CHAPTER C4
BUILDING SERVICES PIPING

Mohammed N. Vohra, P.E.
Senior Mechanical Engineer
Delon Hampton & Associates
Washington, D.C.

Paul A. Bourquin, P.E.
Consultant
Pleasantville, New York

This chapter discusses the building services piping for heating, cooling, and compressed air installed in industrial, institutional, commercial, and public buildings and multiunit residences. Generally building-services piping operates at relatively low temperatures and pressures. ASME Pressure Piping Code, Sec. B31.9, Building Services Piping, was developed to employ a simplified approach. ASME B31.9 covers the piping which does not require the ranges of sizes, pressures, and temperatures covered in ASME Pressure Piping Code, Sec. B31.1, Power Piping.

CONSTRUCTION CODES

Every plot of land is under the authority of a jurisdiction. It is necessary to obtain a building permit from the authorities having jurisdiction over the property on which the building is to be placed. To obtain a permit the plans must show that the building is to be built in conformance with the building code which has been adopted by the local authority. The local authority has its own construction codes or has adopted one of the several national codes.

Building codes are omnibus-type documents which treat all aspects of construction and specify safety requirements as well as referencing safety codes written by other code-writing organizations. Building codes, safety codes, and standards are updated periodically by the issuing organizations, and the latest revision should be used.

A listing of code-writing bodies and the specific sections of the codes which control piping follows:

Building Codes

International Mechanical Code—A comprehensive International Mechanical Code was prepared in 1995 by a development committee appointed by and consisting of representatives of Building Officials and Code Administrators International

TABLE C4.1 Safety Codes

ASME—American Society of Mechanical Engineers
BPVC—Boiler and Pressure Vessel Code
Section I—Power Boilers
Section IV—Heating Boilers
Section VIII—Pressure Vessels
Section IX—Welding and Brazing Qualifications
ASME B31—Code for Pressure Piping
B31.1—Power Piping
B31.3—Process Piping
B31.5—Refrigeration Piping
B31.9—Building Services Piping
NFPA—National Fire Protection Association
National Fire Codes
NFPA 30—Flammable and Combustible Liquids Code
NFPA 30A—Automotive and Marine Service Station Code
NFPA 31—Installation of Oil Burning Equipment
NFPA 32—Drycleaning Plants
NFPA 50—Bulk Oxygen Systems at Consumer Sites
NFPA 51—Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes
NFPA 51B—Cutting and Welding Processes
NFPA 54 (ANSI Z223.1)—National Fuel Gas Code
NFPA 58—Storage and Handling of Liquified Petroleum Gases
NFPA 88B—Repair Garages
NFPA 99—Health Care Facilities
NFPA 407—Aircraft Fuel Servicing

(BOCA), International Conference of Building Officials (ICBO), and Southern Building Code Congress International (SBCCI). The International Mechanical Code is supported and maintained jointly by BOCA, ICBO, and SBCCI for use with each organization's family of codes.

Requirements for piping were specified in the mechanical sections of the building codes and in the referenced safety sections. The 1995 edition of International Mechanical Code supersedes the earlier editions of the individual mechanical codes published by each code writing body, i.e., National Mechanical Code, Uniform Mechanical Code, and Standard Mechanical Code. When referenced, the applicable section of the ASME B31 Pressure Piping Code should be used.

Safety Codes

Safety codes give rules for the construction of piping systems. These codes are often listed as reference documents in building codes. They have also been adopted as law by some states. Applicable codes are listed in Table C4.1

Component Standards

Component standards list dimensions, chemical composition, and tensile strength of materials. They sometimes contain pressure-temperature ratings. These standards are referenced in both the building codes and the safety codes. Component standards used for building piping are listed in Table C4.2.

Responsibility

The ultimate responsibility for the proper design and construction of a building and its various systems remains with the owner. The owner can use professionals and experts to do the actual work and perform the inspections, but in the event of a failure, the owner is the first person who will be sought out for satisfaction. Based on the requirements of the local law, however, the division of responsibility may differ from one jurisdiction to another.

BASIC SYSTEMS

Each piping system in a building is used to convey a fluid to heat, cool, or perform some other service. Energy must be used to move the fluid: For a liquid, the energy is provided by a pump; for steam systems, a boiler; and for compressed air, a compressor. Systems fall into two broad categories:

1. Recirculating
2. Distributing

Steam

Steam systems are usually of a recirculating type to return the condensate to the boiler. If the condensate is not recoverable or may be contaminated, it is wasted and the system becomes, in effect, distributive. The return of a steam-recirculating system is in the form of liquid condensate which is recovered through steam traps which pass the condensed steam in the form of a liquid but do not pass steam. Steam piping should be pitched downward in the direction of steam flow. Steam takeoffs should always be from the top of the main. As condensation is constantly occurring due to heat loss through the pipe walls, a trap must be installed at any rise in pipe elevation, at the end of horizontal mains, and at intermediate points of long runs. Traps are also used at the discharge of heating devices such as radiators, unit heaters, and steam coils.

The condensate system should be pitched downward in the direction of flow to the boiler or recovery tank. If it is not feasible to have continuous pitch to the boiler, a condensate pump can be used and the pump discharge line can change elevation as needed.

Some small low-pressure systems do not use traps; the condensate returns by gravity to the boiler through the supply or return pipes. All piping must pitch downward toward the boiler. Supply pipe-steam velocities should be kept low to prevent slugs of condensate from being carried along with the steam and producing loud knocks at changes in direction. Noise is apt to occur during warm-up when cold pipes result in heavy condensation.

