flow rerouted.
7. Flows and pressure distribution have to be estimated by trial and error or by computer.

W. Constant Volume Flow Systems:

1. Direct Connected Terminals. Flow created by main pump through 3-way valves.
2. Indirect Connected Terminals. Flow created by a separate pump with bypass and without output controls.
   a. Permits variable volume flow systems.
   b. Subcircuits can be operated with high pump heads without penalizing the main pump.
   c. Requires excess flow in the main circulating system.
3. Constant volume flow systems are limited to:
   a. Small systems with a single boiler or chiller.

  b. More than 1 boiler system if boilers are firetube or firebox boilers.
  c. Two chiller systems if chillers are connected in series.
  d. Small low temperature heating water systems with 10 to 20°F. delta T.
  e. Small chilled water systems with 7 to 10°F. delta T.
  f. Condenser water systems.
  g. Large chilled water and heating water systems with primary/secondary pumping systems, constant flow primary circuits.
4. Constant volume flow systems not suited to:
  a. Multiple watertube boiler systems.
  b. Parallel chiller systems.
  c. Parallel boiler systems.
5. Constant volume flow systems are generally energy inefficient.

X. Variable Volume Flow Systems:

1. At partial load, the variable volume flow system return temperatures approach the temperature in the secondary medium.
2. Significantly higher pressure differentials occur at part load and must be considered during design unless variable speed pumps are provided.

Y. Primary/Secondary/Tertiary Systems (PST Systems):

1. PST Systems decouple system circuits hydraulically, thereby making control, operation, and analysis of large systems less complex.
2. Secondary (Tertiary) pumps should always discharge into secondary (tertiary) circuits away from the common piping.
3. Cross-Over Bridge: Cross-over bridge is the connection between the primary (secondary) supply main and the primary (secondary) return main. Size cross-over bridge at a pressure drop of 1–4 Ft./100 Ft.
4. Common Piping: Common piping (sometimes called bypass piping) is the length of piping common to both the primary and secondary circuit flow paths and the secondary and tertiary circuit flow paths. Common piping is the interconnection between the primary and secondary circuits and the secondary and tertiary circuits. The common piping is purposely designed to an extremely low or negligible pressure drop and is generally only 6″ to 24″ long maximum. By designing for an extremely low pressure drop, the common piping ensures hydraulic isolation of the secondary circuit from the primary circuit and the tertiary circuit from the secondary circuit.
5. Extend common pipe size a minimum of 8 diameters upstream and a minimum of 4 diameters downstream when primary flow rate is considerably less than secondary flow rate (i.e., primary pipe size is smaller than secondary pipe size—use larger pipe size) to prevent any possibility of "jet flow." Common piping (bypass piping) in primary/secondary systems or secondary/tertiary systems should be a minimum of 10 pipe diameters in length and the same size as the larger of the two piping circuits.
6. A 1-Pipe Primary System uses one pipe for supply and return. The secondary circuits are in series. Therefore, this system supplies a different supply water temperature to each secondary circuit, and the secondary circuits must be designed for this temperature change.
7. A 2-Pipe Primary System uses two pipes, one for supply and one for return with a cross-over bridge connecting the two. The secondary circuits are in parallel. Therefore, this system supplies the same supply water temperature to each secondary circuit.

19.02 Steam Piping Systems

A. Steam Pipe Sizing (See Appendix C):

1. Low Pressure:
   a. Low Pressure Steam: 0–15 psig.
   b. 0.2–3 psi Total System Pressure Drop Max.
   c. ⅛–½ psi/100 Ft.
2. Medium Pressure:
   a. Medium Pressure Steam: 16–100 psig.
   b. 3–10 psi Total System Pressure Drop Max.
   c. ½–2 psi/100 Ft.
3. High Pressure:
   a. High Pressure Steam: 101–300 psig.
   b. 10–60 psi Total System Pressure Drop Max.
   c. 2–5 psi/100 Ft.
4. Steam Velocity:
   a. 15,000 FPM Maximum.
   b. 6,000–12,000 FPM Recommended.
   c. Low Pressure Systems: 4,000–6,000 FPM.
   d. Medium Pressure Systems: 6,000–8,000 FPM.
   e. High Pressure Systems: 10,000–15,000.
5. Friction Loss Estimate:
   a. 2.0 × System Length (Ft.) × Friction Rate (Ft./100 Ft.).
6. Standard Steel Pipe Sizes—½″, ¾″, 1″, 1¼″, 1½″, 2″, 2½″, 3″, 4″, 6″, 8″, 10″, 12″, 14″, 16″, 18″, 20″, 24″, 30″, 36″, 42″, 48″, 54″, 60″, 72″, 84″, 96″.
7. Total pressure drop in the steam system should not exceed 20% of the total maximum steam pressure at the boiler.
8. Steam condensate liquid to steam volume ratio is 1:1600 at 0 psig.
9. Flash Steam. Flash steam is formed when hot steam condensate under pressure is released to a lower pressure; the temperature drops to the boiling point of the lower pressure, causing some of the condensate to evaporate forming steam. Flash steam occurs whenever steam condensate experiences a drop in pressure and thus produces steam at the lower pressure.
   a. Low pressure steam systems flash steam is negligible and can be generally be ignored.
   b. Medium and high pressure steam systems flash steam is important to utilize and consider when sizing condensate piping.
   c. Flash Steam Recovery Requirements:
      1) To utilize flash steam recovery the condensate must be at a reasonably high pressure (medium and high pressure steam systems) and the traps supplying the condensate must be capable of operating with the back pressure of the flash steam system.
      2) There must be a use or demand for the flash steam at the reduced pressure. Demand for steam at the lower pressure should be greater than the supply of flash steam. The demand for steam should occur at the same time as the flash steam supply.
      3) The steam equipment should be in close proximity to the flash steam source to minimize installation and radiation losses and to fully take advantage of the flash steam recovery system. Flash steam recovery systems are especially advantageous when steam is utilized at multiple pressures within the facility and the distribution systems are already in place.

10. Saturated Steam:
    a. Saturated Steam. Saturated steam is steam that is in equilibrium with the liquid at a given pressure. One pound of steam has a volume of 26.8 Cu.Ft. at atmospheric pressure (0 psig).
    b. Dry Saturated Steam. Dry steam is steam which has been completely evaporated and contains no liquid water in the form of mist or small droplets. Steam systems which produce a dry steam supply are superior to systems which produce a wet steam supply.
    c. Wet Saturated Steam. Wet steam is steam which has not been completely evaporated and contains water in the form of mist or small droplets. Wet steam has a heat content substantially lower than dry steam.
    d. Superheated Steam. Superheated steam is dry saturated steam that is heated, which increases the temperature without increasing the system pressure.
11. Steam Types:
    a. Plant Steam. Steam produced in a conventional boiler system using softened and chemically treated water.
    b. Filtered Steam. Plant steam which has been filtered to remove solid particles (no chemical removal).
    c. Clean Steam. Steam produced in a clean steam generator using distilled, de-ionized, reverse-osmosis, or ultra-pure water.
    d. Pure Steam. Steam produced in a clean steam generator using distilled or de-ionized pyrogen free water, normally defined uncondensed water for injection.
12. Steam Purity versus Steam Quality:
    a. Steam Purity. A qualitative measure of steam contamination caused by dissolved solids, volatiles, or particles in vapor, or by tiny water droplets that may remain in the steam following primary separation in the boiler.
    b. Steam Quality. The ratio of the weight of dry steam to the weight of dry saturated steam and entrained water [Example: 0.95 quality refers to 95 parts steam (95%) and 5 parts water (5%)].

B. Steam Condensate Pipe Sizing (See Appendix C):

1. Steam Condensate Pipe Sizing Criteria Limits:
    a. Pressure Drop: 1⁄16–1.0 Psig/100 Ft.
    b. Velocity. Liquid Systems: 150 Ft./Min. Max.
    c. Velocity. Vapor Systems: 5000 Ft./Min. Max.
2. Recommended Steam Condensate Pipe Sizing Criteria:
    a. Low Pressure Systems:
        1) Pressure Drop: 1⁄8–1⁄4 Psig/100 Ft.
        2) Velocity. Vapor Systems: 2,000 to 3,000 feet per minute.
    b. Medium Pressure Systems:
        1) Pressure Drop: 1⁄8–1⁄4 Psig/100 Ft.
        2) Velocity. Vapor Systems: 2,000 to 3,000 feet per minute.
    c. High Pressure Systems:
        1) Pressure Drop: 1⁄4–1⁄2 Psig/100 Ft.
        2) Velocity. Vapor Systems: 3,000 to 4,000 feet per minute.
3. Wet Returns: Return pipes contain only liquid, no vapor. Wet condensate returns connect to the boiler below the water line so that the piping is always flooded.
4. Dry Returns: Return pipes contain saturated liquid and saturated vapor (most common). Dry condensate returns connect to the boiler above the waterline so that the piping is not flooded and must be pitched in the direction of flow. Dry condensate returns often carry steam, air, and condensate.

5. Open Returns: Return system is vented to atmosphere and condensate lines are essentially at atmospheric pressure (gravity flow lines).
6. Closed Returns: Return system is not vented to atmosphere.
7. Steam traps and steam condensate piping should be selected to discharge at 4 times the condensate rating of air handling heating coils and 3 times the condensate rating of all other equipment for system start-up.

C. Steam and Steam Condensate System Design and Pipe Installation Guidelines:

1. Minimum recommended steam pipe size is ¾ inch. Minimum recommended steam condensate pipe size is 1 inch.
2. Locate all valves, strainers, unions, and flanges so that they are accessible. All valves (except control valves) and strainers should be full size of pipe before reducing size to make connections to equipment and controls. Union and/or flanges should be installed at each piece of equipment, in bypasses and in long piping runs (100 feet or more), to permit disassembly for alteration and repairs.
3. Provide chainwheel operators for all valves in equipment rooms mounted greater than 7′-0″ above floor level and chain should extend to 5′-0″ to 7′-0″ above floor level.
4. All valves should be installed so that valve remains in service when equipment or piping on equipment side of valve is removed.
5. Locate all flow measuring devices in accessible locations with straight section of pipe upstream (10 pipe diameters) and downstream (5 pipe diameters) of device or as recommended by manufacturer.
6. Provide vibration isolators for all piping supports connected to and within 50 feet of isolated equipment, except at base elbow supports and anchor points, throughout mechanical equipment rooms, and for supports of steam mains within 50 feet of boiler or pressure reducing valves.
7. Pitch steam piping downward in direction of flow ¼″ per 10 Ft. (1″ per 40 Ft.) minimum.
8. Where length of branch lines are less than 8 feet, pitch branch lines downward toward mains ½″ per foot minimum.
9. Connect all branch lines to the top of steam mains (45 degree preferred, 90 degree acceptable).
10. Steam piping should be installed with eccentric reducers (flat on bottom) to prevent accumulation of condensate in the pipe and thus increasing the risk of water hammer.
11. Drip leg collection points on steam piping should be the same size as the steam piping to prevent steam condensate from passing over the drip leg and increasing the risk of water hammer. The drip leg collection point should be a minimum of 12 inches long including a minimum 6 inch long dirt leg with the steam trap outlet above the dirt leg.
12. Pitch all steam return lines downward in the direction of condensate flow ½″ per 10 Ft. minimum.
13. Drip legs must be installed at all low points, downfed runouts to all equipment, end of mains, bottom of risers, and ahead of all pressure regulators, control valves, isolation valves and expansion joints.
14. On straight runs with no natural drainage points, install drip legs at intervals not exceeding 200 feet where pipe is pitched downward in the direction of steam flow and a maximum of 100 feet where the pipe is pitched up so that condensate flow is opposite of steam flow.
15. Steam traps used on steam mains and branches shall be minimum ¾″ size.
16. When elevating steam condensate to an overhead return main, it requires 1 psi to elevate condensate 2 Ft. Try to avoid elevating condensate.
17. Control of steam systems with more than 2 million Btuh's should be accomplished with 2 or more control valves (see steam PRVs).

18. Double valves should be installed on the supply side of equipment for isolating steam systems, above 40 psig, with a drain between these valves to visually confirm isolation. The reason for double valving of systems is to ensure isolation because of the large pressure differentials which occur when the system is opened for repairs. Double valve all the following:
    a. Equipment.
    b. Drains.
    c. Vents.
    d. Gauges.
    e. Instrumentation.
19. Steam and steam condensate in a steam system should be maintained at a pH of approximately 8 to 9. A pH of 7 is neutral; below 7 is acid; above 7 is alkaline.
20. Provide stop check valve (located closest to the boiler) and isolation valve with a drain between these valves on the steam supply connections to all steam boilers.
21. Provide steam systems with warm-up valves for in service start-up as shown in the following table. This will allow operators to warm these systems slowly and to prevent a sudden shock or catastrophic system failure when large system valves are opened. Providing warming valves also reduces wear on large system valves when they are only opened a small amount in an attempt to control system warm-up speed.

Bypass and Warming Valves

MAIN VALVE NOMINAL PIPE SIZE	NOMINAL PIPE SIZE	
	SERIES A WARMING VALVES	SERIES B BYPASS VALVES
4	1/2	1
5	3/4	$1\frac{1}{4}$
6	3/4	$1\frac{1}{4}$
8	3/4	$1\frac{1}{2}$
10	1	$1\frac{1}{2}$
12	1	2
14	1	2
16	1	3
18	1	3
20	1	3
24	1	4
30	1	4
36	1	6
42	1	6
48	1	8
54	1	8
60	1	10
72	1	10
84	1	12
96	1	12

Notes:
1. **Series A covers steam service for warming up before the main line is opened, and for balancing pressures where lines are of limited volume.**
2. **Series B covers lines conveying gases or liquids where by-passing may facilitate the operation of the main valve through balancing the pressures on both sides of the disc or discs thereof. The valves in the larger sizes may be of the bolted on type.**

22. Steam System Warming Valve Procedure:
    a. Slowly open the warming supply valve to establish flow and to warm the system.
    b. Once the system pressure and temperature have stabilized, then proceed with the following items listed below, one at a time:
        1) Slowly open the main supply valve.
        2) Close the warming supply valve.
23. Steam System Warm-up Procedure:
    a. Steam system start-up should not exceed 120°F. temperature rise per hour, but boiler or heat exchanger manufacture limitations should be consulted.
    b. It is recommended that no more than a 25°F. temperature rise per hour be used when warming steam systems. Slow warming of the steam system allows for system piping, supports, hangers, and anchors to keep up with system expansion.
    c. Low pressure steam systems (15 psig and less) should be warmed slowly at 25°F. temperature rise per hour until system design pressure is reached.
    d. Medium and high pressure steam systems (above 15 psig) should be warmed slowly at 25°F. temperature rise per hour until 250°F-15 psig system temperature-pressure is reached. At this temperature-pressure the system should be permitted to settle for at least 8 hours or more (preferably overnight). The temperature-pressure maintenance time gives the system piping, hangers, supports, and anchors a chance to catch up with the system expansion. After allowing the system to settle, the system can be warmed up to 120 psig or system design pressure in 25 psig pressure increments; allow the system to settle for an hour before increasing the pressure to the next increment. When the system reaches 120 psig and the design pressure is above 120 psig, the system should be allowed to settle for at least 8 hours or more (preferably overnight). The pressure maintenance time gives the system piping, hangers, supports, and anchors a chance to catch up with the system expansion. After allowing the system to settle, the system can be warmed up to 300 psig or system design pressure in 25 psig pressure increments; allow the system to settle for an hour before increasing the pressure to the next increment.

D. Low Pressure Steam Pipe Materials:

1. 2″ and Smaller:
    a. Pipe: Black Steel Pipe, *ASTM A53, Schedule 40,* Type E or S, Grade B
       Fittings: Black Cast Iron Screw Fittings, 125 lb., *ANSI/ASME B16.4*
       Joints: Pipe Threads, General Purpose (American) *ANSI/ASME B1.20.1*
2. 2½″ thru 10″:
    a. Pipe: Black Steel Pipe, *ASTM A53, Schedule 40,* Type E or S, Grade B
       Fittings: Steel Butt-Welding Fittings, 125 lb., *ANSI/ASME B16.9*
       Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9*
3. 12″ and Larger:
    a. Pipe: Black Steel Pipe, *ASTM A53,* ⅜″ wall, Type E or S, Grade B
       Fittings: Steel Butt-Welding Fittings, 125 lb., *ANSI/ASME B16.9*
       Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9*

E. Low Pressure Steam Condensate Pipe Materials:

1. 2″ and Smaller:
    a. Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B
       Fittings: Black Cast Iron Screw Fittings, 250 lb., *ANSI/ASME B16.4*
       Joints: Pipe Threads, General Purpose (American) *ANSI/ASME B1.20.1*

2. 2½″ and Larger:
    a. Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B
       Fittings: Steel Butt-Welding Fittings, 250 lb., *ANSI/ASME B16.9*
       Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9*

F. Medium and High Pressure Steam and Steam Condensate Pipe:

1. 1½″ and Smaller:
    a. Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B
       Fittings: Forged Steel Socket-Weld, 300 lb., *ANSI B16.11*
       Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9*
    b. Pipe: Carbon Steel Pipe, *ASTM A106, Schedule 80,* Grade B
       Fittings: Forged Steel Socket-Weld, 300 lb., *ANSI B16.11*
       Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9*
2. 2″ and Larger:
    a. Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B
       Fittings: Steel Butt-Welding Fittings, 300 lb., *ANSI/ASME B16.9*
       Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9*
    b. Pipe: Carbon Steel Pipe, *ASTM A106, Schedule 80,* Grade B
       Fittings: Steel Butt-Welding Fittings, 300 lb., *ANSI/ASME B16.9*
       Joints: Welded pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9*

G. Pipe Testing:

1. 1.5 × System Working Pressure.
2. 100 Psi Minimum.

H. Steam Pressure Reducing Valves (PRV):

1. PRV Types:
    a. Direct Acting:
        1) Low Cost.
        2) Limited ability to respond to changing load and pressure.
        3) Suitable for systems with low flow requirements.
        4) Suitable for systems with constant loads.
        5) Limited control of downstream pressure.
    b. Pilot-Operated:
        1) Close control of downstream pressure over a wide range of upstream pressures.
        2) Suitable for systems with varying loads.
        3) Ability to respond to changing loads and pressures.
        4) Types:
            a) Pressure-Operated-Pilot.
            b) Temperature-Pressure-Operated-Pilot.
2. Use multiple stage reduction where greater than 100 psig reduction is required or where greater than 50 psig reduction is required to deliver a pressure less than 25 psig operating pressure or when intermediate steam pressure is required.
3. Use multiple PRVs where system steam capacity exceeds 2″ PRV size, when normal operation calls for 10% of design load for sustained periods, or when there are two distinct load requirements (i.e., summer/winter). Provide number of PRV's to suit project.
    a. If system capacity for a single PRV exceeds 2″ PRV size but is not larger than 4″ PRV size, use 2 PRVs with ⅓ and ⅔ capacity split.
    b. If system capacity for a single PRV exceeds 4″ PRV size, use 3 PRV's with 25%, 25%, and 50% or 15%, 35%, and 50% capacity split to suit project.

4. Smallest PRV to be no greater than ⅓ of system capacity. Maximum size PRV to be 4″ (6″ when 4″ PRV will require more than 3 valves per stage).
5. PRV bypass to be 2 pipe sizes smaller than largest PRV.
6. Provide 10 pipe diameters from PRV inlet to upstream header.
7. Provide 20 pipe diameters from PRV outlet to downstream header.
8. Maximum Pipe Velocity Upstream and Downstream of PRV:
   a. 8″ and Smaller: 10,000 FPM.
   b. 10″ and Larger: 8,000 FPM.
   c. Where low sound levels are required reduce velocities by 25% to 50%.
   d. If outlet velocity exceeds those listed above, use noise suppressor.
9. Avoid abrupt changes in pipe size. Use concentric reducers.
10. Limit pipe diameter changes to two pipe sizes per stage of expansion.

I. Safety Relief Valves:

1. The safety relief valve must be capable of handling the volume of steam as determined by the high pressure side of the largest PRV or the bypass, whichever is greater.
2. Use multiple safety relief valves if the capacity of a 4″ safety relief valve is exceeded. Each valve must have a separate connection to the pipeline.
3. Safety, Relief, and Safety Relief Valve testing is dictated by the Insurance Underwriter.

J. Steam Traps:

1. Steam Trap Types:
   a. A steam trap is a self-actuated valve that closes in the presence of steam and opens in the presence of steam condensate or non-condensible gases.
   b. Thermostatic Traps: React to differences in temperature between steam and cooled condensate. Condensate must be subcooled for the trap to operate properly. Thermostatic traps work best in drip and tracing service and where steam temperature and pressure are constant and predictable.
      1) Liquid Expansion Thermostatic Trap.
      2) Balanced Pressure Thermostatic Trap:
         a) Balanced pressure traps change their actuation temperature automatically with changes in steam pressure. Balanced pressure traps are used in application where system pressure varies.
         b) During start-up and operation, this trap discharges air and other non-condensibles very well. This trap is often used as a stand-alone air vent in steam systems.
         c) The balanced pressure trap will cause condensate to back up in the system.
      3) Bimetal Thermostatic Trap:
         a) Bimetal traps are rugged and resist damage from steam system events such as water hammer, freezing, superheated steam, and vibration.
         b) Bimetal traps cannot compensate for steam system pressure changes.
         c) Bimetal traps have a slow response time to changing process pressure and temperature conditions.
      4) Bellows Thermostatic Trap.
      5) Capsule Thermostatic Trap.
   c. Mechanical Traps: Operate by the difference in density between steam and condensate (buoyancy operated).
      1) Float & Thermostatic Traps:
         a) Process or modulating applications—will work in almost any application—heat exchangers, coils, humidifiers, etc.

b) Simplest type of mechanical trap
c) The F&T trap is the only trap that provides continuous, immediate, and modulating condensate discharge.
d) A thermostat valve is open when cold or when below saturation (steam) temperature to allow air to bleed out during system start-up and operation. The valve closes when the system reaches steam temperature.

2) Bucket Traps.
3) Inverted Bucket Traps:
a) Work best in applications with constant load and constant pressure—drips.
b) When the inverted bucket is filled with steam, it rises and closes the discharge valve preventing the discharge of steam. When the inverted bucket is filled with condensate, it drops opening the valve and discharging the condensate.
c) Inverted bucket traps are poor at removal of air and other non-condensible gases.

d. Kinetic Traps: Rely on the difference in flow characteristics of steam and condensate and the pressure created by flash steam.
1) Thermodynamic Traps:
a) Thermodynamic traps work best in drip and tracing service.
b) Thermodynamic traps can remove air and other non-condensibles during start-up only if the system pressures are increased slowly; because of this thermodynamic traps often require a separate air vent.
c) These traps snap open and snap shut and the sound can be annoying if used in noise sensitive areas.
d) The thermodynamic trap is rugged because is has only one moving part and is resistant to water hammer, superheated steam, freezing, and vibration.

2) Impulse or Piston Traps.
3) Orifice Traps.

2. Steam Trap Selection:
a. HVAC equipment steam traps should be selected to discharge three to four times the condensate rating of the equipment for system start-up.
b. Boiler header steam traps should be selected to discharge 3 to 5 times the condensate carryover rating of the boilers (typically 10%).
c. Steam main piping steam traps should be selected to discharge 2 to 3 times the condensate generated during the start-up mode caused by radiation losses.
d. Steam branch piping steam traps should be selected to discharge 3 times the condensate generated during the start-up mode caused by radiation losses.
e. Use float and thermostatic (F&T) traps for all steam supplied equipment.
1) Thermostatic traps may be used for steam radiators, steam finned tube, and other non-critical equipment, in lieu of F&T traps.
2) A combination of an inverted bucket trap and an F&T trap in parallel, with F&T trap installed above inverted bucket trap, may be used, in lieu of F&T traps.

f. Use inverted bucket traps for all pipeline drips.

3. Steam Trap Functions:
a. Steam traps allow condensate to flow from the heat exchanger or other device to minimize fouling, prevent damage, and to allow the heat transfer process to continue.
b. Steam traps prevent steam escape from the heat exchanger or other device.
c. Steam traps vent air or other non-condensible gases to prevent corrosion and allow heat transfer.

4. Common Steam Trap Problems:
a. Steam Leakage: Like all valves the steam trap seat is subject to damage, corrosion, and/or erosion. When the trap seat is damaged, the valve will not seal; thus, the steam trap will leak live steam.

b. Air Binding: Air, carbon dioxide, hydrogen, and other non-condensible gases trapped in a steam system will reduce heat transfer and can defeat steam trap operation.
c. Insufficient Pressure Difference: Steam traps rely on a positive pressure difference between the upstream steam pressure and the downstream condensate pressure to discharge condensate. When this is not maintained, the discharge of condensate is impeded.
   1) Overloading of the condensate return system is one cause: too much back pressure.
   2) Steam pressure that is too low is another cause.
d. Dirt: Steam condensate often contains dirt, particles of scale and corrosion, and other impurities from the system that can erode and damage the steam traps. Strainers should always be placed upstream of the steam traps to extend life.
e. Freezing: Freezing is normally only a problem when the steam system is shut down or idles and liquid condensate remains in the trap.
f. Noise: Thermodynamic traps are generally the only trap that produces noise when it operates. All other traps operate relatively quietly.
g. Maintenance: Steam traps, as with all valves, must be maintained. Most steam traps can be maintained in-line without removing the body from the connecting piping.

5. Steam Trap Characteristics are given in the following table.

Steam Trap Comparison

CHARACTERISTIC	STEAM TRAP TYPE		
	INVERTED BUCKET	FLOAT & THERMOSTATIC	LIQUID EXPANSION THERMOSTATIC
Method of Operation	Intermittent, Condensate drainage is continuous, discharge is intermittent	Continuous	Intermittent
No Load	Small Dribble	No Action	No Action
Light Load	Intermittent	Usually Continuous but May Cycle at High Pressures	Continuous, Usually Dribble Action
Normal Load	Intermittent	Usually Continuous but May Cycle at High Pressures	May Blast at High Pressures
Full or Overload	Continuous	Continuous	Continuous
Energy Conservation	Excellent	Good	Fair
Resistance to Wear	Excellent	Good	Fair
Corrosion Resistance	Excellent	Good	Good
Resistance to Hydraulic Shock	Excellent	Poor	Poor
Vents Air and CO_2 at Steam Temperature	Yes	No	No
Ability to Vent Air at Very Low Pressure (1/4 Psig)	Poor	Excellent	Good
Ability to Handle Start-up Air Loads	Fair	Excellent	Excellent
Operation Against Back Pressure	Excellent	Excellent	Excellent
Resistance to Damage from Freezing, Cast Iron Trap not Recommended	Good	Poor	Good
Ability to Purge System	Excellent	Fair	Good
Performance on Very Light Loads	Excellent	Excellent	Excellent
Responsiveness to Slugs of Condensate	Immediate	Immediate	Delayed
Ability to Handle Dirt	Excellent	Poor	Fair
Comparative Physical Size	Large	Large	Small
Ability to Handle Flash Steam	Fair	Poor	Poor

Steam Trap Comparison

CHARACTERISTIC	STEAM TRAP TYPE		
	INVERTED BUCKET	FLOAT & THERMOSTATIC	LIQUID EXPANSION THERMOSTATIC
Usual Mechanical Failure Mode	Open	Closed with Air Vent Open	Open or Closed Depending on Design
Subcooling	No	No	Yes
Venting	Fair	Excellent	Excellent
Seat Pressure Rating	Yes	Yes	N/A
Advantages	Rugged	Continuous condensate discharge	Utilizes sensible heat of condensate
	Tolerates water hammer without damage	Handles rapid pressure changes	Allows discharge of non-condensibles at startup to the set point temperature
		High non-condensible capacity	Not affected by superheated steam, water hammer, or vibration
			Resists freezing
Disadvantages	Discharges non-condensibles slowly (additional air vent required)	Float can be damaged by water hammer	Element subject to corrosion damage
	Level of condensate can freeze, damaging the trap body	Level of condensate in chamber can freeze, damaging float and body	Condensate backs up into the drain line and/or process
	Must have water seal to operate - subject to loosing prime	Some thermostatic air vent designs are susceptible to corrosion	
	Pressure fluctuations and superheated steam can cause loss of water seal		
Recommended Services	Continuous operation where non-condensible venting is not critical and rugged construction is important	Heat exchangers with high and variable heat transfer rates	Ideal for tracing used for freeze protection
		When condensate pump is required	Freeze protection - water and condensate lines and traps
		Batch processes that require frequent startup of an air filled system	Non-critical temperature control of heated tanks

Steam Trap Comparison

CHARACTERISTIC	STEAM TRAP TYPE		
	BALANCED PRESSURE THERMOSTATIC	BIMETAL THERMOSTATIC	THERMODYNAMIC
Method of Operation	Intermittent	Intermittent	Intermittent
No Load	No Action	No Action	No Action
Light Load	Continuous, Usually Dribble Action	Continuous, Usually Dribble Action	Intermittent
Normal Load	May Blast at High Pressures	May Blast at High Pressures	Intermittent
Full or Overload	Continuous	Continuous	Continuous
Energy Conservation	Fair	Fair	Poor
Resistance to Wear	Fair	Fair	Poor
Corrosion Resistance	Good	Good	Excellent
Resistance to Hydraulic Shock	Good	Good	Excellent
Vents Air and CO_2 at Steam Temperature	No	No	No
Ability to Vent Air at Very Low Pressure (1/4 Psig)	Good	Good	Not Recommended for Low Pressure Applications
Ability to Handle Start-up Air Loads	Excellent	Excellent	Poor
Operation Against Back Pressure	Excellent	Excellent	Poor
Resistance to Damage from Freezing, Cast Iron Trap not Recommended	Good	Good	Good
Ability to Purge System	Good	Good	Excellent
Performance on Very Light Loads	Excellent	Excellent	Poor
Responsiveness to Slugs of Condensate	Delayed	Delayed	Delayed
Ability to Handle Dirt	Fair	Fair	Poor
Comparative Physical Size	Small	Small	Small
Ability to Handle Flash Steam	Poor	Poor	Poor