TABLE C4.2 Component Standards

Ferrous pipe and tubing	
ASME	
B36.10	Welded and Seamless Wrought Steel Pipe
B36.19	Stainless Steel Pipe
ASTM	
A53	Pipe, Steel-Black and Galvanized, Welded and Seamless
A106	Seamless Carbon Steel Pipe for High Temperature Service
A135	Electric-Resistance-Welded Steel Pipe
A139	Electric Fusion Welded Steel Pipe
A211	Spiral-Welded Steel or Iron Pipe
A312	Seamless & Welded Austenitic Stainless Steel Pipe
A377	Ductile Iron Pressure Pipe
A539	Electric-Resistance-Welded Coiled Steel Tubing for Gas and Fuel Oil Lines
ANSI/AWWA	
A21.51/C151	Ductile Iron Pipe Centrifugally Cast in Metal Molds or Sand-Lined Molds for Water or Other Liquids
AGA/ANSI	
A21.52	Ductile Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds for Gas
Ferrous fittings and valves	
ASME	
B16.1	Cast Iron Pipe Flanges and Flanged Fittings
B16.3	Malleable Iron Fittings, Classes 150 and 300
B16.4	Cast Iron Threaded Fittings, Classes 125 and 250
B16.5	Pipe Flanges and Flanged Fittings
B16.9	Factory-Made Wrought Steel Butt-Weld Fittings
B16.10	Face-to-Face and End-to-End Dimensions of Valves
B16.11	Forged Steel Fittings, Socket-Weld, and Threaded
B16.14	Ferrous Pipe Plugs, Bushings and Lock Nuts with Pipe Threads
B16.28	Wrought Steel Butt-Weld Short Radius Elbows and Returns
B16.33	Manually Operated Metallic Gas Valves for Use in Gas Piping Systems up to 125 psig
B16.34	Valves—Flanged, Threaded, and Welding End
B16.39	Malleable Iron Threaded Pipe Unions, Classes 150, 250, and 300
B16.42	Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300
B16.47	Large Diameter Steel Flanges
ASTM	
A403	Wrought Austenitic Stainless Steel Piping Fittings
MSS	
SP-43	Wrought Stainless Steel Butt-Weld Fittings
SP-76	Butterfly Valves
SP-70	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71	Cast Iron Swing Check Valves, Flanged and Threaded Ends
SP-72	Ball Valves with Flanged or Butt-Weld Ends for General Service
SP-78	Cast Iron Plug Valves, Flanged or Threaded Ends
SP-83	Carbon Steel Pipe Unions, Socket-Weld or Threaded
SP-84	Steel Valves, Socket-Weld and Threaded Ends
SP-85	Cast Iron Globe and Angle Valves, Flanged and Threaded Ends

TABLE C4.2 Component Standards (*Continued*)

Copper and aluminum pipe and tubing	
ASTM	
B42	Seamless Copper Pipe, Standard Sizes
B43	Seamless Red Brass Pipe, Standard Sizes
B68	Seamless Copper Tube, Bright Annealed
B75	Seamless Copper Tube
B88	Seamless Copper Water Tube
B210	Aluminum-Alloy Drawn Seamless Tube
B241	Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
B251	General Requirements for Wrought Seamless Copper and Copper-Alloy Tube
B302	Threadless Copper Pipe
B547	Aluminum-Alloy Formed and Arc Welded Round Tube
Copper and aluminum fittings and valves	
ASME	
B16.15	Cast Bronze Threaded Fittings, Classes 125 and 250
B16.18	Cast Copper-Alloy Solder Joint Pressure Fittings
B16.22	Wrought Copper and Copper-Alloy Solder Joint Pressure Fittings
B16.24	Bronze Pipe Flanges and Flanged Fittings, Classes 150 and 300
B16.26	Cast Copper-Alloy Fittings for Flared Copper Tubes
B361	Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings
MSS	
SP-80	Bronze Gate, Globe, Angle, and Check Valves
Other components and standards	
ASME	
B1.20.1	Pipe Threads
B16.21	Nonmetallic Flat Gaskets for Pipe Flanges
B16.25	Butt-Weld Ends for Pipe, Valves, Flanges and Fittings
B18.2.1	Square and Hex Bolts and Screws
B18.2.2	Square and Hex Nuts
ASTM	
A36	Structural Steel
A183	Carbon Steel Track Bolts and Nuts
A193	Alloy-Steel and Stainless Steel Bolting Materials for High Temperature Service
A194	Carbon and Alloy-Steel Nuts for Bolts for High Pressure and High Temperature Service
A307	Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength
B32	Solder Metal
ANSI/AWWA	
A21.11/C111	Rubber-Gasket Joints for Ductile Iron and Gray-Iron Pressure Pipe and Fittings
ANSI/AWS	
A5.1	Covered Carbon Steel Arc Welding Electrodes
A5.2	Iron and Steel Oxyfuel Gas Welding Rods
A5.3	Aluminum and Aluminum-Alloy Covered Arc Welding Electrodes

TABLE C4.2 Component Standards (*Continued*)

ANSI/AWS (*Continued*)	
A5.6	Covered Copper and Copper-Alloy Welding Rods and Electrodes
A5.7	Copper and Copper-Alloy Bare Welding Rods and Electrodes
A5.8	Brazing Filler Metal
A5.9	Corrosion-Resisting Chromium and Chromium-Nickel Steel Bare and Composite Metal Cored and Stranded Welding Electrodes and Welding Rods
A5.10	Aluminum and Aluminum-Alloy Bare Welding Rods and Electrodes
A5.12	Tungsten Arc Welding Electrodes (Non-Consumable)
A5.18	Carbon Steel Filler Metals for Gas Shielded Arc Welding
A5.20	Carbon Steel Electrodes for Flux Cored Arc Welding
A5.22	Flux Cored Corrosion-Resisting Chromium and Chromium-Nickel Steel Electrodes
MSS	
SP-6	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP-25	Standard Marking System for Valves, Fittings, Flanges, and Unions
SP-58	Pipe Hangers and Supports—Materials, Design, and Manufacture
SP-69	Pipe Hangers and Supports—Selection and Application
SP-89	Pipe Hangers and Supports—Fabrication and Installation Practices
ASTM	
E488	Test Method for Strength of Anchors in Concrete and Masonry Elements
ANSI/AWWA	
A21.50/C150	Thickness Design of Ductile Iron Pipe
Nonmetallic pipe and fittings*	
ASTM	
F412	Definition of Terms Relating to Plastic Piping Systems
D1788	Specifications for Acrylonitrile-Butadiene-Styrene (ABS) Plastics, Rigid
D1527	ABS Plastic Pipe, Schs 40 and 80
D2235	Solvent Cement for ABS Plastic Pipe and Fittings
D2468	ABS Plastic Pipe Fittings, Sch 40
D3965	Rigid ABS Compounds for Pipe and Fittings
D2581	Specifications for Polybutylene (PB) Plastics Molding and Extrusion Materials
D2657	Standard Practice for Heat-Joining Polyolefin Pipe and Fittings
D2666	PB Plastic Tubing
D3000	PB Plastic Pipe (SDR-PR) Based on Outside Diameter
D1248	Specifications for Polyethylene (PE) Plastics Molding and Extrusion Materials
D2104	PE Plastic Pipe, Sch 40
D2447	PE Plastic Pipe, Schs 40 and 80, Based on Outside Diameter
D2683	Socket-Type PE Fittings for Outside Diameter Controlled PE Pipe and Tubing
D2737	PE Plastic Tubing
D3350	Specifications for PE Plastic Pipe and Fittings Materials
D1784	Specifications for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds
F437	Threaded CPVC Plastic Pipe Fittings, Sch 80
F438	Socket-Type CPVC Plastic Pipe Fittings, Sch 40

TABLE C4.2 Component Standards (*Continued*)