Steam Trap Comparison

CHARACTERISTIC	STEAM TRAP TYPE		
	BALANCED PRESSURE THERMOSTATIC	BIMETAL THERMOSTATIC	THERMODYNAMIC
Usual Mechanical Failure Mode	Open or Closed Depending on Design	Open or Closed Depending on Design	Open, Dirt can cause to fail closed
Subcooling	Yes	Yes	No
Venting	Excellent	Excellent	Fair
Seat Pressure Rating	N/A	N/A	N/A
Advantages	Small and lightweight	Small and Lightweight	Rugged, withstands corrosion, water hammer, high pressure, and superheated steam
	Maximum discharge of non-condensibles at startup	Maximum discharge of non-condensibles at startup	Handles wide pressure range
	Unlikely to freeze	Unlikely to freeze and unlikely to be damaged if it does freeze	Compact and simple
		Rugged; Withstands corrosion, water hammer, high pressure, and superheated steam	Audible operations warns when repair is needed
Disadvantages	Some types of damage by water hammer, corrosion, and superheated steam	Responds slowly to load and pressure changes	Poor operation with very low pressure steam or high back pressure
	Condensate backs up into the drain line and/or process	More condensate backup than Balance Pressure Thermostatic Trap	Requires slow pressure buildup to remove air at startup to prevent air binding
		Back pressure changes operating characteristics	Noisy operation
Recommended Services	Batch processing requiring rapid discharge of non-condensibles at startup	Drip legs on constant-pressure steam mains	Steam main drips, tracers
	Drip legs on steam mains and tracing	Installations subject to ambient conditions below freezing	Constant-pressure, constant-load applications
	Installations subject to ambient conditions below freezing		Installations subject to ambient conditions below freezing

6. Steam Trap Inspection
   a. Method #1 is shown in the following table:

TRAP FAILURE RATE	STEAM TRAP INSPECTION FREQUENCY
OVER 10%	EVERY 2 MONTHS
5 TO 10%	EVERY 3 MONTHS
LESS THAN 5%	EVERY 6 MONTHS

b. Method #2 is shown in the following table:

SYSTEM PRESSURE	STEAM TRAP INSPECTION FREQUENCY
0 TO 30 PSIG	ANNUALLY
30 TO 100 PSIG	SEMI-ANNUALLY
100 TO 250 PSIG	QUARTERLY OR MONTHLY
OVER 250 PSIG	MONTHLY OR WEEKLY

19.03 Refrigerant Systems and Piping

A. Refrigeration System Design Considerations:

1. Refrigeration Load and System Size:
   a. Conduction Heat Gains, Sensible.
   b. Radiation Heat Gains, Sensible.
   c. Convection/Infiltration Heat Gains, Sensible and Latent.
   d. Internal Heat Gains, Lights, People, Equipment.
   e. Product Load, Sensible and Latent.
2. Part Load Performance, Minimum vs Maximum Load.
3. Piping Layout and Design:
   a. Assure proper refrigerant flow to feed evaporators.
   b. Size piping to limit excessive pressure drop and temperature rise and to minimize first cost.
   c. Assure proper lubricating oil flow to compressors and protect compressors for loss of lubricating oil flow.
   d. To prevent liquid (oil or refrigerant) from entering the compressors.
   e. Maintain a clean and dry system.
   f. To prevent refrigeration system leaks.
4. Refrigerant type selection and refrigerant limitations.
5. System operation, partial year or year round regardless of ambient conditions.
6. Load variations during short time periods.
7. Evaporator frost control.
8. Oil management under varying load conditions.
9. Heat exchange method.
10. Secondary coolant selection.
11. Installed cost, operating costs, maintenance costs, system efficiency and system simplicity.
12. Safe operation for building inhabitants.
13. Operating pressure and pressure ratios, single stage vs. two stage vs. multi-staged.
14. Special electrical requirements.

B. Refrigerant Pipe Design Criteria:

1. Halocarbon Refrigerants:
   a. Liquid Lines (Condensers to Receivers)—100 FPM or Less.

b. Liquid Lines (Receivers to Evaporator)—300 FPM or Less.
c. Compressor Suction Line—900 to 4,000 FPM.
d. Compressor Discharge Line—2,000 to 3,500 FPM.
e. Defrost Gas Supply Lines—1,000 to 2,000 FPM.
f. Condensate Drop Legs—150 FPM or Less.
g. Condensate Mains—100 FPM or less.
h. Pressure loss due to refrigerant liquid risers is 0.5 psi per foot of lift.
i. Liquid lines should be sized to produce a pressure drop due to friction that corresponds to a 1°F. to 2°F. change in saturation temperature or less.
j. Discharge and suction lines should be sized to produce a pressure drop due to friction that corresponds to a 2°F. change in saturation temperature or less.
k. Pump suction pipe sizing should be 2.5 fps maximum. Oversizing of pump suction piping should be limited to one pipe size.

2. Standard Steel Pipe Sizes: ½″, ¾″, 1″, 1¼″, 1½″, 2″, 2½″, 3″, 4″, 6″, 8″, 10″, 12″, 14″, 16″, 18″, 20″.
3. Standard Copper Pipe Sizes: ⅜″, ½″, ⅝″, ¾″, ⅞″, 1″, 1⅛″, 1¼″, 1⅜″, 1½″, 1⅝″, 2″, 2⅛″, 2½″, 2⅝″, 3″, 3⅛″, 3⅝″, 4″, 4⅛″, 6″, 8″, 10″, 12″.
4. Ammonia Refrigerant:
   a. Liquid lines should be sized for 2.0 Psi/100 Ft. of equivalent pipe length or less. Liquid lines should be sized for a 3:1, 4:1 or 5:1 overfeed ratio (4:1 recommended).
   b. Suction lines should be sized for 0.25, 0.5 or 1.0°F./100 Ft. of equivalent pipe length.
   c. Discharge lines should be sized for 1.0°F./100 Ft. of equivalent pipe length.
   d. Pump suction pipe sizing should be 3.0 fps maximum. Oversizing of pump suction piping should be limited to one pipe size.
   e. Cooling Water Flow Rate: 0.1 GPM/Ton.

C. Halocarbon Refrigerant Pipe Materials:

1. Pipe: Type "L (ACR)" Copper Tubing, *ASTM B280,* Hard Drawn.
   Fittings: Wrought Copper Solder Joint Fittings, *ANSI/ASME B16.22.*
   Joints: Classification BAg-1 (silver) AWS A5.8 Brazed-Silver Alloy brazing. Brazing shall be conducted using a brazing flux. Do not use an acid flux.

D. Ammonia Refrigerant Pipe Materials:

1. Liquid Lines:
   a. 1½″ and Smaller: Schedule 80 minimum
   b. 2″ to 6″: Schedule 40 minimum
   c. 8″ and Larger: Schedule 30 minimum
2. Suction, Discharge, and Vapor Lines
   a. 1½″ and Smaller: Schedule 80 minimum
   b. 2″ to 6″: Schedule 40 minimum
   c. 8″ and Larger: Schedule 30 minimum
3. Fittings:
   a. Couplings, elbows, tees, and unions for threaded piping systems must constructed of forged steel with a pressure rating of 300 psi.
   b. Welding fitting must match weight of pipe.
   c. Low pressure side piping, vessels, and flanges should be designed for 150 psi.
   d. High pressure side piping, vessels, and flanges should be designed for 250 psi if the system is water or evaporative cooled and 300 psi if the system is air cooled.
4. Joints:
   a. 1¼″ pipe and smaller may be threaded although, welded systems are superior.
   b. 1½″ pipe and larger must be welded.

5. Recommended Low Pressure Side Piping Requirements:
   a. 1¼″ and Smaller:
      Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B or Carbon Steel
      Pipe, *ASTM A106, Schedule 80,* Type S, Grade B.
      Fittings: Forged Steel Threaded Fittings, 3,000 Lb.
      Joints: Pipe Threads, General Purpose (American) *ANSI/ASME B1.20.1*
      OR
      Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B or Carbon Steel
      Pipe, *ASTM A106, Schedule 80,* Type S, Grade B.
      Fittings: Forged Steel Socket Weld, 150 Lb. *ANSI B16.11.*
      Joints: Welded Pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*
   b. 1½″:
      Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B or Carbon Steel
      Pipe, *ASTM A106, Schedule 80,* Type S, Grade B.
      Fittings: Forged Steel Socket Weld, 150 Lb. *ANSI B16.11.*
      Joints: Welded Pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*
   c. 2″ and Larger:
      Pipe: Black Steel Pipe, *ASTM A53, Schedule 40,* Type E or S, Grade B or Carbon Steel
      Pipe, *ASTM A106, Schedule 40,* Type S, Grade B.
      Fittings: Steel Butt-Welding Fittings, 150 Lb., *ANSI/ASME B16.9.*
      Joints: Welded Pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*

6. Recommended High Pressure Side Piping Requirements:
   a. 1¼″ and Smaller:
      Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B or Carbon Steel
      Pipe, *ASTM A106, Schedule 80,* Type S, Grade B.
      Fittings: Forged Steel Threaded Fittings, 3,000 Lb.
      Joints: Pipe Threads, General Purpose (American) *ANSI/ASME B1.20.1*
      OR
      Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B or Carbon Steel
      Pipe, *ASTM A106, Schedule 80,* Type S, Grade B.
      Fittings: Forged Steel Socket Weld, 300 Lb. *ANSI B16.11.*
      Joints: Welded Pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*
   b. 1½″:
      Pipe: Black Steel Pipe, *ASTM A53, Schedule 80,* Type E or S, Grade B or Carbon Steel
      Pipe, *ASTM A106, Schedule 80,* Type S, Grade B.
      Fittings: Forged Steel Socket Weld, 300 Lb. *ANSI B16.11.*
      Joints: Welded Pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*
   c. 2″ and Larger:
      Pipe: Black Steel Pipe, *ASTM A53, Schedule 40,* Type E or S, Grade B or Carbon Steel
      Pipe, *ASTM A106, Schedule 40,* Type S, Grade B.
      Fittings: Steel Butt-Welding Fittings, 300 Lb., *ANSI/ASME B16.9.*
      Joints: Welded Pipe, *ANSI/AWS D1.1* and *ANSI/ASME Sec. 9.*

E. Refrigerant Piping Installation:

1. Slope piping 1 percent in direction of oil return.
2. Install horizontal hot gas discharge piping with ½″ per 10 feet downward slope away from the compressor.
3. Install horizontal suction lines with ½″ per 10 feet downward slope to the compressor, with no long traps or dead ends which may cause oil to separate from the suction gas and return to the compressor in damaging slugs.
4. Liquid lines may be installed level.
5. Provide line size liquid indicators in main liquid line leaving condenser or receiver. Install moisture-liquid indicators in liquid lines between filter dryers and thermostatic expansion valves and in liquid line to receiver.
6. Provide line size strainer upstream of each automatic valve. Provide shutoff valve on each side of strainer.
7. Provide permanent filter dryers in low temperature systems and systems using hermetic compressors.
8. Provide replaceable cartridge filter dryers with three valve bypass assembly for solenoid valves that is adjacent to receivers.
9. Provide refrigerant charging valve connections in liquid line between receiver shutoff valve and expansion valve.
10. Normally only refrigerant suction lines are insulated, but liquid lines should be insulated where condensation will become a problem and hot gas lines should be insulated where personal injury from contact may pose a problem.
11. Refrigerant lines should be installed a minimum of 7′6″ feet above the floor.

F. Refrigerant Properties:

1. Halocarbon refrigerants absorb 40–80 Btuhs/Lb. and ammonia absorbs 500–600 Btuhs/Lb.
2. Ammonia refrigeration systems require smaller piping than halocarbon refrigeration systems for the same pressure drop and capacity.
3. Human or living tissue contact with many refrigerants in their liquid state can cause instant freezing, frostbite, solvent defatting or dehydration, and/or caustic or acid burns.
4. Leak detectors are essential for all halocarbon refrigerants because they are generally heavier than air, are odorless, and can cause suffocation due to oxygen depravation. Ammonia is lighter than air and has a distinctive and unmistakable odor.
5. Ammonia Properties:
    a. Refrigerant Grade Ammonia:
        99.98% Ammonia Minimum.
        0.015% Water Maximum.
        3 ppm Oil Maximum.
        0.2 ml/g Non-Condensable Gases.
    b. Agricultural Grade Ammonia:
        99.5% Ammonia Minimum.
        0.5% Water Maximum.
        0.2% Water Minimum.
        5 ppm Oil Maximum.

c. Ammonia Limitations are shown in the following table:

Concentration of Ammonia in the Air	Limitations/Symptoms
4 ppm	Detectable by human sense of smell.
25 ppm	Maximum ACGIH Permissible Exposure Limit (PEL). Maximum European Government Limit
30 - 35 ppm	Uncomfortable - breathing support desired or required. Common level around ammonia print machines. Maximum recommended exposure 15 minutes (ACGIH).
50 ppm	Maximum OSHA & NIOSH Permissible Exposure Limit (PEL).
100 ppm	Noticeable irritation to the eyes, throat, and mucous membranes.
400 ppm	Mucous membranes may be destroyed with prolonged contact with ammonia. No serious health threat with infrequent and less than 1 hour exposures.
500 ppm	Immediate Danger to Life and Health (IDLH) Limit.
700 ppm	Significant eye irritation.
1,700 ppm	Convulsive coughing occurs. Fatal after short exposures of less than one half hour.
2,500 ppm	Exposure in as short a time as 30 minutes is dangerous. Affects show up several days later - pulmonary edema (water in the lungs).
5,000 ppm and Above	Immediate hazard to life due to suffocation. Full face respiratory protection is required including eyes. Causes respiratory spasm, strangulation, and asphyxia - no exposure permissible.
15,000 ppm and Above	Full body protection required - ammonia reacts with body perspiration to form a caustic solution that attacks the skin causing burns and blisters.
160,000 - 270,000 ppm	Flammable in air at 68°F.
15.5% by Volume	Lower Flammability Limit (LFL) also referred to Lower Explosive Limit (LEL)

6. Refrigerant physical properties are shown in the following table:

REFRIGERANT PHYSICAL PROPERTIES								
REFRIGERANT		ASHRAE STD 15 GROUP NO.	MOLECULAR MASS	BOILING POINT AT 14.7 PSIA °F.	FREEZING POINT °F.	CRITICAL		
NO.	NAME					TEMP. °F.	PRESS. PSIA	VOLUME FT³/LB.
R-11	---	A1	137.38	74.87	-168.0	388.4	639.5	0.0289
R-12	---	A1	120.93	-21.62	-252.0	233.6	596.9	0.0287
R-13	---	A1	104.47	-114.60	-294.0	83.9	561.0	0.0277
R-13B1	---	A1	148.93	-71.95	-270.0	152.6	575.0	0.0215
R-14	---	A1	88.01	-198.30	-299.0	-50.2	543.0	0.0256
R-22	---	A1	86.48	-41.36	-256.0	204.8	721.9	0.0305
R-40	---	B2	50.49	-11.60	-144.0	289.6	968.7	0.0454
R-113	---	A1	187.39	117.63	-31.0	417.4	498.9	0.0278
R-114	---	A1	170.94	38.80	-137.0	294.3	473.0	0.0275
R-115	---	A1	154.48	-38.40	-159.0	175.9	457.6	0.0261
R-123	---	B1	152.93	82.17	-160.9	362.8	532.9	---
R-134a	---	A1	102.03	-15.08	-141.9	214.0	589.8	0.0290
R-142b	---	A2	100.50	14.40	-204.0	278.8	598.0	0.0368
R-152a	---	A2	66.05	-13.00	-178.6	236.3	652.0	0.0439
R-170	ETHANE	A3	30.07	-127.85	-297.0	90.0	709.8	0.0830
R-290	PROPANE	A3	44.10	-43.73	-305.8	206.3	617.4	0.0728
R-C318	---	A1	200.04	21.50	-42.5	239.6	403.6	0.0258
R-500	---	A1	99.31	-28.30	-254.0	221.9	641.9	0.0323
R-502	---	A1	111.63	-49.80	---	179.9	591.0	0.0286
R-503	---	A1	87.50	-127.60	---	67.1	607.0	0.0326
R-600	BUTANE	A3	58.13	31.10	-217.3	305.6	550.7	0.0702
R-600a	ISOBUTANE	A3	58.13	10.89	-255.5	275.0	529.1	0.0725
R-611	---	B2	60.05	89.20	-146.0	417.2	870.0	0.0459
R-717	AMMONIA	B2	17.03	-28.00	-107.9	271.4	1657.0	0.0680
R-744	CARBON DIOXIDE	A1	44.01	-109.20	-69.9	87.9	1070.0	0.0342
R-764	SULFUR DIOXIDE	B1	64.07	14.00	-103.9	315.5	1143.0	0.0306
R-1150	ETHYLENE	A3	28.05	-154.7	-272.0	48.8	742.2	0.0700
R-1270	PROPYLENE	A3	42.09	-53.86	-301.0	197.2	670.3	0.0720