ASTM (*continued*)	
F439	Socket-Type CPVC Plastic Pipe Fittings, Sch 80
F441	CPVC Plastic Pipe, Schs 40 and 80
F442	CPVC Plastic Pipe (SDR-PR)
F493	Specification for Solvent Cements for CPVC Plastic Pipe and Fittings
D2846	CPVC Plastic Hot- and Cold-Water Distribution Systems
D1785	PVC Plastic Pipe, Schs 40 and 80
D2241	PVC Pressure-Rated Pipe (SDR Series)
D2464	Threaded PVC Plastic Pipe Fittings, Sch 80
D2466	PVC Plastic Pipe Fittings, Sch 40
D2467	Socket-Type PVC Plastic Pipe Fittings, Sch 80
D2564	Solvent Cements for PVC Plastic Pipe and Fittings
D2855	Practice for Making Solvent-Cemented Joints with PVC Pipe and Fittings
D2310	Standard Classification for Machine-Made Reinforced Thermosetting-Resin Pipe (RTRP)
D2517	Reinforced Epoxy Resin Gas Pressure Pipe and Fittings
D2996	Filament-Wound Reinforced Thermosetting-Resin Pipe
D3517	Fiberglass (RTRP) Pressure Pipe
D3754	Fiberglass (RTRP) Sewer and Industrial Pressure Pipe

* This list is limited to some of the basic piping standards. There are more than 200 ASTM standards relating to plastic pipe.

Condenser Water

A typical condenser-water system recirculates the water from the refrigeration machine condenser, through the pump, up to the sprays on the top of the cooling tower, and from the basin of the tower back to the condenser. Since this is an open system, expansion of the water is not a factor; the water level in the basin compensates.

Because it is sprayed through the air, the water contains oxygen and other contaminants and becomes extremely corrosive. For many years chromates were used to inhibit steel-pipe corrosion with success. Recent environmental rules have prohibited chromate water treatment, and new methods which require closer control are being used. It is important to clean condenser-water systems carefully and monitor treatment closely to prevent the destruction of the piping system.

Chilled Water

Chilled water systems are closed recirculating systems and therefore require expansion tanks. An open expansion tank can be used at the highest point of the system, with makeup water provided through a tank level control device. Expansion can also be provided for by use of a closed hydropneumatic tank at any point in the system. For this type of tank the water level is maintained by a pressure pump controlled by a tank-level sensor. As sufficient air pressure must be maintained above the water in the tank to support the water to the highest point of the system, it is sometimes necessary to provide a method for increasing the air pressure in the tank. The tank must be constructed for the proper pressure, and a relief valve must be provided. The corrosion problem is not as severe as in condenser-water systems, but water treatment should be used.

Hot Water

A high-temperature hot-water system is a closed recirculating system that returns the hot water to the boiler. High-temperature hot water is relatively high-pressure water distributed to the point of usage by means of pumps. High-temperature hot water can be directly piped to heating coils or to heat exchanger where it can be converted to a lower pressure system, steam, or low-temperature hot water. Generally the circulation is limited to mechanical rooms for safety concerns.

Low-temperature hot water is a relatively low-pressure recirculating system and requires an expansion tank when a heat exchanger is utilized for conversion. Air vents and air separators are required to remove trapped air which affects the flows. Because it is a secondary recirculating system, water treatment is required. Normally an expansion tank is a closed hydro-pneumatic tank equipped with an air diaphragm which is sized to meet the expansion of the fluid in the system.

Compressed Air

A compressed-air system is an example of a distributive system. The air is piped to its point of use for a control or tool system, at which point energy is recovered and reduced to atmospheric pressure and released.

PIPE DESIGN

Piping systems are designed to withstand the combined effects of the internal pressure and temperature of the contained fluid and other external stress-imposing forces such as expansion or contraction, support spans, earthquake, and wind.

The internal pressure produces two types of stresses in the pipe:

1. *Hoop stress,* also called the tangential stress, is the result of the radial pressure in the pipe. This force tends to split the pipe open along a seam.
2. *Longitudinal stress* is caused by the force of the pressure on the end of the pipe. This force is exerted equally on a closed end such as a cap or on an open component such as an elbow. It acts along the axis of the pipe and tends to pull the pipe apart around its circumference or at a joint. Other longitudinal stresses are caused by the pipe acting as a beam between supports and by expansion or contraction where the pipe ends are fixed by anchors.

Pressure

The internal pressure of steam systems is the gauge pressure of the steam as determined by the boiler control or the setting of a pressure-reducing valve. For compressed air or other gasses, the gauge pressure is determined by the compressor control or the setting of a regulator. This pressure can be considered constant throughout the system.

For liquid piping systems the pressure at any point is determined by adding the pressure produced by the circulating pump to the static pressure. The static pressure is calculated in a state of no flow (pump off) and is the result of the weight of the liquid in the pipe from the highest point of the system to the lowest. This pressure varies with the elevation of each point in the piping.

The pressure in liquid-piping systems is also referred to as *head*. This is the height of a column of the liquid in the pipe which would be supported by the pressure.

The weight of one cubic foot (0.028 cubic meter) of water at Standard Temperature and Pressure (STP) is 62.5 pounds (28.3 kg.). The footprint of a cubic foot is 144 square inches. The weight per square inch of a column of water one foot high is:

$$62.5/144 = 0.43 \text{ psi (3 kPa) or}$$
$$1 \text{ psi (6.9 kPa)} = 2.3 \text{ ft (0.7 m) of water}$$

For circulating liquid piping systems, the datum pressure is at the expansion tank. With an open tank the pressure at the surface is atmospheric (0 psig). A hydropneumatic tank has a regulator or relief valve which determines the pressure on the surface of the water in the tank. The pressure at other points in the system is found by adding the pressure produced by the circulating pump to the static pressure of the system. For a flowing closed-loop system the pump pressure is highest at the pump discharge and will decrease, due to friction, as the fluid flows through the pipe and other elements of the system back to the pump suction. For a system which may have no flow with the pump running, the pump shutoff pressure may be imposed on the system, depending on the location of the expansion tank. See Fig. C4.1 for examples.

In Fig. C4.1*b* a 30-story building with two subgrade levels could have a water piping–elevation difference of 400 ft (122 m) from the open expansion-tank water surface in the penthouse down to the pump in the basement. This is called a static head of 400 ft (122 m) the design static pressure would be calculated as follows:

$$400 \text{ ft} \times 0.43 \text{ psi/ft} = 172 \text{ psi (1186 kPa)}$$

Horizontal offsets in the piping system do not affect the static pressure.

The total pump head is 70 ft, which is required to overcome the resistance of the system. The pump-discharge pressure in this example is 48 ft, or 21 psi, which when added to the static pressure would provide the system design pressure:

$$\text{Design pressure} = 172 \text{ psi} + 21 \text{ psi} = 193 \text{ psi (1331 kPa)}$$

All pipe, fittings, valves, pumps, and heat exchangers on the pump-discharge part of the system must be designed to withstand this pressure at the lower elevation. If it is possible to block the flow in the system, a study should be made to see if the pump shutoff pressure may cause a higher design pressure. On the suction side of the pump, the design pressure will be 172 psi (118 kPa), which will be the pressure when the pump is not operating. It is advantageous to locate the heat exchangers and associated valves in the lower pressure portion of the piping system. At the higher elevations it is economical to use valves and fittings of a lower pressure class rating.

Temperature

The pipe-material temperature is considered to be the same as the temperature of the fluid in the pipe. For saturated steam systems it is the saturation temperature corresponding to the gauge pressure. The temperature is important since the

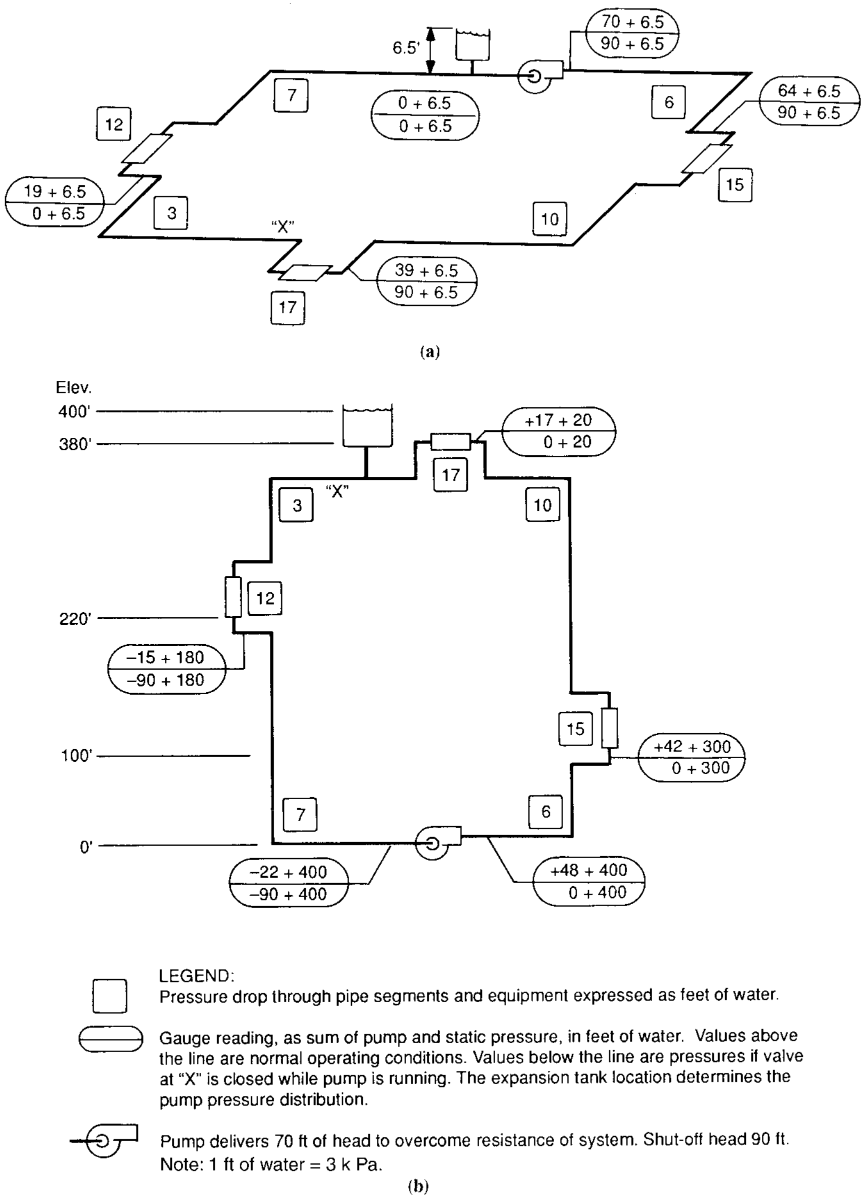

FIGURE C4.1 (*a*) Horizontal piping system; (*b*) vertical piping system.

strength of materials used in the systems decreases as the temperature rises. For ferrous materials in building systems fluid temperatures are not usually high enough to be a factor. However, copper and aluminum and the joints in these materials can be affected by the temperatures encountered. Thermoplastics, as a group, lose strength rapidly as the temperatures rise above 70°F (21°C). At 100°F (38°C) they have lost approximately 25 percent of their strength and at 140°F (60°C) less than 50 percent remains.

Allowable Stress

Allowable stresses for pipe materials are tabulated in the safety codes listed in Table C4.1. As this chapter concerns piping in buildings, App. A of ASME B31.9, Building Services Piping, will be used for allowable stress values.

The published allowable stresses are determined for various materials by using the lowest of the following criteria for each material:

1. Cast iron or ductile iron
   - ***a.*** One-tenth of the specified minimum yield strength at room temperature
   - ***b.*** One-tenth of the tensile strength at the listed temperature

2. Malleable iron
   - ***a.*** One-fifth of the specified minimum tensile strength at room temperature
   - ***b.*** One-fifth of the tensile strength at the listed temperature

3. Other metals
   - ***a.*** One-fourth of the specified minimum tensile strength at room temperature
   - ***b.*** One-fourth of the tensile strength at the listed temperature
   - ***c.*** Two-thirds of the specified minimum yield strength at room temperature
   - ***d.*** Two-thirds of the yield strength at the listed temperature

4. Thermoplastics
   - ***a.*** One-half of the hydrostatic design basis at design temperature as determined by the methods in ASTM D2837

5. Reinforced thermosetting resins
   - ***a.*** One-half of the hydrostatic design basis at design temperature as determined by the methods in ASTM D2992

The tensile and yield strengths are found in the standards listed in Table C4.2 for each material specification. The shear and bearing stress values of pipe materials can be determined by applying multipliers:

$$\text{Shear stress} = 0.8 \times \text{basic allowable stress}$$

$$\text{Bearing stress} = 1.6 \times \text{basic allowable stress}$$

When pipe is produced by a method of manufacture which results in a welded longitudinal seam, the basic allowable stress for the pipe is modified by a factor E, called the joint efficiency factor. Table C4.3 lists some piping materials used for building piping and the allowable stresses and E factors for each material. The listed values are SE, which is the product of the allowable stress S and the longitudinal joint efficiency factor E.