REFRIGERANT TYPE	ENERGY ABSORPTION RATE BTU/LB.				
	40°F.	20°F.	0°F.	-20°F.	-40°F.
R-11	80.863	82.507	84.126	85.732	87.335
R-12	64.649	66.953	69.098	71.116	73.038
R-22	86.503	90.344	93.891	97.193	100.296
R-123	76.787	78.078	79.167	80.162	81.340
R-134a	84.011	87.589	90.925	94.063	97.050
R-502	61.687	65.069	68.101	70.795	73.162
R-717 AMMONIA	535.936	552.858	568.692	583.540	597.482

19.04 Glycol Solution Systems

A. Glycol System Design Considerations:

1. HVAC system glycol applications should use an industrial grade ethylene glycol (phosphate based) or propylene glycol (phosphate based) with corrosion inhibitors without fouling. Specify glycol to have ZERO silicate content.
2. Automobile antifreeze solutions should *NOT* be used for HVAC systems because they contain silicates to protect aluminum engine parts. But these silicates found in automobile antifreeze causes fouling in HVAC systems.
3. Consider having the antifreeze dyed to facilitate leak detection.
4. Glycol systems should be filled with a high quality water, preferably distilled or deionized (deionized recommended) water, or filled with pre-diluted solutions of industrial grade glycol. Water should have less than 25 ppm of chloride and sulfate, and less than 50 ppm of hard water ions (Ca++, Mg++). City water is treated with chlorine, which is corrosive.
5. Automatic makeup water systems should be avoided to prevent system contamination or system dilution. A low level liquid alarm should be used in lieu of an automatic fill line.
6. Systems should be clean with little or no corrosion.
7. Industrial grade glycol will last up to 20 years in a system if properly maintained.
8. Propylene glycol should be used where low oral toxicity is important or where incidental contact with drinking water is possible.
9. Expansion tank sizing is critical to the design of glycol systems. The design should allow for a glycol level of about two-thirds full during operation. Glycol will expand about 6 percent.
10. Water quality should be analyzed at each site for careful evaluation of the level of corrosion protection required.
11. Foaming of a glycol system is usually caused by air entrainment, improper expansion tank design, contamination by organics (oil, gas) or solids, or improper system operation. Foaming will reduce heat transfer and aggravate cavitation corrosion.
12. A buffering agent should be added to maintain fluid alkalinity, minimize acidic corrosive attack, and counteract fluid degradation. Proper buffering agents will reduce fluid maintenance, extend fluid life, and be less sensitive to contamination.

13. A non-absorbent bypass filter, of the sock or cartridge variety, should be installed in each glycol system.
14. An annual chemical analysis should be conducted to determine the glycol content, oxidative degradation, foaming agent concentration, inhibitor concentration, buffer concentration, freezing point, and pH, reserve alkalinity.

ETHYLENE GLYCOL CHARACTERISTICS	PROPYLENE GLYCOL CHARACTERISTICS
MORE EFFECTIVE FREEZE POINT DEPRESSION	LESS EFFECTIVE FREEZE POINT DEPRESSION
BETTER HEAT TRANSFER EFFICIENCY	LOWER HEAT TRANSFER EFFICIENCY
LOWER VISCOSITY	HIGHER VISCOSITY
LOW FLAMMABILITY	LOW FLAMMABILITY
LOW CHEMICAL OXYGEN DEMAND - MORE FRIENDLY TO THE ENVIRONMENT	HIGH CHEMICAL OXYGEN DEMAND - LESS FRIENDLY TO THE ENVIRONMENT
BIODEGRADES IN A REASONABLE PERIOD OF TIME - 10 TO 20 DAYS COMPLETELY	GREATER RESISTANCE TO COMPLETE BIODEGRADATION - MORE THAN 20 DAYS
NON-CARCINOGENIC	NON-CARCINOGENIC
HIGHER LEVEL OF ACUTE (SHORT TERM) AND CHRONIC (LONG TERM) TOXICITY TO HUMANS AND ANIMALS WHEN TAKEN ORALLY - TARGETS THE KIDNEY	LOWER LEVEL OF ACUTE (SHORT TERM) AND CHRONIC (LONG TERM) TOXICITY TO HUMANS AND ANIMALS WHEN TAKEN ORALLY
MILD EYE IRRITANT	MILD EYE IRRITANT
LESS IRRITATING TO THE SKIN	MORE IRRITATING TO THE SKIN
NO ADVERSE REPRODUCTIVE EFFECTS IN LIFETIME OR THREE GENERATION STUDIES	NO ADVERSE REPRODUCTIVE EFFECTS IN LIFETIME OR THREE GENERATION STUDIES
AT HIGH CONCENTRATIONS DURING PREGNANCY, WILL CAUSE BIRTH DEFECTS AND TOXIC TO THE FETUS	AT THE SAME CONCENTRATIONS DURING PREGNANCY, WILL NOT CAUSE BIRTH DEFECTS
RELATIVELY NON-TOXIC TO SEWAGE MICROORGANISMS NEEDED FOR BIODEGRADATION AND TO AQUATIC LIFE	RELATIVELY NON-TOXIC TO SEWAGE MICROORGANISMS NEEDED FOR BIODEGRADATION AND TO AQUATIC LIFE

Ethylene Glycol

% GLYCOL SOLUTION	TEMPERATURE °F. FREEZE POINT	TEMPERATURE °F. BOILING POINT	SPECIFIC HEAT	SPECIFIC GRAVITY (1)	EQUATION FACTOR
0	+32	212	1.00	1.000	500
10	+26	214	0.97	1.012	491
20	+16	216	0.94	1.027	483
30	+4	220	0.89	1.040	463
40	-12	222	0.83	1.055	438
50	-34	225	0.78	1.067	416
60	-60	232	0.73	1.079	394
70	<-60	244	0.69	1.091	376
80	-49	258	0.64	1.101	352
90	-20	287	0.60	1.109	333
100	+10	287+	0.55	1.116	307

Propylene Glycol

% GLYCOL SOLUTION	TEMPERATURE °F. FREEZE POINT	TEMPERATURE °F. BOILING POINT	SPECIFIC HEAT	SPECIFIC GRAVITY (1)	EQUATION FACTOR
0	+32	212	1.000	1.000	500
10	+26	212	0.980	1.008	494
20	+19	213	0.960	1.017	488
30	+8	216	0.935	1.026	480
40	-7	219	0.895	1.034	463
50	-28	222	0.850	1.041	442
60	<-60	225	0.805	1.046	421
70	<-60	230	0.750	1.048	393
80	<-60	230+	0.690	1.048	362
90	<-60	230+	0.645	1.045	337
100	<-60	230+	0.570	1.040	296

Note for ethylene and propylene glycol tables

1. Specific gravity with respect to water at 60°F.

19.05 Air Conditioning (AC) Condensate Piping

A. AC Condensate Flow:

1. Range: 0.02–0.08 GPM/Ton
2. Average: 0.04 GPM/Ton
3. Unitary Packaged AC Equipment: 0.006 GPM/Ton
4. Air Handling Units (100% outside Air): 0.100 GPM/1,000 CFM
5. Air Handling Units (50% Outdoor Air): 0.065 GPM/1,000 CFM

6. Air Handling Units (25% Outdoor Air): 0.048 GPM/1,000 CFM
7. Air Handling Units (15% Outdoor Air): 0.041 GPM/1,000 CFM
8. Air Handling Units (0% Outdoor Air): 0.030 GPM/1,000 CFM

B. AC Condensate Pipe Sizing

1. Minimum Pipe Sizes are given in the following table.

AC TONS	MINIMUM DRAIN SIZE
0 -20	1"
21 - 40	1-1/4"
41 - 60	1-1/2"
61 - 100	2"
101 - 250	3"
251 & LARGER	4"

2. Pipe size shall not be smaller than drain pan outlet. Minimum size below grade and below ground floor shall be 2½″ (4″ Allegheny Co., PA). Drain shall have slope of not less than ⅛″ per foot.
3. Some localities require AC condensate to be discharged to storm sewers, some require AC condensate to be discharged to sanitary sewers, and some permit AC condensate to be discharged to either storm or sanitary sewers. Verify pipe sizing and discharge requirements with local authorities and codes.

19.06 Valves

A. Valve Types:

1. Balancing Valves:
   a. Duty: Balancing, Shutoff (Manual or Automatic).
   b. A valve specially designed for system balancing.
2. Ball Valves Full Port:
   a. Duty: Shutoff.
   b. A valve with a spherical shaped internal flow device which rotates open and closed to permit flow or to obstruct flow through the valve. The valve goes from full open to full close in a quarter turn. The opening in the spherical flow device is the same size or close to the same size as the pipe.
3. Ball Valves, Reduced Port:
   a. Duty: Balancing, Shutoff.
   b. A valve with a spherical shaped internal flow device which rotates open and closed to permit flow or to obstruct flow through the valve. The valve goes from full open to full close in a quarter turn. The opening in the spherical flow device is smaller than the pipe size.
4. Butterfly Valves:
   a. Duty: Shutoff, Balancing.

  b. A valve with a disc shaped internal flow device which rotates open and closed to permit flow or to obstruct flow through the valve. The valve goes from full open to full close in a quarter turn.
5. Check Valves:
  a. Duty: Control Flow Direction.
  b. A valve which is opened by the flow of fluid in one direction and which closes automatically to prevent flow in the reverse direction. (Types: Ball, Disc, Globe, Piston, Stop, Swing).
6. Gate Valves:
  a. Duty: Shutoff.
  b. A valve with a wedge or gate shaped internal flow device which moves on an axis perpendicular to the direction of flow.
7. Globe Valves:
  a. Duty: Throttling.
  b. A valve with a disc or plug which moves on an axis perpendicular to the valve seat.
8. Plug Valves:
  a. Duty: Shutoff, Balancing.
  b. A valve with a cylindrical or conical shaped internal flow device which rotates open and closed to permit flow or obstruct flow through the valve. The valve goes from full open to full close in a quarter turn.
9. Control Valves. Control valves are mechanical devices used to control flow of steam, water, gas, and other fluids.
  a. 2-Way. Temperature Control, Modulate Flow to Controlled Device, Variable Flow System.
  b. 3-Way Mixing. Temperature Control, Modulate Flow to Controlled Device, Constant Flow System; 2 inlets and 1 outlet.
  c. 3-Way Diverting. Used to Divert Flow; generally cannot modulate flow—2 position: 1 inlet and 2 outlets.
  d. Quick Opening Control Valves: Quick opening control valves produce wide free port area with relatively small percentage of total valve stem stroke. Maximum flow is approached as the valve begins to open.
  e. Linear Control Valves: Linear control valves produce free port areas that are directly related to valve stem stroke. Opening and flow are related in direct proportion.
  f. Equal Percentage Control Valves: Equal percentage control valves produce an equal percentage increase in the free port area with each equal increment of valve stem stroke. Each equal increment of opening increases flow by an equal percentage over the previous value (most common HVAC control valve).
  g. Control valves are normally smaller than line size unless used in 2-position applications (open/closed).
  h. Control valves should normally be sized to provide 20 to 60% of the total system pressure drop.
    1) Water system control valves should be selected with a pressure drop equal to 2–3 times the pressure drop of the controlled device.

       OR

       Water system control valves should be selected with a pressure drop equal to 10 Ft. or the pressure drop of the controlled device, whichever is greater.

       OR

       Water system control valves for constant flow systems should be sized to provide 25% of the total system pressure drop.

       OR

Water system control valves for variable flow systems should be sized to provide 10% of the total system pressure drop or 50% of the total available system pressure.

2) Steam control valves should be selected with a pressure drop equal to 75% of inlet steam pressure.

10. Specialty Valves:
    Triple Duty Valves: Combination Check, Balancing, and Shutoff.
    Backflow Preventer: Prevent Contamination of Domestic Water System. For HVAC applications use reduced pressure backflow preventers.
11. Valves used for balancing need not be line size. Balancing valves should be selected for midrange of its adjustment.

B. Valve Terms:

1. Actuator. A mechanical, hydraulic, electric, or pneumatic device or mechanism used to operate a valve.
2. Adjustable Travel Stop. A mechanism used to limit the internal flow device travel.
3. Back Face. The side of the flange opposite the gasket.
4. Blind Flange. A flange with a sealed end to provide a pressure tight closure of a flanged opening.
5. Body. The pressure containing shell of a valve or fitting with ends for connection to the piping system.
6. Bonnet. A valve body component which contains an opening for the stem. The bonnet may be bolted (Bolted Bonnet), threaded (Threaded Bonnet), or a union (Union Bonnet).
7. Bronze Mounted. The seating surfaces of the valve are made of brass or bronze.
8. Butt Welding Joints. A joint made to pipes, valves, and fittings with ends adapted for welding by abutting the ends and welding them together.
9. Chainwheel. A manual actuator which uses a chain-driven wheel to turn the valve flow device by turning the stem, handwheel, or gearing.
10. Cock. A form of a plug valve.
11. Cold Working Pressure. Maximum pressure at which a valve or fitting is allowed to operate at ambient temperature.
12. Concentric Reducer. A reducer in which both of the openings are on the same centerline.
13. Eccentric Reducer. A reducer with the small end off center.
14. Elbow, Long Radius. An elbow with a centerline turning radius of 1½ times the nominal size of the elbow.
15. Elbow, Short Radius. An elbow with a centerline turning radius of 1 times the nominal size of the elbow.
16. Face-to-Face Dimension. The dimension from the face of the inlet to the face of the outlet of the valve or fitting.
17. Female End. Internally threaded portion of a pipe, valve, or fitting.
18. Flanged Joint. A joint made with an annular collar designed to permit a bolted connection.
19. Grooved Joint. A joint made with a special mechanical device using a circumferential groove cut into or pressed into the pipes, valves, and fittings to retain a coupling member.
20. Handwheel. The valve handle shaped in the form of a wheel.
21. Inside Screw. The screw mechanism which moves the internal flow device is located within the valve body.
22. Insulating Unions (Dielectric Unions). Used in piping systems to prevent dissimilar metals from coming into direct contact with each other (See Galvanic Action Paragraph).

23. Male End. Externally threaded portion of pipes, valves, or fittings.
24. Memory Stop. A device which allows for the repeatable operation of a valve at a position other than full open or full closed, often used to set or mark a balance position.
25. Nipple. A short piece of pipe with boths ends externally threaded.
26. Nominal Pipe Size (NPS). Standard pipe size but not necessarily the actual dimension.
27. Non-Rising Stem. When the valve is operated, the stem does not rise through the bonnet; the internal flow device rises on the stem.
28. Outside Screw and Yoke (OS&Y). The valve packing is located between the stem threads and the valve body. The valve has a threaded stem which is visible.
29. Packing. A material that seals around the movable penetration of the valve stem.
30. Rising Stem. When the valve is operated, the stem rises through the bonnet and the internal flow device is moved up or down by the moving stem.
31. Safety-Relief Valves. A valve which automatically relieves the system pressure when the internal pressure exceeds a set value. Safety-relief valves may operate on pressure only or on a combination pressure and temperature.
    a. Safety Valve. An automatic pressure relieving device actuated by the static pressure upstream of the valve and characterized by full opening pop action. A safety valve is used primarily for gas or vapor service.
    b. Relief Valve. An automatic pressure relieving device actuated by the static pressure upstream of the valve which opens further with the increase in pressure over the opening pressure. A relief valve is used primarily for liquid service.
    c. Safety Relief Valve. An automatic pressure actuated relieving device suitable for use either as a safety valve or relief valve, depending on application.
    d. Safety, Relief, and Safety Relief Valve testing is dictated by the Insurance Underwriter.
32. Seat. The portion of the valve which the internal flow device presses against to form a tight seal for shutoff.
33. Slow Opening Valve. A valve which requires at least five 360 degree turns of the operating mechanism to change from fully closed to fully open.
34. Socket Welding Joint. A joint made with a socket configuration to fit the ends of the pipes, valves, or fittings and then fillet welded in place.
35. Soldered Joint. A joint made with pipes, valves, or fittings in which the joining is accomplished by soldering or brazing.
36. Stem. A device which operates the internal flow control device.
37. Threaded Joint. A joint made with pipes, valves, or fittings in which the joining is accomplished by threading the components.
38. Union. A fitting which allows the assembly or disassembly of the piping system without rotating the piping.

C. Valve Abbreviations

TE	Threaded End
FE	Flanged End
SE	Solder End
BWE	Butt Weld End
SWE	Socket Weld End
TB	Threaded Bonnet
BB	Bolted Bonnet
UB	Union Bonnet
TC	Threaded Cap
BC	Bolted Cap
UC	Union Cap

IBBM	Iron Body, Bronze Mounted
DI	Ductile Iron
SB	Silver Brazed
DD	Double Disc
SW	Solid Wedge Disc
RWD	Resilient Wedge Disc
FW	Flexible Wedge
HW	Handwheel
NRS	Non-Rising Stem
RS	Rising Stem
OS&Y	Outside Screw & Yoke
ISNRS	Inside Screw NRS
ISRS	Inside Screw RS
FF	Flat Face
RF	Raised Face
HF	Hard Faced
MJ	Mechanical Joint
RJ	Ring Type Joint
F&D	Face and Drilled Flange
CWP	Cold Working Pressure
OWG	Oil, Water, Gas, Pressure
SWP	Steam Working Pressure
WOG	Water, Oil, Gas, Pressure
WWP	Water Working Pressure
FTTG	Fitting
FLG	Flange
DWV	Drainage-Wast-Vent Fitting
NPS	Nominal Pipe Size
IPS	Iron Pipe Size
NPT	National Standard Pipe Thread Taper

19.07 Expansion Loops (See Chapter 5 and Appendix D)

A. L-Bends. Anchor Force = 500 Lbs./Dia. Inch.

B. Z-Bends. Anchor Force = 200–500 Lbs./Dia. Inch.

C. U-Bends. Anchor Force = 200 Lbs./Dia. Inch.

D. Locate anchors at beam locations, and avoid anchor locations at steel bar joists if at all possible.

19.08 Strainers

A. Strainers shall be full line size.

B. Water Systems:

1. Strainer Type:
   - a. 2″ and Smaller: “Y” Type
   - b. 2½″ to 16″: Basket Type
   - c. 18″ and Larger: Multiple Basket Type

2. Strainer Perforation Size:
   a. 4″ and Smaller: 0.057″ Dia. Perforations
   b. 5″ and Larger: 0.125″ Dia. Perforations
   c. Double perforation diameter for condenser water systems.

C. Steam Systems:

1. Strainer Type: "Y" Type
2. Strainer Perforation Size:
   a. 2″ and Smaller: 0.033″ Dia. Perforations
   b. 2½″ and Smaller: 3⁄64″ Dia. Perforations

D. Strainer Pressure Drops, Water Systems: Pressure drops listed below are based on the GPM and pipe sizing of 4.0 Ft./100 Ft. pressure drop or 10 Ft./Sec. velocity:

1. 1½″ and Smaller (Y-Type & Basket Type):
   a. Pressure Drop < 1.0 PSI, 2.31 Ft. H_2O
2. 2″–4″ (Y-Type & Basket Type):
   a. Pressure Drop ≅ 1.0 PSI, 2.31 Ft. H_2O
3. 5″ and Larger:
   a. Y-Type Pressure Drop ≅ 1.5 PSI, 3.46 Ft. H_2O
   b. Basket Type Pressure Drop ≅ 1.0 PSI, 2.31 Ft. H_20

19.09 Expansion Tanks and Air Separators

A. Minimum (Fill) Pressure:

1. Height of System + 5 to 10 psi OR 5–10 psi, whichever is greater.

B. Maximum (System) Pressure:

1. 150 Lb. Systems: 45–125 psi
2. 250 Lb. Systems: 125–225 psi

C. System Volume Estimate:

1. 12 Gal./Ton
2. 35 Gal./BHP

D. Connection Location:

1. Suction Side of Pump(s).
2. Suction side of Primary Pumps when used in Primary/Secondary/Tertiary Systems. An alternate location in Primary/Secondary/Tertiary Systems with a single secondary circuit may be the suction side of the secondary pumps.

E. Expansion Tank Design Considerations:

1. Solubility of Air in Water. The amount of air water can absorb and hold in solution is temperature and pressure dependant. As temperature increases, maximum solubility decreases, and as pressure increases, maximum solubility increases. Therefore, expansion tanks are generally connected to the suction side of the pump (lowest pressure point).
2. Expansion tank sizing. If due to space or structural limitations the expansion tank must be undersized, the minimum expansion tank size should be capable of handling at least ½ of the system expansion volume. With less than this capacity, system start-up

becomes a tedious and extremely sensitive process. If the expansion tank is undersized, an automatic drain should be provided and operated by the control system in addition to the manual drain. Size both the manual and automatic drains to enable a quick dump of a water logged tank (especially critical with undersized tanks) within the limits of the nitrogen fill speed and system pressure requirements.

3. System Volume Changes:
   a. System start-up and shutdown results in the largest change in system volume.
   b. System volume expansion and contraction must be evaluated at full load and partial load. Variations caused by load changes are described below:
      1) In constant flow systems, heating water return temperatures rise and chilled water temperatures drop as load decreases until at no load the return temperature is equal to the supply temperature. Heating systems expand and cooling systems contract at part load.
      2) In variable flow systems, heating water return temperatures drop and chilled water return temperatures rise as load decreases until at no load the return temperature equals the temperature in the secondary medium. Heating systems contract and cooling systems expand at part load.
4. Expansion tanks are used to accept system volume changes, and a gas cushion (usually air or nitrogen) pressure is maintained by releasing the gas from the tank and readmitting the gas into the tank as the system water expands and contracts, respectively. Expansion tanks are used where constant pressurization in the system must be maintained.
5. Cushion tanks are used in conjunction with expansion tanks and are limited in size. As system water expands, pressure increases in the cushion tank until reaching the relief point, at which time it discharges to a lower pressure expansion tank. As the system water contracts, pressure decreases in the cushion tank until reaching a low limit, at which time the pump starts and pumps the water from the low pressure expansion tank to the cushion tank, thus increasing the pressure. Cushion tank relief and makeup flow rates are based on the initial expansion of a heating system or the initial contraction of a cooling system during start-up, because this will be the largest change in system volume for either system.
6. Compression tanks build their own pressure through the thermal expansion of the system contents. Compression tanks are not recommended on medium or high temperature heating water systems.
7. When expansion tank level transmitters are provided for building automation control systems, the expansion tank level should be provided from the level transmitter with local readout at the expansion tank, compression tank, or cushion tank. Also provide a sight glass or some other means of visually verifying level in tank and accuracy of transmitter.
8. When expansion tank pressure transmitters are provided for building automation control systems, the expansion tank pressure should be provided from the pressure transmitter with local readout at the expansion tank, compression tank, or cushion tank. Also provide pressure gauge at tank to verify transmitter.
9. Nitrogen relief from expansion, cushion, or compression tank must be vented to outside (noise when discharging is quite deafening). Vent can be tied into the vent off of the blowdown separator. Also need to provide nitrogen pressure monitoring and alarms and manual nitrogen relief valves.
10. Expansion tank sizing can be simplified using the tables and their respective corrections factors that follow. These tables can be especially helpful for preliminary sizing.
    a. Low-temperature systems. Tables on pages 199–203.
    b. Medium-temperature systems. Tables on pages 204–208.
    c. High-temperature systems. Tables on pages 209–213.

F. Air Separators

1. Air separators shall be full line size.

Expansion Tank Sizing, Low Temperature Systems

TANK SIZED EXPRESSED AS A PERCENTAGE OF SYSTEM VOLUME				
MAXIMUM SYSTEM TEMPERATURE °F.	EXPANSION TANK TYPE			
	CLOSED TANK	OPEN TANK	DIAPHRAGM TANK	
			TANK VOLUME	ACCEPTANCE VOLUME
100	2.21	1.37	1.32	0.59
110	3.08	1.87	1.83	0.82
120	3.71	2.24	2.21	0.99
130	4.81	2.87	2.86	1.28
140	5.67	3.37	3.37	1.51
150	6.77	3.99	4.03	1.80
160	7.87	4.61	4.68	2.10
170	9.20	5.36	5.48	2.45
180	10.53	6.11	6.27	2.81
190	11.87	6.86	7.06	3.16
200	13.20	7.61	7.86	3.52
210	14.77	----	8.79	3.93
220	16.34	----	9.72	4.35
230	17.90	----	10.66	4.77
240	19.71	----	11.73	5.25
250	21.51	----	12.80	5.73

Notes:

1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 10 Psig.
3. Table based on maximum operating pressure: 30 Psig.
4. For initial and maximum pressures different from those listed above, multiply tank size only (not Acceptance Volume) by correction factors contained in the Low Temperature System Correction Factor Tables below.

Closed Expansion Tank Sizing, Low Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	5	10	15	20	25	30	35	40	45	50
5	1.76	1.06	0.83	0.71	0.64	0.59	0.56	0.53	0.51	0.50
10	2.66	1.55	1.18	**1.00**	0.89	0.82	0.76	0.72	0.69	0.67
15	3.73	2.14	1.60	1.34	1.18	1.07	0.99	0.94	0.89	0.86
20	4.99	2.81	2.08	1.72	1.50	1.36	1.25	1.17	1.11	1.06
25	6.43	3.57	2.62	2.15	1.86	1.67	1.53	1.43	1.35	1.29
30	8.05	4.43	3.22	2.62	2.26	2.02	1.84	1.71	1.61	1.53
35	9.85	5.37	3.88	3.14	2.69	2.39	2.18	2.02	1.89	1.80
40	11.83	6.41	4.60	3.70	3.16	2.80	2.54	2.35	2.20	2.07
45	13.99	7.54	5.39	4.31	3.66	3.23	2.93	2.70	2.52	2.37
50	16.34	8.75	6.23	4.96	4.21	3.70	3.34	3.07	2.86	2.69
55	18.86	10.06	7.13	5.66	4.78	4.20	3.78	3.46	3.22	3.02
60	21.57	11.46	8.09	6.41	5.40	4.72	4.24	3.88	3.60	3.37
65	24.46	12.95	9.11	7.20	6.05	5.28	4.73	4.32	4.00	3.75
70	27.53	14.53	10.20	8.03	6.73	5.87	5.25	4.78	4.42	4.13
75	30.77	16.20	11.34	8.91	7.45	6.48	5.79	5.27	4.86	4.54
80	34.21	17.96	12.55	9.84	8.21	7.13	6.36	5.78	5.33	4.96
85	37.82	19.81	13.81	10.81	9.01	7.81	6.95	6.31	5.81	5.41
90	41.61	21.75	15.13	11.83	9.84	8.52	7.57	6.86	6.31	5.87
95	45.59	23.79	16.52	12.89	10.71	9.25	8.22	7.44	6.83	6.35
100	49.74	25.91	17.97	13.99	11.61	10.02	8.89	8.04	7.37	6.84

Notes:
1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 10 Psig.
3. Table based on maximum operating pressure: 30 Psig.

Closed Expansion Tank Sizing, Low Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	55	60	65	70	75	80	85	90	95	100
5	0.48	0.47	0.47	0.46	0.45	0.44	0.44	0.43	0.43	0.43
10	0.65	0.63	0.62	0.61	0.59	0.59	0.58	0.57	0.56	0.56
15	0.83	0.80	0.78	0.77	0.75	0.74	0.73	0.72	0.71	0.70
20	1.03	0.99	0.96	0.94	0.92	0.90	0.89	0.87	0.86	0.85
25	1.24	1.19	1.16	1.13	1.10	1.08	1.06	1.04	1.02	1.00
30	1.47	1.41	1.37	1.33	1.29	1.26	1.24	1.21	1.19	1.17
35	1.71	1.65	1.59	1.54	1.50	1.46	1.43	1.40	1.37	1.35
40	1.98	1.89	1.82	1.77	1.71	1.67	1.63	1.59	1.56	1.53
45	2.26	2.16	2.07	2.00	1.94	1.89	1.84	1.80	1.76	1.73
50	2.55	2.44	2.34	2.26	2.18	2.12	2.06	2.01	1.97	1.93
55	2.86	2.73	2.62	2.52	2.44	2.36	2.30	2.24	2.19	2.14
60	3.19	3.04	2.91	2.80	2.70	2.62	2.54	2.48	2.42	2.36
65	3.54	3.36	3.21	3.09	2.98	2.88	2.80	2.72	2.65	2.59
70	3.90	3.70	3.53	3.39	3.27	3.16	3.06	2.98	2.90	2.83
75	4.27	4.05	3.87	3.71	3.57	3.45	3.34	3.24	3.16	3.08
80	4.67	4.42	4.21	4.04	3.88	3.75	3.63	3.52	3.43	3.34
85	5.08	4.81	4.58	4.38	4.21	4.06	3.92	3.81	3.70	3.61
90	5.51	5.21	4.95	4.73	4.54	4.38	4.23	4.10	3.99	3.88
95	5.95	5.62	5.34	5.10	4.89	4.71	4.55	4.41	4.28	4.17
100	6.41	6.05	5.74	5.48	5.26	5.06	4.88	4.73	4.59	4.46

Notes:
1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 10 Psig.
3. Table based on maximum operating pressure: 30 Psig.