TABLE C4.3 Allowable Stresses

Material & ASTM Spec. no.	Grade	Available sizes NPS (DN)	*E* factor	Strengths		Max allowable stress value *SE* (ksi) for metal temperature not over			
				Min. tensile (ksi)	Min. yield (ksi)	0–100°F	200°F	300°F	400°F
Carbon steel									
Seamless pipe and tube									
A 53	B	¼ to 26 (8 to 650)	1.00	60.0	35.0	15.0	15.0	15.0	15.0
A 106	B	¼ to 30 (8 to 750)	1.00	60.0	35.0	15.0	15.0	15.0	15.0
Electric resistance welded pipe and tube									
A 53	B	2 to 20 (50 to 500)	0.85	60.0	35.0	12.8	12.8	12.8	12.8
A 135	B	2 to 30 (50 to 750)	0.85	60.0	35.0	12.8	12.8	12.8	12.8
Furnace butt welded (continuous weld) pipe and tube									
A 53	F	½ to 4 (15 to 100)	0.60	45.0	25.0	6.8	6.8	6.8	6.8
Wrought welding fittings									
A 234	WPB	½ to 42 (15 to 1050)	1.00	60.0	35.0	15.0	15.0	15.0	15.0
Stainless steel; welded pipe and tube									
A 312	TP304	¼ to 30 (8 to 750)	0.85	75.0	30.0	18.8	15.7	14.1	13.0
A 312	TP316	¼ to 30 (8 to 750)	0.85	75.0	30.0	18.8	16.2	14.6	13.4

TABLE C4.3 Allowable Stresses (*Continued*)

Material & ASTM Spec. no.	Grade	Available sizes NPS (DN)	*E* factor	Strengths		Max allowable stress value *SE* (ksi) for metal temperature not over			
				Min. tensile (ksi)	Min. yield (ksi)	0–100°F	200°F	300°F	400°F
Ductile iron									
C151/A21.51		4 to 48 (100 to 1200)	—	60.0	42.0	4.2	4.2	4.2	4.2
Aluminum Alloy; seamless pipe and tube									
B 241	3003	¾ to 24 (20 to 600)	0	14.0	—	3.4	3.4	2.4	1.4
B 241	6061	¾ to 24 (20 to 600)	T4	26.0	—	6.5	6.5	6.0	4.5
Copper and copper alloys; seamless pipe and tube									
B 75	102–142	¼–12 (8–300)	annealed	30.0	9.0	6.0	4.8	4.7	3.0
B 75	102–142	¼–12 (8–300)	light drawn	36.0	30.0	9.0	9.0	9.0	8.2
B 75	102–142	¼–12 (8–300)	hard drawn	45.0	40.0	11.3	11.3	11.3	4.3
B 88	102–122	¼–12 (8–300)	annealed	30.0	9.0	6.0	4.8	4.8	3.0
B 88	102–122	¼–12 (8–300)	drawn	36.0	30.0	9.0	9.0	9.0	8.2
Structural shapes for pipe supports									
A 36	—	—	—	58.0	36.0	11.6	11.6	11.6	11.6
Bolts, nuts, and studs for flanges and supports									
A 307	B	—	—	55.0	—	7.0	7.0	7.0	7.0

Pipe Wall Thickness

The dimensions of steel pipe are governed by ASME B36.10M. This standard lists nominal pipe sizes (NPS) from NPS 1/8 to NPS 80 (DN 6 to DN 2000), with a range of wall thicknesses for each size. There are 23 different standardized wall thicknesses listed for NPS 8 (DN 200) pipe. Not all of the diameters and thicknesses are manufactured by the mills on a regular basis. Before making a selection check with a pipe supply warehouse for availability. Mills will make large quantities on order.

Pipe sizes up to and including NPS 12 (DN 300) have a standardized outside diameter which is greater than the nominal size. For sizes NPS 14 (DN 350) and larger the outside diameter is equal to the nominal size.

Two different systems for describing commonly used pipe-wall thicknesses have developed. The first, which has been used commercially for many years, uses these designations:

STD	Standard
XS	Extra strong, also called extra heavy
XXS	Double extra strong, also called double extra heavy

The second system developed from an attempt to establish a set of schedule numbers. Each schedule was to designate a wall thickness for each pipe size so the pressure-carrying capacity would be the same regardless of size. Some schedules in use are

Sch 40	Schedule 40
Sch 80	Schedule 80
Sch 160	Schedule 160

Standard and Sch 40 are the same thickness through NPS 10 (DN 250). Standard wall thickness is ⅜ (9.5 mm) in for all larger sizes, whereas Sch 40 becomes increasingly thicker. Extra strong and Sch 80 are the same thickness for all sizes through NPS 8 (DN 200). For all larger sizes extra strong pipe remains at ½-in (12.7 mm) wall thickness whereas Sch 80 becomes increasingly thicker.

Even though pipe-stress calculations are seldom required for building piping, a brief review of the basics is given so that the principles can be understood. To find the required pipe-wall thickness to contain the fluid at the design pressure use the following formula:

$$t_m = \frac{PD}{2SE} + A \tag{C4.1}$$

Conversely, to find the pressure a pipe of known wall thickness will withstand the formula is

$$P = \frac{2SE(t_m - A)}{D} \tag{C4.2}$$

where t_{in} = minimum required wall thickness (in)
P = internal design pressure (psig)
D = outside pipe diameter (in)
S = basic allowable stress (psi)

E = longitudinal joint efficiency factor
A = allowance for corrosion, mill tolerance, joint preparation, mechanical strength, and so on

For example, this is the procedure to find the proper wall for a NPS 2 (DN 50) 125-psig (860 kg/mm^2) steam line with threaded fittings using A53 Grade B ERW pipe:

$$t_m = \frac{PD}{2SE} + A$$

$$P = 125 \text{ psig } (878 \text{ kg/mm}^2)$$

$$D = 2.375 \text{ in } (60 \text{ mm})$$

$$SE = 12{,}800 \text{ psi } (90{,}000 \text{ kg/mm}^2)$$

$$= 0.012 \text{ in} + A \ (0.3 \text{ mm} + A)$$

The factor A requires some consideration. The corrosion allowance depends on the expected service and the maintenance of a chemical water-treatment system. For closed systems a value of 0.025 in (0.6 mm) may be sufficient. For open systems a value of 0.065 in (1.6 mm) or higher may be needed. These values can be varied for the expected service conditions in the system being designed. The allowable mill minus tolerance for A53 pipe is given in the ASTM specification as 12.5 percent of the nominal wall thickness. If the pipe is to be threaded or grooved, the depth of the groove or the depth of the thread, as listed in Table C4.4, plus a tolerance of 0.015 in (0.4 mm) should be allowed. For threaded NPS 2 (DN 50) standard weight pipe which has a nominal wall thickness of 0.154 in (4 mm) the factor A will equal the sum of:

Corrosion allowance =	0.025
Mill tolerance = 0.125 × 0.154 =	0.019
Thread depth (from Table C4.4) = 0.070 + 0.015	= 0.085
Total A	= 0.129

Note: 1 in = 25.4 mm

The minimum required wall thickness plus allowance is

$$t_m = 0.012 \text{ in } + 0.129 \text{ in } = 0.141 \text{ in } (3.6 \text{ mm})$$

Select the next larger commercially available wall thickness for use. In this case standard weight pipe with a wall thickness of 0.154 in (4 mm) is suitable for the service.

Mechanical strength should be considered as the overriding wall thickness needed to withstand the shear loads at hangers, the rough handling during installation, and unanticipated use of the pipe such as for scaffolding or hoisting after installation.

If in the above example the pipe was used for 5-psig (34 kPa) steam, the wall thickness needed to withstand the pressure would be 0.0005 in. The allowances do not change so the minimum pipe wall thickness required would be 0.0005 in (0.013 mm) + 0.129 in, which is 0.1295 in (3.3 mm). This points out that the prime consider-

TABLE C4.4 Thread and Groove Depths (tolerances not included)

Nominal pipe size (DN)	Thread depth (in)*	Groove depth (in)†
½ (15)	0.057	—
¾ (20)	0.057	0.056
1 (25)	0.070	0.063
1¼ (32)	0.070	0.063
1½ (40)	0.070	0.063
2 (50)	0.070	0.063
2½ (65)	0.100	0.078
3 (80)	0.100	0.078
4 (100)	0.100	0.083
5 (125)	0.100	0.084
6 (150)	0.100	0.085
8 (200)		0.092
10 (250)		0.094
12 (300)		0.109
14 (350)		0.109
16 (400)		0.109
18 (450)		0.109
20 (500)		0.109
24 (600)		0.172

* Dimension *h*, the height of thread, from ASME B1.20.1, Pipe Threads—General Purpose. Pipe more than 6 in is rarely threaded.

† Reference groove depth as listed by Victaulic Co.

General Note: As the plus tolerance on the pipe's outside diameter increases, the fixed thread or groove diameter cuts away more of the pipe wall thickness. Victaulic limits the plus tolerance to 1⁄32 in. This is less than that allowed by ASTM A53 or A106. If the pipe is 1⁄32 in oversize, the groove or thread depth is increased by about 30 percent. If large pipe is to be used for grooving, the plus tolerance should be stated on the pipe purchase order.

Note: 1 in = 25.4 mm.

For DN equivalents refer to Chap. A1 or App. E2.

ation for low-pressure piping systems is the mechanical strength rather than pressure containment.

Elbows, Bends, and Miters

A change in pipe direction for building piping is done by using an elbow fitting. Bends and miters may also be used but are generally not economical when labor costs are high.

Additional wall thickness must be provided when a bend is made, since the heel of the bend will stretch and thin. Table C4.5 gives the added thickness needed to provide the required minimum thickness in a 90° finished bend. The flattening of pipe during a bend should not result in a reduction of the original diameter by more than 8 percent.

For miter joints, an angular offset of 3° or less is considered to be the same as a girth weld and does not require an increase in the calculated pipe-wall thickness. The angular offset is the change in direction of the axis of the pipe. A 3° offset will result in a miter angle of 1½° to be cut on the end of each of the pipe segments to be joined. Miters can be used for offsets from 3° to 45° at pressures of 50 psig

TABLE C4.5 Pipe Thickness for Bends

Radius of bend pipe diameters*	Thickness increase†
6 or greater	$1.06t_m$
5	$1.08t_m$
4	$1.14t_m$
3	$1.24t_m$

* The pipe diameter is the nominal diameter.
† t_m is the minimum required wall thickness.

(345 kPa) or less. For miters at higher pressures the formulas in ASME B31.9 or B31.3 should be used.

Pipe Branch Design

Branch connections for pipe sizes under NPS 3 (DN 80) are usually made with threaded or grooved tees. For larger pipe sizes with welded joints, branches are made by using a welding tee, an integrally reinforced outlet fitting, or by welding the branch pipe directly to the main using a full-penetration weld.

When welding the branch directly to the main, the opening in the main for the branch pipe weakens the main, and the need for added reinforcement to replace the removed material must be evaluated. Reinforcement is *not* needed when

1. The branch connection is made using a fitting made to an ASME B16.9-listed standard

2. The branch connection is made using a threaded or socket-weld coupling not exceeding

a. NPS 2 (DN 50) or

b. One-fourth the nominal diameter of the main

The coupling wall thickness should be not less than that of the branch pipe and welded to the main with a full penetration weld.

3. An integrally reinforced outlet fitting is used

Table C4.6 lists the maximum internal pressure permitted without reinforcement for various combinations of branch and main sizes for ASTM A53 Grade B and A106 Grade B pipe at 90° and 45° branch angles. For pressures higher than those listed, use a fitting or use the rules in ASME B31.1 for determining the required reinforcement and the method of application.

Closures and Blanks

Closures are made at the end of pipe runs using standard fittings such as caps, plugs, or blind flanges. A flat plate can also be used as a closure when it is welded to the pipe with a full penetration weld.

TABLE C4.6 Maximum Operating Pressures for Unreinforced Welded Branch Connections—Valid to 650°F—for ASTM A53, A135, and A106 Grade B Pipe. S = 15,000 psi

NPS (DN)		Standard weight pipe Pressure (psig)		Extra heavy pipe Pressure (psig)	
Main	Branch	90° branch	45° branch	90° branch	45° branch
3 (80)	2 (50)	842	713	1252	1076
4 (100)	3 (80)	720	620	1105	963
	2 (50)	723	613	1096	942
6 (150)	4 (100)	567	490	934	816
	3 (80)	583	502	955	831
	2 (50)	582	494	945	813
8 (200)	6 (150)	489	426	826	724
	4 (100)	503	435	830	724
	3 (80)	515	444	846	735
	2 (50)	513	437	835	719
10 (250)	8 (200)	443	387	667	586
	6 (150)	448	389	674	589
	4 (100)	458	396	674	587
	3 (80)	468	403	686	595
	2 (50)	465	398	674	580
12 (300)	10 (250)	385	336	544	477
	8 (200)	387	337	570	499
	6 (150)	390	339	574	501
	4 (100)	356	345	573	498
	3 (80)	406	350	582	504
	2 (50)	404	345	570	491
14 (350)	12 (300)	346	302	483	424
	10 (250)	352	307	498	436
	8 (200)	353	308	522	457
	6 (150)	356	309	525	459
	4 (100)	363	314	523	455
	3 (80)	371	319	531	461
	2 (50)	368	314	520	448
16 (400)	14 (350)	301	263	420	368
	12 (300)	304	266	426	373
	10 (250)	310	270	439	384
	8 (200)	311	270	460	403
	6 (150)	313	272	463	404
	4 (100)	319	276	460	400
	3 (80)	325	280	467	404
	2 (50)	322	275	456	393
18 (450)	16 (400)	265	231	369	323
	14 (350)	269	234	376	329
	12 (300)	272	237	381	333
	10 (250)	276	241	393	343
	8 (200)	277	241	412	360
	6 (150)	279	242	413	360
	4 (100)	284	246	411	357
	3 (80)	290	249	416	360
	2 (50)	287	245	406	350

TABLE C4.6 Maximum Operating Pressures for Unreinforced Welded Branch Connections—Valid to 650°F—for ASTM A53, A135, and A106 Grade B Pipe. S = 15,000 psi (*Continued*)