Diaphragm Expansion Tank Sizing, Low Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	5	10	15	20	25	30	35	40	45	50
5	2.21	1.33	1.04	0.89	0.80	0.74	0.70	0.67	0.64	0.62
10	2.66	1.55	1.18	**1.00**	0.89	0.82	0.76	0.72	0.69	0.67
15	3.11	1.78	1.33	1.11	0.98	0.89	0.83	0.78	0.74	0.71
20	3.55	2.00	1.48	1.22	1.07	0.96	0.89	0.84	0.79	0.76
25	4.00	2.22	1.63	1.34	1.16	1.04	0.95	0.89	0.84	0.80
30	4.45	2.45	1.78	1.45	1.25	1.11	1.02	0.95	0.89	0.85
35	4.89	2.67	1.93	1.56	1.34	1.19	1.08	1.00	0.94	0.89
40	5.34	2.89	2.08	1.67	1.43	1.26	1.15	1.06	0.99	0.94
45	5.79	3.12	2.23	1.78	1.52	1.34	1.21	1.12	1.04	0.98
50	6.24	3.34	2.38	1.89	1.61	1.41	1.27	1.17	1.09	1.03
55	6.68	3.57	2.53	2.01	1.69	1.49	1.34	1.23	1.14	1.07
60	7.13	3.79	2.68	2.12	1.78	1.56	1.40	1.28	1.19	1.12
65	7.58	4.01	2.82	2.23	1.87	1.64	1.47	1.34	1.24	1.16
70	8.03	4.24	2.97	2.34	1.96	1.71	1.53	1.39	1.29	1.21
75	8.47	4.46	3.12	2.45	2.05	1.79	1.59	1.45	1.34	1.25
80	8.92	4.68	3.27	2.57	2.14	1.86	1.66	1.51	1.39	1.29
85	9.37	4.91	3.42	2.68	2.23	1.93	1.72	1.56	1.44	1.34
90	9.82	5.13	3.57	2.79	2.32	2.01	1.79	1.62	1.49	1.38
95	10.26	5.36	3.72	2.90	2.41	2.08	1.85	1.67	1.54	1.43
100	10.71	5.58	3.87	3.01	2.50	2.16	1.91	1.73	1.59	1.47

Notes:

1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 10 Psig.
3. Table based on maximum operating pressure: 30 Psig.

Diaphragm Expansion Tank Sizing, Low Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	55	60	65	70	75	80	85	90	95	100
5	0.61	0.59	0.58	0.57	0.56	0.56	0.55	0.55	0.54	0.54
10	0.65	0.63	0.62	0.61	0.59	0.59	0.58	0.57	0.56	0.56
15	0.69	0.67	0.65	0.64	0.62	0.61	0.60	0.60	0.59	0.58
20	0.73	0.71	0.69	0.67	0.65	0.64	0.63	0.62	0.61	0.60
25	0.77	0.74	0.72	0.70	0.68	0.67	0.66	0.64	0.63	0.63
30	0.81	0.78	0.76	0.73	0.71	0.70	0.68	0.67	0.66	0.65
35	0.85	0.82	0.79	0.77	0.74	0.73	0.71	0.69	0.68	0.67
40	0.89	0.86	0.82	0.80	0.77	0.75	0.74	0.72	0.71	0.69
45	0.93	0.89	0.86	0.83	0.80	0.78	0.76	0.74	0.73	0.71
50	0.97	0.93	0.89	0.86	0.83	0.81	0.79	0.77	0.75	0.74
55	1.01	0.97	0.93	0.89	0.86	0.84	0.81	0.79	0.78	0.76
60	1.06	1.00	0.96	0.92	0.89	0.87	0.84	0.82	0.80	0.78
65	1.10	1.04	1.00	0.96	0.92	0.89	0.87	0.84	0.82	0.80
70	1.14	1.08	1.03	0.99	0.95	0.92	0.89	0.87	0.85	0.83
75	1.18	1.12	1.06	1.02	0.98	0.95	0.92	0.89	0.87	0.85
80	1.22	1.15	1.10	1.05	1.01	0.98	0.95	0.92	0.89	0.87
85	1.26	1.19	1.13	1.08	1.04	1.01	0.97	0.94	0.92	0.89
90	1.30	1.23	1.17	1.12	1.07	1.03	1.00	0.97	0.94	0.92
95	1.34	1.27	1.20	1.15	1.10	1.06	1.02	0.99	0.96	0.94
100	1.38	1.30	1.24	1.18	1.13	1.09	1.05	1.02	0.99	0.96

Notes:
1. **Table based on initial temperature: 50°F.**
2. **Table based on initial pressure: 10 Psig.**
3. **Table based on maximum operating pressure: 30 Psig.**

Expansion Tank Sizing, Medium Temperature Systems

TANK SIZED EXPRESSED AS A PERCENTAGE OF SYSTEM VOLUME					
MAXIMUM SYSTEM TEMPERATURE °F.	EXPANSION TANK TYPE				
	CLOSED TANK	OPEN TANK	DIAPHRAGM TANK		
			TANK VOLUME	ACCEPTANCE VOLUME	
250	263.25	----	18.02	5.73	
260	285.30	----	19.53	6.21	
270	310.23	----	21.24	6.75	
280	335.16	----	22.95	7.29	
290	360.08	----	24.65	7.83	
300	387.88	----	26.56	8.44	
310	415.67	----	28.46	9.04	
320	443.47	----	30.36	9.65	
330	474.13	----	32.46	10.32	
340	504.80	----	34.56	10.98	
350	538.33	----	36.86	11.71	

Notes:

1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 200 Psig.
3. Table based on maximum operating pressure: 300 Psig.
4. For initial and maximum pressures different from those listed above, multiply tank size only (not Acceptance Volume) by correction factors contained in the Medium Temperature System Correction Factor Tables below.

Closed Expansion Tank Sizing, Medium Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	10	20	30	40	50	60	70	80	90	100
30	0.36	0.21	0.16	0.14	0.13	0.12	0.11	0.10	0.10	0.10
40	0.52	0.30	0.23	0.19	0.17	0.15	0.14	0.14	0.13	0.13
50	072	0.41	0.30	0.25	0.22	0.20	0.18	0.17	0.16	0.16
60	0.94	0.52	0.39	0.32	0.28	0.25	0.23	0.21	0.20	0.19
70	1.19	0.66	0.48	0.39	0.34	0.30	0.28	0.26	0.24	0.23
80	1.47	0.80	0.58	0.47	0.41	0.36	0.33	0.31	0.29	0.27
90	1.78	0.97	0.70	0.56	0.48	0.43	0.39	0.36	0.34	0.32
100	2.12	1.14	0.82	0.66	0.56	0.49	0.45	0.41	0.39	0.36
110	2.49	1.34	0.95	0.76	0.64	0.57	0.51	0.47	0.44	0.41
120	2.88	1.54	1.09	0.87	0.74	0.65	0.58	0.54	0.50	0.47
130	3.31	1.76	1.25	0.99	0.83	0.73	0.66	0.60	0.56	0.52
140	3.77	2.00	1.41	1.11	0.94	0.82	0.73	0.67	0.62	0.58
150	4.26	2.25	1.58	1.25	1.05	0.91	0.82	0.75	0.69	0.65
160	4.78	2.52	1.76	1.39	1.16	1.01	0.90	0.82	0.76	0.71
170	5.32	2.80	1.96	1.54	1.28	1.11	0.99	0.90	0.83	0.78
180	5.90	3.09	2.16	1.69	1.41	1.22	1.09	0.99	0.91	0.85
190	6.50	3.40	2.37	1.85	1.54	1.34	1.19	1.08	0.99	.92
200	7.14	3.73	2.59	2.02	1.68	1.45	1.29	1.17	1.08	**1.00**
210	7.81	4.07	2.82	2.20	1.83	1.58	1.40	1.27	1.16	1.08
220	8.50	4.42	3.06	2.39	1.98	1.71	1.51	1.37	1.25	1.16
230	9.22	4.79	3.32	2.58	2.13	1.84	1.63	1.47	1.35	1.25
240	9.98	5.18	3.58	2.78	2.30	1.98	1.75	1.58	1.44	1.34
250	10.76	5.58	3.85	2.98	2.47	2.12	1.87	1.69	1.54	1.43
260	11.57	5.99	4.13	3.20	2.64	2.27	2.00	1.80	1.65	1.52

Notes:
1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 200 Psig.
3. Table based on maximum operating pressure: 300 Psig.

Closed Expansion Tank Sizing, Medium Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	110	120	130	140	150	160	170	180	190	200
30	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08
40	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.10	0.10
50	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13
60	0.19	0.18	0.17	0.17	0.17	0.16	0.16	0.16	0.15	0.15
70	0.22	0.21	0.21	0.20	0.20	0.19	0.19	0.18	0.18	0.18
80	0.26	0.25	0.24	0.23	0.23	0.22	0.22	0.21	0.21	0.21
90	0.30	0.29	0.28	0.27	0.26	0.26	0.25	0.25	0.24	0.24
100	0.35	0.33	0.32	0.31	0.30	0.29	0.28	0.28	0.27	0.27
110	0.39	0.38	0.36	0.35	0.34	0.33	0.32	0.31	0.31	0.30
120	0.44	0.42	0.41	0.39	0.38	0.37	0.36	0.35	0.34	0.33
130	0.50	0.47	0.45	0.44	0.42	0.41	0.40	0.39	0.38	0.37
140	0.55	0.52	0.50	0.48	0.47	0.45	0.44	0.43	0.42	0.41
150	0.61	0.58	0.55	0.53	0.51	0.49	0.48	0.47	0.46	0.44
160	0.67	0.63	0.61	0.58	0.56	0.54	0.52	0.51	0.50	0.48
170	0.73	0.69	0.66	0.63	0.61	0.59	0.57	0.55	0.54	0.53
180	0.80	0.76	0.72	0.69	0.66	0.64	0.62	0.60	0.58	0.57
190	0.87	0.82	0.78	0.75	0.72	0.69	0.67	0.65	0.63	0.61
200	0.94	0.89	0.84	0.81	0.77	0.74	0.72	0.70	0.68	0.66
210	1.01	0.96	0.91	0.87	0.83	0.80	0.77	0.75	0.73	0.71
220	1.09	1.03	0.97	0.93	0.89	0.86	0.83	0.80	0.78	0.75
230	1.17	1.10	1.04	1.00	0.95	0.92	0.88	0.85	0.83	0.81
240	1.25	1.18	1.12	1.06	1.02	0.98	0.94	0.91	0.88	0.86
250	1.33	1.26	1.19	1.13	1.08	1.04	1.00	0.97	0.94	0.91
260	1.42	1.34	1.27	1.20	1.15	1.10	1.06	1.03	0.99	0.96

Notes:

1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 200 Psig.
3. Table based on maximum operating pressure: 300 Psig.

Diaphragm Expansion Tank Sizing, Medium Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	10	20	30	40	50	60	70	80	90	100
30	1.74	1.03	0.79	0.67	0.60	0.55	0.52	0.50	0.48	0.46
40	2.06	1.19	0.90	0.75	0.67	0.61	0.57	0.54	0.51	0.49
50	2.37	1.35	1.00	0.83	0.73	0.66	0.61	0.57	0.55	0.52
60	2.69	1.50	1.11	0.91	0.79	0.71	0.66	0.61	0.58	0.56
70	3.01	1.66	1.21	0.99	0.86	0.77	0.70	0.65	0.62	0.59
80	3.33	1.82	1.32	1.07	0.92	0.82	0.75	0.69	0.65	0.62
90	3.64	1.98	1.43	1.15	0.98	0.87	0.79	0.73	0.69	0.65
100	3.96	2.14	1.53	1.23	1.05	0.93	0.84	0.77	0.72	0.68
110	4.28	2.30	1.64	1.31	1.11	0.98	0.88	0.81	0.76	0.71
120	4.60	2.46	1.74	1.39	1.17	1.03	0.93	0.85	0.79	0.75
130	4.92	2.62	1.85	1.47	1.24	1.08	0.97	0.89	0.83	0.78
140	5.23	2.78	1.96	1.55	1.30	1.14	1.02	0.93	0.86	0.81
150	5.55	2.93	2.06	1.63	1.36	1.19	1.07	0.97	0.90	0.84
160	5.87	3.09	2.17	1.71	1.43	1.24	1.11	1.01	0.93	0.87
170	6.19	3.25	2.27	1.79	1.49	1.30	1.16	1.05	0.97	0.90
180	6.50	3.41	2.38	1.86	1.56	1.35	1.20	1.09	1.01	0.94
190	6.82	3.57	2.49	1.94	1.62	1.40	1.25	1.13	1.04	0.97
200	7.14	3.73	2.59	2.02	1.68	1.45	1.29	1.17	1.08	**1.00**
210	7.46	3.89	2.70	2.10	1.75	1.51	1.34	1.21	1.11	1.03
220	7.78	4.05	2.80	2.18	1.81	1.56	1.38	1.25	1.15	1.06
230	8.09	4.21	2.91	2.26	1.87	1.61	1.43	1.29	1.18	1.10
240	8.41	4.36	3.02	2.34	1.94	1.67	1.47	1.33	1.22	1.13
250	8.73	4.52	3.12	2.42	2.00	1.72	1.52	1.37	1.25	1.16
260	9.05	4.68	3.23	2.50	2.06	1.77	1.56	1.41	1.29	1.19

Notes:

1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 200 Psig.
3. Table based on maximum operating pressure: 300 Psig.

Diaphragm Expansion Tank Sizing, Medium Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	110	120	130	140	150	160	170	180	190	200
30	0.45	0.44	0.43	0.42	0.41	0.41	0.40	0.40	0.39	0.39
40	0.48	0.46	0.45	0.44	0.43	0.43	0.42	0.41	0.41	0.40
50	0.50	0.49	0.48	0.46	0.45	0.45	0.44	0.43	0.43	0.42
60	0.53	0.52	0.50	0.49	0.48	0.47	0.46	0.45	0.44	0.44
70	0.56	0.54	0.52	0.51	0.50	0.49	0.48	0.47	0.46	0.45
80	0.59	0.57	0.55	0.53	0.52	0.51	0.49	0.48	0.48	0.47
90	0.62	0.60	0.57	0.56	0.54	0.53	0.51	0.50	0.49	0.48
100	0.65	0.62	0.60	0.58	0.56	0.55	0.53	0.52	0.51	0.50
110	0.68	0.65	0.62	0.60	0.58	0.57	0.55	0.54	0.53	0.52
120	0.71	0.67	0.65	0.62	0.60	0.59	0.57	0.56	0.54	0.53
130	0.74	0.70	0.67	0.65	0.62	0.61	0.59	0.57	0.56	0.55
140	0.76	0.73	0.70	0.67	0.65	0.63	0.61	0.59	0.58	0.56
150	0.79	0.75	0.72	0.69	0.67	0.64	0.63	0.61	0.59	0.58
160	0.82	0.78	0.74	0.71	0.69	0.66	0.64	0.63	0.61	0.60
170	0.85	0.81	0.77	0.74	0.71	0.68	0.66	0.64	0.63	0.61
180	0.88	0.83	0.79	0.76	0.73	0.70	0.68	0.66	0.64	0.63
190	0.91	0.86	0.82	0.78	0.75	0.72	0.70	0.68	0.66	0.64
200	0.94	0.89	0.84	0.81	0.77	0.74	0.72	0.70	0.68	0.66
210	0.97	0.91	0.87	0.83	0.79	0.76	0.74	0.71	0.69	0.67
220	1.00	0.94	0.89	0.85	0.81	0.78	0.76	0.73	0.71	0.69
230	1.02	0.97	0.92	0.87	0.84	0.80	0.78	0.75	0.73	0.71
240	1.05	0.99	0.94	0.90	0.86	0.82	0.79	0.77	0.74	0.72
250	1.08	1.02	0.96	0.92	0.88	0.84	0.81	0.79	0.76	0.74
260	1.11	1.05	0.99	0.94	0.90	0.86	0.83	0.80	0.78	0.75

Notes:

1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 200 Psig.
3. Table based on maximum operating pressure: 300 Psig.