NPS (DN)		Standard weight pipe Pressure (psig)		Extra heavy pipe Pressure (psig)	
Main	Branch	90° branch	45° branch	90° branch	45° branch
20 (500)	18 (450)	236	206	329	288
	16 (400)	239	209	333	292
	14 (350)	243	212	340	297
	12 (300)	245	214	345	301
	10 (250)	249	217	355	310
	8 (200)	250	218	372	325
	6 (150)	251	218	373	326
	4 (100)	256	221	371	322
	3 (80)	261	225	376	325
	2 (50)	258	221	366	315
24 (600)	20 (500)	196	171	273	238
	18 (450)	198	173	276	241
	16 (400)	200	175	280	245
	14 (350)	203	177	285	249
	12 (300)	205	179	289	253
	10 (250)	209	182	298	260
	8 (200)	209	182	312	273
	6 (150)	210	182	313	273
	4 (100)	214	185	310	269
	3 (80)	218	188	314	272
	2 (50)	215	184	306	263

Notes: Pressures change directly with the ratio of SE to S.

1. For A53 Type F Butt Weld Pipe use a multiplier of 0.75.
2. If the branch opening in the main cuts the stem of pipe with a longitudinal weld, multiply table values by
   Electric resistance weld pipe 0.85
   Type F butt weld pipe 0.45
3. Based on the rules in B31.1.
4. A 12½ percent mill tolerance and a 1⁄32-in corrosion allowance have been used to calculate the pipe wall thickness for this table.
5. 1 in. = 25.4 mm.
6. For DN equivalents refer to Chap. A1 or App. E2.

The minimum thickness of the closure plate, *tc*, can be calculated by

$$t_c = d\sqrt{CP/S} + A \tag{C4.3}$$

where d = inside pipe diameter (in)
C = $0.5t_m/T$, but not less than 0.3
t_m = minimum required pipe-wall thickness (in)
T = nominal wall thickness of pipe (in)
P = internal design pressure (psi)
S = maximum allowable stress of plate material (psi)

A blank can be installed between two flanges to close off a portion of a system. The minimum thickness of the blank, t_b, can be calculated by

$$t_b = d_g \sqrt{3P/16S} + A \tag{C4.4}$$

where d_g = inside diameter of the gasket (in)

When the blank is to be left in place during operation, use the same nomenclature as above. If the blank is to be used only during hydrostatic testing, P is the test pressure and S is 0.95 times the specified minimum yield strength of the blank material.

PIPE MATERIALS

Pipe, fittings, and valves suitable for building service piping systems are available in many different materials. A brief discussion of the advantages and disadvantages of commonly used materials follows.

Steel

Steel (ASTM A53, A106) is the most widely used material for pipe. Its advantages are strength, availability, and economy. Because of its wide use there is a large pool of skilled labor knowledgeable in its installation. The disadvantages of steel pipe are its weight and low resistance to corrosion.

Copper

Copper tube (ASTM B88) is widely used as a material for sizes up to 3 or 4 in. It is available up to 8 in and on order up to 12 in, but it is not usually economical in the larger sizes. ASTM B88 gives dimensions for copper tube up to NPS 12 (DN 300) but it is not commonly made. Refer to App. E3M.

The nominal sizes of copper tubing approximate the inside diameter. The outside diameter is always ⅛ in (3 mm) larger than the nominal size. Copper tube for refrigerant service (ACR tube) is referred to by its actual outside diameter.

Copper tube is furnished in two tempers—drawn and annealed. The pressure rating of annealed tube is about 60 percent of that of drawn tube. When joints are made by brazing, the tube in the vicinity of the joint becomes annealed and the annealed pressure rating should be used. Drawn tubing is used for most building applications. Drawn tubing has been work hardened and is furnished in straight lengths. In the annealed form the tube is soft and very easily bent. It is furnished in coils or straight lengths.

Copper pressure tube is furnished in three standard thicknesses which vary with the size. The heaviest is Type K, followed by Type L and Type M. All three are suitable, but Type M is thin walled and does not have mechanical strength and is therefore easily damaged.

The advantages of copper are its resistance to corrosion and the fact that it is light weight. It is not as strong as steel and not available in sizes over 12 in. Copper can readily be bent using bending tools which keep the tube from flattening. The disadvantages of copper as a material are its low strength compared to steel and its high cost. The high cost is offset in the smaller sizes by the ease of installation.

Red Brass Pipe

Red brass pipe (ASTM B43) is made up to NPS 12 (DN 300) for standard weight and NPS 10 (DN 250) for extra strong weight. Copper tube has largely replaced brass pipe for reasons of economy. It is made to steel pipe dimensions and is sometimes used where the added mechanical strength is needed.

Thermoplastics

Thermoplastics, which are discussed in detail in Part D of this handbook, are widely used for liquids with temperatures up to 100°F (38°C) for PVC and 180°F (82°C) for CPVC. These plastics have exceptional resistance to corrosion, are light weight, easy to install, and readily available and economical. The disadvantages of thermoplastics are lower strength, which necessitates short hanger spans, high coefficients of expansion, which must be compensated for when using long straight runs of pipe, and the emission of toxic fumes under fire conditions. Fire codes in some locations do not permit the use of some plastic materials.

PVC pipe can be used as underground pressure pipe as well as for aboveground service.

Thermosetting Resins

Thermosetting resins are used for reinforced thermosetting resin pipe (RTPP), also called fiberglass reinforced plastic (FRP) pipe. This pipe is made in larger sizes and can be used at higher pressures and temperatures than thermoplastics. It is suitable for aboveground or underground service. Refer to Part D, Chap. D2 of this handbook for more information. See manufacturers' data for specific ratings.

Ductile Iron

Ductile iron has replaced cast iron as water main pipe and is used for corrosion-resistant buried pipe. It is stronger and less brittle than cast iron. Ductile-iron pipe is made in standard thickness classes, the use of which is determined by the depth of bury and laying condition. This pipe is made in standard sizes from NPS 3 to NPS 54 (75 mm to 1350 mm).

Stainless Steel and Aluminum

Stainless steel and aluminum are expensive and therefore used only when corrosion resistance and strength are needed. Schedule 5S and Schedule 10S light-wall stainless pipe are commonly used to reduce cost.

Discontinued Pipe

Discontinued pipe materials, which are no longer made, are A72 wrought iron pipe, low-alloy (Yoloy) pipe, and ASTM A120 steel pipe.

PIPE FITTINGS AND JOINTS

Pipe joints fall into two basic categories—restrained and unrestrained. Restrained joints have inherent mechanical properties that prevent the joint from separating axially as well as containing the fluid. Unrestrained joints rely on packing to contain the fluid and the friction of the packing to keep the joints from separating. Systems with unrestrained joints must be provided with external restraint if they are to withstand pressure.

Bell and spigot piping is unrestrained. Mechanical joint and sleevetype couplings, which rely on a bolted gland retainer, are also unrestrained.