Expansion Tank Sizing, High Temperature Systems

TANK SIZED EXPRESSED AS A PERCENTAGE OF SYSTEM VOLUME				
MAXIMUM SYSTEM TEMPERATURE °F.	EXPANSION TANK TYPE			
	CLOSED TANK	OPEN TANK	DIAPHRAGM TANK	
			TANK VOLUME	ACCEPTANCE VOLUME
350	1,995.03	----	47.71	11.71
360	2,119.30	----	50.68	12.44
370	2,243.58	----	53.65	13.17
380	2,378.48	----	56.88	13.96
390	2,524.02	----	60.36	14.82
400	2,669.56	----	63.84	15.67
410	2,815.10	----	67.32	16.53
420	2,981.90	----	71.31	17.51
430	3,138.07	----	75.04	18.42
440	3,315.51	----	79.29	19.46
450	3,492.95	----	83.53	20.51

Notes:
1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 600 Psig.
3. Table based on maximum operating pressure: 800 Psig.
4. For initial and maximum pressures different from those listed above, multiply tank size only (not Acceptance Volume) by correction factors contained in the High Temperature System Correction Factor Tables below.

Closed Expansion Tank Sizing, High Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	20	40	60	80	100	120	140	160	180	200
160	0.68	0.37	0.27	0.22	0.19	0.17	0.16	0.15	0.14	0.13
180	0.83	0.46	0.33	0.27	0.23	0.20	0.19	0.17	0.16	0.15
200	1.01	0.55	0.39	0.32	0.27	0.24	0.22	0.20	0.19	0.18
220	1.19	0.64	0.46	0.37	0.31	0.28	0.25	0.23	0.22	0.20
240	1.40	0.75	0.53	0.43	0.36	0.32	0.29	0.26	0.25	0.23
260	1.62	0.86	0.61	0.49	0.41	0.36	0.32	0.30	0.28	0.26
280	1.85	0.98	0.70	0.55	0.46	0.41	0.37	0.33	0.31	0.29
300	2.10	1.11	0.78	0.62	0.52	0..46	0.41	0.37	0.35	0.32
320	2.37	1.25	0.88	0.69	0.58	0.51	0.45	0.41	0.38	0..36
340	2.65	1.40	0.98	0.77	0.64	0.56	0.50	0.46	0.42	0.39
360	2.95	1.55	1.08	0.85	0.71	0.62	0.55	0.50	0.46	0.43
380	3.27	1.71	1.19	0.94	0.78	0.68	0.60	0.55	0.50	0.47
400	3.60	1.88	1.31	1.02	0.85	0.74	0.66	0.59	0.55	0.51
420	3.95	2.06	1.43	1.12	0.93	0.80	0.71	0.65	0.59	0.55
440	4.31	2.25	1.56	1.21	1.01	0.87	0.77	0.70	0.64	0.59
460	4.69	2.44	1.69	1.31	1.09	0.94	0.83	0.75	0.69	0.64
480	5.08	2.64	1.83	1.42	1.17	1.01	0.90	0.81	0.74	0.69
500	5.50	2.85	1.97	1.53	1.26	1.09	0.96	0.87	0.79	0.73
520	5.92	3.07	2.12	1.64	1.36	1.17	1.03	0.93	0.85	0.78
540	6.37	3.29	2.27	1.76	1.45	1.25	1.10	0.99	0.90	0.84
560	6.82	3.53	2.43	1.88	1.55	1.33	1.17	1.05	0.96	0.89
580	7.30	3.77	2.59	2.00	1.65	1.41	1.25	1.12	1.02	0.94
600	7.79	4.02	2.76	2.13	1.75	1.50	1.32	1.19	1.08	**1.00**
620	8.30	4.28	2.93	2.26	1.86	1.59	1.40	1.26	1.15	1.06
640	8.82	4.54	3.11	2.40	1.97	1.69	1.48	1.33	1.21	1.12
660	9.36	4.81	3.30	2.54	2.09	1.78	1.57	1.41	1.28	1.18
680	9.91	5.10	3.49	2.69	2.20	1.88	1.65	1.48	1.35	1.24
700	10.49	5.39	3.69	2.84	2.33	1.99	1.74	1.56	1.42	1.31

Notes:

1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 600 Psig.
3. Table based on maximum operating pressure: 800 Psig.

Closed Expansion Tank Sizing, High Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	220	240	260	280	300	320	340	360	380	400
160	0.13	0.12	0.12	0.11	0.11	0.11	0.11	0.10	0.10	0.10
180	0.15	0.14	0.14	0.13	0.13	0.13	0.12	0.12	0.12	0.12
200	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13
220	0.19	0.19	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.15
240	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.17
260	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.19	0.19	0.19
280	0.28	0.26	0.25	0.24	0.23	0.23	0.22	0.21	0.21	0.20
300	0.31	0.29	0.28	0.27	0.26	0.25	0.24	0.24	0.23	0.22
320	0.34	0.32	0.31	0.29	0.28	0.27	0.27	0.26	0.25	0.25
340	0.37	0.35	0.33	0.32	0.31	0.30	0.29	0.28	0.27	0.27
360	0.40	0.38	0.37	0.35	0.34	0.32	0.31	0.31	0.30	0.29
380	0.44	0.42	0.40	0.38	0.37	0.35	0.34	0.33	0.32	0.31
400	0.48	0.45	0.43	0.41	0.39	0.38	0.37	0.36	0.35	0.34
420	0.52	0.49	0.46	0.44	0.43	0.41	0.40	0.38	0.37	0.36
440	0.56	0.53	0.50	0.48	0.46	0.44	0.42	0.41	0.40	0.39
460	0.60	0.56	0.54	0.51	0.49	0.47	0.45	0.44	0.43	0.41
480	0.64	0.60	0.57	0.55	0.52	0.50	0.49	0.47	0.45	0.44
500	0.69	0.65	0.61	0.58	0.56	0.54	0.52	0.50	0.48	0.47
520	0.73	0.69	0.65	0.62	0.59	0.57	0.55	0.53	0.51	0.50
540	0.78	0.73	0.69	0.66	0.63	0.61	0.58	0.56	0.54	0.53
560	0.83	0.78	0.74	0.70	0.67	0.64	0.62	0.60	0.58	0.56
580	0.88	0.83	0.78	0.74	0.71	0.68	0.65	0.63	0.61	0.59
600	0.93	0.87	0.83	0.78	0.75	0.72	0.69	0.66	0.64	0.62
620	0.98	0.92	0.87	0.83	0.79	0.76	0.73	0.70	0.68	0.66
640	1.04	0.97	0.92	0.87	0.83	0.80	0.76	0.74	0.71	0.69
660	1.10	1.03	0.97	0.92	0.88	0.84	0.80	0.77	0.75	0.72
680	1.15	1.08	1.02	0.97	0.92	0.88	0.84	0.81	0.78	0.76
700	1.21	1.14	1.07	1.01	0.87	0.92	0.89	0.85	0.82	0.80

Notes:
1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 600 Psig.
3. Table based on maximum operating pressure: 800 Psig.

Diaphragm Expansion Tank Sizing, High Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	20	40	60	80	100	120	140	160	180	200
160	2.39	1.32	0.96	0.78	0.67	0.60	0.55	0.51	0.48	0.46
180	2.64	1.44	1.04	0.84	0.72	0.64	0.59	0.54	0.51	0.48
200	2.88	1.56	1.12	0.90	0.77	0.68	0.62	0.57	0.54	0.51
220	3.13	1.69	1.21	0.97	0.82	0.73	0.66	0.61	0.57	0.53
240	3.37	1.81	1.29	1.03	0.87	0.77	0.69	0.64	0.59	0.56
260	3.62	1.93	1.37	1.09	0.92	0.81	0.73	0.67	0.62	0.58
280	3.86	2.05	1.45	1.15	0.97	0.85	0.76	0.70	0.65	0.61
300	4.11	2.18	1.53	1.21	1.02	0.89	0.80	0.73	0.67	0.63
320	4.35	2.30	1.61	1.27	1.07	0.93	0.83	0.76	0.70	0.66
340	4.60	2.42	1.70	1.33	1.12	0.97	0.87	0.79	0.73	0.68
360	4.84	2.55	1.78	1.40	1.17	1.01	0.90	0.82	0.76	0.71
380	5.09	2.67	1.86	1.46	1.21	1.05	0.94	0.85	0.78	0.73
400	5.34	2.79	1.94	1.52	1.26	1.09	0.97	0.88	0.81	0.75
420	5.58	2.91	2.02	1.58	1.31	1.13	1.01	0.91	0.84	0.78
440	5.83	3.04	2.11	1.64	1.36	1.18	1.04	0.94	0.87	0.80
460	6.07	3.16	2.19	1.70	1.41	1.22	1.08	0.97	0.89	0.83
480	6.32	3.28	2.27	1.76	1.46	1.26	1.11	1.00	0.92	0.85
500	6.56	3.40	2.35	1.82	1.51	1.30	1.15	1.04	0.95	0.88
520	6.81	3.53	2.43	1.89	1.56	1.34	1.18	1.07	0.97	0.90
540	7.05	3.65	2.52	1.95	1.61	1.38	1.22	1.10	1.00	0.93
560	7.30	3.77	2.60	2.01	1.66	1.42	1.25	1.13	1.03	0.95
580	7.55	3.90	2.68	2.07	1.71	1.46	1.29	1.16	1.06	0.98
600	7.79	4.02	2.76	2.13	1.75	1.50	1.32	1.19	1.08	**1.00**
620	8.04	4.14	2.84	2.19	1.80	1.54	1.36	1.22	1.11	1.02
640	8.28	4.26	2.92	2.25	1.85	1.58	1.39	1.25	1.14	1.05
660	8.53	4.39	3.01	2.32	1.90	1.63	1.43	1.28	1.17	1.07
680	8.77	4.51	3.09	2.38	1.95	1.67	1.46	1.31	1.19	1.10
700	9.02	4.63	3.17	2.44	2.00	1.71	1.50	1.34	1.22	1.12

Notes:

1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 600 Psig.
3. Table based on maximum operating pressure: 800 Psig.

Diaphragm Expansion Tank Sizing, High Temperature System Correction Factors

INITIAL PRESSURE PSIG	PRESSURE INCREASE - PSIG INITIAL PRESSURE + PRESSURE INCREASE = MAXIMUM OPERATING PRESSURE									
	220	240	260	280	300	320	340	360	380	400
160	0.44	0.42	0.41	0.40	0.39	0.38	0.37	0.36	0.36	0.35
180	0.46	0.44	0.43	0.42	0.40	0.39	0.39	0.38	0.37	0.36
200	0.49	0.47	0.45	0.43	0.42	0.41	0.40	0.39	0.38	0.38
220	0.51	0.49	0.47	0.45	0.44	0.43	0.41	0.41	0.40	0.39
240	0.53	0.51	0.49	0.47	0.45	0.44	0.43	0.42	0.41	0.40
260	0.55	0.53	0.50	0.49	0.47	0.46	0.44	0.43	0.42	0.41
280	0.57	0.55	0.52	0.50	0.49	0.47	0.46	0.45	0.44	0.43
300	0.60	0.57	0.54	0.52	0.50	0.49	0.47	0.46	0.45	0.44
320	0.62	0.59	0.56	0.54	0.52	0.50	0.49	0.47	0.46	0.45
340	0.64	0.61	0.58	0.56	0.54	0.52	0.50	0.49	0.47	0.46
360	0.66	0.63	0.60	0.57	0.55	0.53	0.52	0.50	0.49	0.48
380	0.69	0.65	0.62	0.59	0.57	0.55	0.53	0.51	0.50	0.49
400	0.71	0.67	0.64	0.61	0.58	0.56	0.54	0.53	0.51	0.50
420	0.73	0.69	0.66	0.63	0.60	0.58	0.56	0.54	0.53	0.51
440	0.75	0.71	0.67	0.64	0.62	0.59	0.57	0.56	0.54	0.52
460	0.78	0.73	0.69	0.66	0.63	0.61	0.59	0.57	0.55	0.54
480	0.80	0.75	0.71	0.68	0.65	0.63	0.60	0.58	0.57	0.55
500	0.82	0.77	0.73	0.70	0.67	0.64	0.62	0.60	0.58	0.56
520	0.84	0.79	0.75	0.71	0.68	0.66	0.63	0.61	0.59	0.57
540	0.86	0.81	0.77	0.73	0.70	0.67	0.65	0.62	0.60	0.59
560	0.89	0.83	0.79	0.75	0.72	0.69	0.66	0.64	0.62	0.60
580	0.91	0.85	0.81	0.77	0.73	0.70	0.67	0.65	0.63	0.61
600	0.93	0.87	0.73	0.78	0.75	0.72	0.69	0.66	0.64	0.62
620	0.95	0.89	0.84	0.80	0.76	0.73	0.70	0.68	0.66	0.64
640	0.98	0.92	0.86	0.82	0.78	0.75	0.72	0.69	0.67	0.65
660	1.00	0.94	0.88	0.84	0.80	0.76	0.73	0.71	0.68	0.66
680	1.02	0.96	0.90	0.85	0.81	0.78	0.75	0.72	0.69	0.67
700	1.04	0.98	0.92	0.87	0.83	0.79	0.76	0.73	0.71	0.68

Notes:
1. Table based on initial temperature: 50°F.
2. Table based on initial pressure: 600 Psig.
3. Table based on maximum operating pressure: 800 Psig.

19.10 Galvanic Action

A. Galvanic action results from the electrochemical variation in the potential of metallic ions. If two metals of different potentials are placed in an electrolytic medium (i.e., water), the one with the higher potential will act as an anode and will corrode. The metal with the lower potential, being the cathode, will be unchanged. The greater the separation of the two metals on the chart below, the greater the speed and severity of the corrosion. The list below is in order of their anodic-cathodic characteristics (i.e., metals listed below will corrode those listed above, for example, copper will corrode steel).

Magnesium Alloys
Alclad 3S
Aluminum Alloys
Low-Carbon Steel
Cast Iron
Stainless Steel, Type 410
Stainless Steel, Type 430
Stainless Steel, Type 404
Stainless Steel, Type 304
Stainless Steel, Type 316
Hastelloy A
Lead-Tin Alloys
Brass
Copper
Bronze
90/10 Copper-Nickel
70/30 Copper-Nickel
Inconel
Silver
Stainless Steel (passive)
Monel
Hastelloy C
Titanium

19.11 Piping System Installation Hierarchy (Easiest to Hardest to Install)

A. Natural Gas, Medical Gases, and Laboratory Gases, Easiest to Install.

B. Chilled Water, Heating Water, Domestic Cold and Hot Water Systems, and other Closed HVAC and Plumbing Systems.

C. Steam and Steam Condensate.

D. Refrigeration Piping Systems.

E. Sanitary Systems, Storm Water Systems, AC Condensate Systems, Hardest to Install.

19.12 *ASME B31 Piping Code* Comparison

ASME B31 Piping Code Comparison

ITEM	POWER PIPING ASME B31.1 - 1998	PROCESS PIPING ASME B31.3 - 1996	BUILDING SERVICES PIPING ASME B31.9 - 1996
Application	Power & Auxiliary Piping for Electric Generating Stations, Industrial and Institutional Plants, Central & District Heating/Cooling Plants, and Geothermal Heating Systems.	Petroleum Refineries, Chemical, Pharmaceutical, Textile, Paper, Semiconductor, and Cryogenic Plants.	Industrial, Institutional, Commercial, and Public Buildings and Multi-Unit Residences.
Services	Systems include, but are not limited to, Steam, Water, Oil, Gas, and Air.	Systems include, but are not limited to, raw, intermediate, and finished chemicals, petroleum products, gas, steam air water, fluidized solids, refrigerants, and cryogenic fluids.	Systems include, but are not limited to, water for heating and cooling, condensing water, steam or other condensate, other nontoxic liquids, steam, vacuum, other nontoxic, nonflammable gases, and combustible liquids including fuel oil.
General Limitations	This Code does not apply to building services piping within the property limits or buildings of industrial and institutional facilities which is in the scope of ASME B31.9 except that piping beyond the limitations of material, size, temperature, pressure, and service specified in ASME B31.9 shall conform to the requirements of ASME B31.1. This Code excludes power boilers in accordance with the ASME Boiler and Pressure Vessel Code (BPVC) Section I.	This code excludes piping systems for internal gauge pressures above zero but less than 15 psig provided the fluid is nonflammable, nontoxic, and not damaging to human tissue and its temperature is from -20 °F through 366 °F This Code excludes power boilers in accordance with the ASME Boiler and Pressure Vessel Code Section I and boiler external piping which is required to conform to ASME B31.1.	This Code prescribes requirements for the design, materials, fabrication, installation, inspection, examination, and testing of piping systems for building services. It includes piping systems in the building or within the property limits. This Code excludes power boilers in accordance with the ASME Boiler and Pressure Vessel Code Section I and boiler external piping which is required to conform to ASME B31.1.

ASME B31 Piping Code Comparison

ITEM	POWER PIPING ASME B31.1 - 1998	PROCESS PIPING ASME B31.3 - 1996	BUILDING SERVICES PIPING ASME B31.9 - 1996
Pipe Size Limitations	No Limit	No Limit	Carbon Steel - 30" OD Nominal Pipe Size and 0.5" Wall (30" XS Steel Pipe) Copper - 12" Nominal Pipe Size Stainless Steel - 12" OD Nominal Pipe Size and 0.5" Wall
Pressure Limitations	No Limit	No Limit	Steam & Condensate - 150 Psig Liquids - 350 Psig Vacuum - 1 Atmosphere External Pressure Compressed Air & Gas - 150 Psig
Temperature Limitations	No Limit	No Limit	Steam & Condensate - 366 °F. Maximum (150 Psig) Other Gases & Vapors - 200 °F Maximum Non-Flammable Liquids - 250 °F Maximum Minimum Temperature All Services - 0 °F
Bypass Requirements	All bypasses must be in accordance with MSS-SP-45. Pipe weight shall be minimum Schedule 80.	Bypasses not addressed - recommend following B31.1	Bypasses not addressed - recommend following B31.1

ASME B31 Piping Code Comparison

ITEM	POWER PIPING ASME B31.1 - 1998	PROCESS PIPING ASME B31.3 - 1996	BUILDING SERVICES PIPING ASME B31.9 - 1996
Class I Boiler Systems - ASME BPVC Section I	Boiler External Piping is governed by ASME B31.1 All other piping may be governed by this Code within the limitations of the Code.	Boiler External Piping is governed by ASME B31.1 All other piping may be governed by this Code within the limitations of the Code.	Boiler External Piping is governed by ASME B31.1 All other piping may be governed by this Code within the limitations of the Code.
Class IV Boiler Systems - ASME BPVC Section IV	All piping, including boiler external piping, may be governed by this Code within the limitations of the Code.	All piping, including boiler external piping, may be governed by this Code within the limitations of the Code.	All piping, including boiler external piping, may be governed by this Code within the limitations of the Code.

Class I Boiler Systems

1. Class I Steam Boiler Systems are constructed for Working Pressures above 15 Psig.
2. Class I Hot Water Boiler Systems are constructed for Working Pressures above 160 Psig and/or Working Temperatures above 250 ^{o}F.

Class IV Boiler Systems

1. Class IV Steam Boiler Systems are constructed with a maximum Working Pressure of 15 Psig.
2. Class IV Hot Water Boiler Systems are constructed with a maximum Working Pressure of 160 Psig and a maximum Working Temperature of 250 ^{o}F.

Class I Boiler External Piping

1. Steam Boiler Piping - ASME Code piping is required from the boiler through the 1st stop check valve to the 2nd Stop Valve.
2. Steam Boiler Feedwater Piping - ASME Code piping is required from the boiler through the 1st stop valve to the check valve for single boiler feedwater installations and from the boiler through the 1st stop valve and through the check valve to the 2nd stop valve at the feedwater control valve for multiple boiler installations.
3. Steam Boiler Bottom Blowdown Piping - ASME Code Piping is required from the boiler through the 1st stop valve to the 2nd stop valve.
4. Steam Boiler Surface Blowdown Piping - ASME Code Piping is required from the boiler to the 1st stop valve.
5. Steam & Hot Water Boiler Drain Piping - ASME Code Piping is required from the boiler through the 1st stop valve to the 2nd stop valve.
6. Hot Water Boiler Supply and Return Piping - ASME Code piping is required from the boiler through the 1st stop check valve to the 2nd Stop Valve on both the supply and return piping.

Class IV Boiler External Piping

1. All Class IV Boiler External Piping is governed by the respective piping system code.

ASME B31 Piping Code Comparison

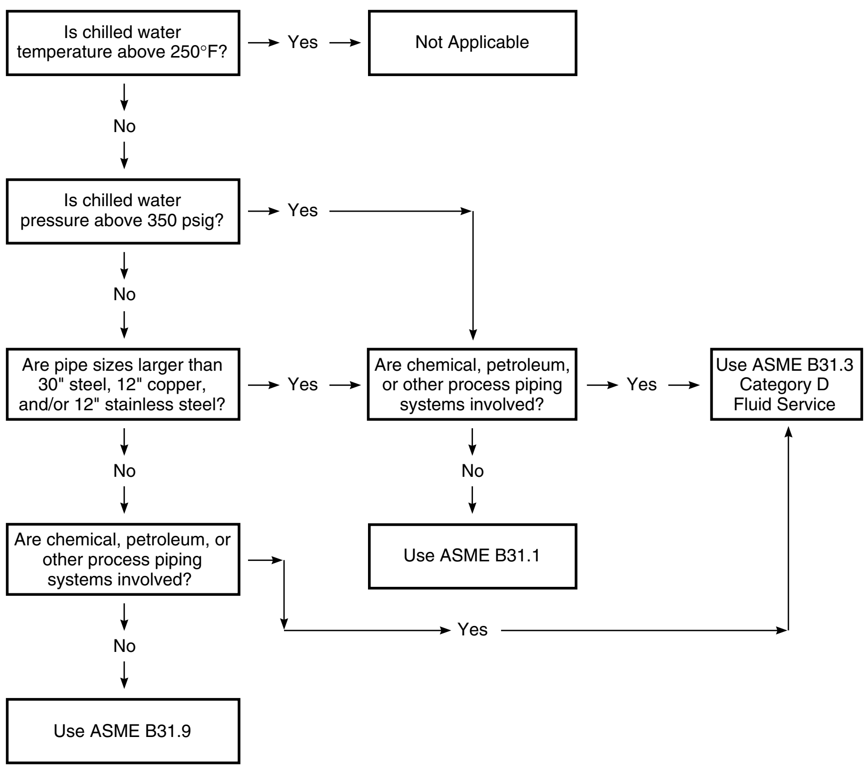
ITEM	POWER PIPING ASME B31.1 - 1998	PROCESS PIPING ASME B31.3 - 1996	BUILDING SERVICES PIPING ASME B31.9 - 1996
Piping Classifications	No Classifications required by this Code. The Code deals with and governs all piping under its jurisdiction the same.		No Classifications required by ths Code. The Code deals with and governs all piping under its jurisdiction the same.
Low Temp Chilled Water (0 - 40 °F)		D	
Chilled Water (40 - 60 °F)		D	
Condenser Water (60 - 110 °F)		D	
Low Temp Heating Water (110 - 250 °F)		N	
High Temp Heating Water (250 - 450 °F)		N - Except Boiler Ext. Piping B31.1 applicable	
Low Press. Steam (15 Psig and Less)		N	
High Press. Steam (Above 15 Psig)		N - Except Boiler Ext. Piping B31.1 applicable	
Hydrostatic Pressure Testing	Test Medium - Water, unless subject to freezing	Test Medium - Water, unless subject to freezing	Test Medium - Water, unless subject to freezing
	Boiler External Piping - ASME BPVC Section I	N/A	N/A
	Nonboiler External Piping - 1.5 times the design pressure but not to exceed max. allowable system pressure for a minimum of 10 minutes.	Category D or N Fluid Service - 1.5 times the design pressure but not to exceed max. allowable system pressure for a minimum of 10 minutes.	Nonboiler External Piping - 1.5 times the design pressure but not to exceed max. allowable system pressure for a minimum of 10 minutes.
	All Other Services - 1.5 times the design pressure but not to exceed max. allowable system pressure fo a minimum of 10 minutes.		All Other Services - 1.5 times the design pressure but not to exceed max. allowable system pressure fo a minimum of 10 minutes.

ASME B31 Piping Code Comparison

ITEM	POWER PIPING ASME B31.1 - 1998	PROCESS PIPING ASME B31.3 - 1996	BUILDING SERVICES PIPING ASME B31.9 - 1996
Examination, Inspection, and Testing Requirements	The degree of examination, inspection, and testing, and the acceptance standards must be mutually agreed upon by the manufacturer, fabricator, erector, or contractor and the Owner. Class I Steam & Hot Water Systems - Nondestructive testing and visual examinations are required by this Code. Percentage and types of tests performed must be agreed upon. Class IV Steam & Hot Water Systems - Visual examination only. All other Services - Visual examination only. If more rigorous examination or testing is required, it must be mutually agreed upon.	The degree of examination, inspection, and testing, and the acceptance standards must be mutually agreed upon by the manufacturer, fabricator, erector, or contractor and the Owner. Category D Fluid Service - Visual Examination Category N Fluid Service - Visual Examination, 5% Random Examination of components, fabrication, welds, and installation. Random radiographic or ultrasonic testing of 5% of circumferential butt welds. If more rigorous examination or testing is required, it must be mutually agreed upon.	The degree of examination, inspection, and testing, and the acceptance standards must be mutually agreed upon by the manufacturer, fabricator, erector, or contractor and the Owner. All Services - Visual Examinations. If more rigorous examination or testing is required, it must be mutually agreed upon.
Nondestructive Testing	Radiographic Ultrasonic Eddy Current Liquid Penetrant Magnetic Particle Hardness Tests	Radiographic Ultrasonic Eddy Current Liquid Penetrant Magnetic Particle Hardness Tests	Radiographic Ultrasonic Eddy Current Liquid Penetrant Magnetic Particle Hardness Tests

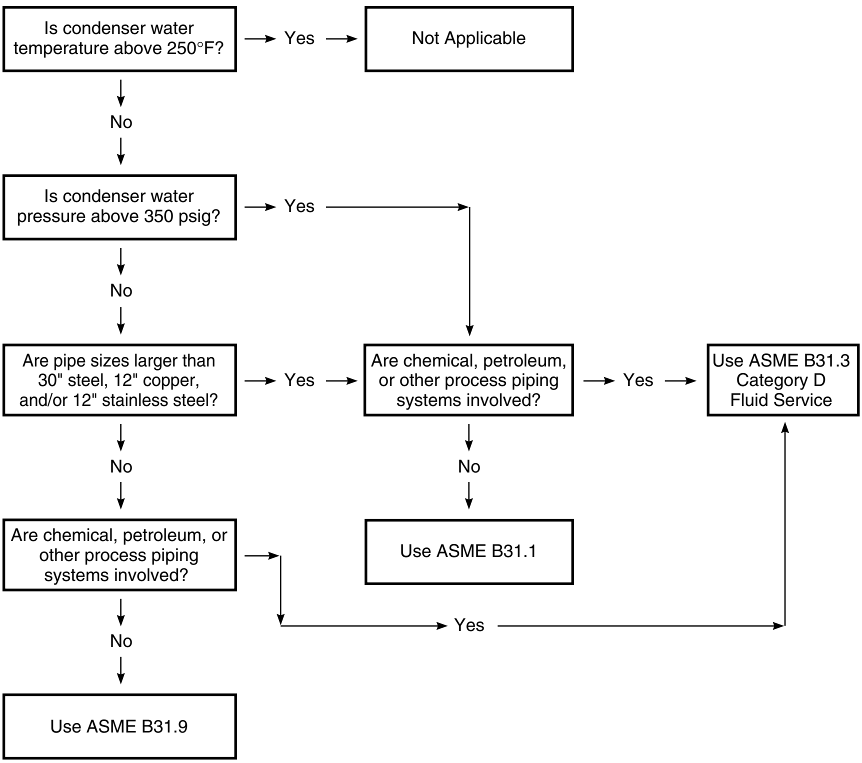
ASME B31 Chilled Water System Decision Diagram

Chilled Water Systems (0–60°F.)



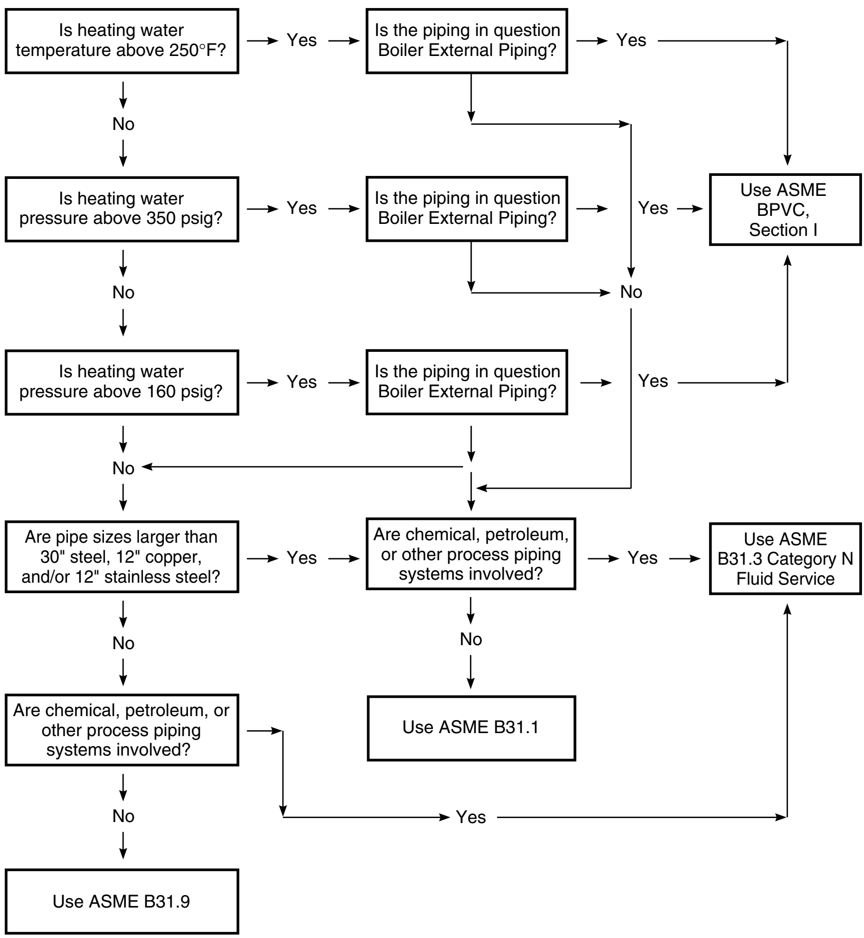
ASME B31 Condenser Water System Decision Diagram

Condenser Water Systems (60–110°F.)



ASME B31 Heating Water System Decision Diagram

Heating Water Systems (110–450°F.)



ASME B31 Steam & Condensate System Decision Diagram

Steam & Steam Condensate Systems (0–300 PSIG)