Threaded, flanged, and grooved joints are restrained. Welded, soldered, brazed, flared, and compression joints are considered to be restrained but are dependent on the skill of the assembler.

Some of the fittings discussed here are also made for higher pressures and temperatures than those mentioned.

Steel Pipe

Steel pipe is joined by threading, welding, or grooving. Threaded fittings are made of cast iron, malleable iron, ductile iron, and forged steel for joining pipe up to NPS 8 (DN 200). It is an industry standard, however, to change to welding or grooving at sizes above NPS 2 (DN 50). Threaded joints are made using ASME B1.20.1 standard taper pipe threads. Pipe lighter than standard weight must not be threaded.

Cast iron threaded fittings (ASME B16.4) are made in Class 125 (standard) and Class 250 (extra heavy) and are used in most threaded applications. Cast iron is brittle, so if ductility or higher strength is required malleable- or ductile-iron fittings should be used.

Malleable-iron threaded fittings (ASME B16.3) are made in Classes 150 and 300 and are stronger and less brittle than cast iron. Care must be taken when threading steel pipe into Class 150 malleable-iron fittings. The joint can be overtightened since the malleable fitting will stretch. Two threads should be exposed on the pipe when the joint is properly made up.

Ductile-iron threaded fittings are made in Class 300 and fall between the Class 150 and 300 malleable-iron fittings in strength. There is no listed ASTM standard for ductile-iron threaded fittings.

Forged-steel threaded fittings (ASME B16.11) are made in smaller sizes and have high pressure-temperature ratings. They are used primarily for high-pressure steam.

Welding is normally used to join steel pipe from NPS 2 ½ (DN 65) and up. Welding fittings (ASME B16.9) are made to match steel-pipe diameters and wall thicknesses. They are furnished with a standard bevel end for butt welding to the pipe. Weld fittings have the same pressure-temperature ratings as the equivalent thickness scamless pipe.

For smaller sizes, forged steel socket-weld fittings (ASME B16.11) can be used for high-pressure service.

Properly made welded joints are as strong as the pipe, do not deteriorate, and have a smooth inside contour to minimize friction losses.

Flanges are used in large piping to connect to valves and equipment and to provide a means of disassembly in welded piping systems. Flanges are made of cast iron, ductile iron, bronze, and steel.

Cast-iron threaded flanges and flanged fittings (ASME B16.1) are available in Classes 125 and 250. Ductile-iron threaded flanges and flanged fittings (ASME B16.42) are made in Classes 150 and 300. Threaded flanges are used for mounting equipment and valves in larger sized threaded pipe systems.

Class 125 cast-iron flanges have a flat face and are often mated to Class 150 steel flanges which have a raised face. Great care must be taken in tightening the bolts to avoid cracking the cast-iron flange. The steel flanges can be ordered with the raised face removed by machining.

Steel flanges (ASME B16.5) are made in Classes 150 and 300 for the services discussed in this chapter. They are available for higher pressures up to Class 2500. Steel flanges are generally used in welded piping systems. These flanges are made in weld neck, slip-on, and socket weld configurations. Classes 150 and 300 have a raised face.

Gasket material (ASME B16.21) should be suitable for the fluid and pressure to be contained. Full-face gaskets are used for flat-faced flanged joints and ring gaskets are used in raised-face joints. The flange bolts should be suitable for the pressure and flange facings.

Grooved pipe–joining systems are made by several manufacturers, but as yet there is no ASME standard for dimensions or pressure ratings. All the leading manufacturers use the same "standard" cut-groove and roll-groove dimensions. The joint consists of a circumferential groove cut into the outside of each pipe, close to the end to be joined. A coupling with continuous internal ridges engages the grooves in the pipe, and a gasket inside the coupling is expanded by the pressure in the pipe and seals against the pipe and coupling.

Grooves can be rolled into standard weight and lighter steel pipe. Cut grooves can be used on standard weight and thicker pipe. Gaskets are available for a great variety of liquids and gases.

These systems are extremely versatile and offer many advantages. They are easy to install, have inherent expansion compensation and flexibility, and are easy to disassemble. Grooved systems are not recommended for steam.

Copper Tube

Copper tube is joined by soldering or brazing using solder joint fittings (ASME B16.18, B16.22) or using flare (ASME B16.26) or compression fittings. Solder joints are also referred to as sweat joints.

Solder (ASTM B32) is defined as a filler metal whose melting point does not exceed 800°F (427°C). Brazing filler metals (ANSI/AWS A5.8) are specified as those whose melting points are 1000°F (538°C) or higher. Soldered and brazed joints rely on capillary attraction to draw molten filler metal into the gap between the socket on the fitting end and the tube.

The strength of the joint depends upon the composition of the solder used. Brazing provides much stronger joints than soldering but anneals drawn tubing in the vicinity of the joint. It is against the law to use solders containing lead for

TABLE C4.7 Pressure Ratings of Copper Tube Joints*

Solder or brazing alloy used in joints	Service temperature (°F max.)	Tube size, Types *K*, *L*, and *M* (in): Water, noncorrosive liquids and gases ¼–1	1¼–2	2½–4	5–8†	10–12†	Steam All
50–50	100	200	175	150	130	100	—
Tin-lead	150	150	125	100	90	70	—
Solder	200	100	90	75	70	50	—
ASTM B32 Gr 50A‡	250	85	75	50	45	40	15
95–5	100	500	400	300	270	150	—
Tin-antimony	150	400	350	275	250	150	—
Solder	200	300	250	200	180	140	—
ASTM B32 GR 95TA	250	200	175	150	135	110	15
Brazing alloys	200	§	§	§	§	§	—
ANSI/AWS A5.8	250	300	210	170	150	150	—
(melting above 1000°F)	350	270	190	150	150	150	120

* Ratings for solder joints are from ASME B16.22 and B16.18. Ratings for brazed joints and steam are from *The Copper Tube Handbook,* published by the Copper Development Association, Inc.
† B31.9 prohibits compressed air or other gases above 20 psig in these sizes.
‡ It is prohibited by law to use lead solder for potable water.
§ The pressure rating of the tube determines the strength of this joint.
Note: 1.8 °C = °F − 32.

drinking water–piping systems, but they can be used for heating, cooling, and other building-service applications. Table C4.7 gives working pressures for copper-tube joints made by soldering and brazing.

Flared and compression-type fittings are made by many manufacturers for copper, steel, stainless steel, and aluminum tubing. Fittings are available for sizes NPS 2 (DN 50) and under but are used primarily in sizes NPS 1 (DN 25) and under. These joints can be taken apart and reassembled with ease. The manufacturers' catalogs give pressure ratings which can be as strong as the tube being joined.

Grooved-joint couplings and fittings are made to match copper-tube sizes. Since tube walls are thin, roll grooving is used.

Bronze pipe flanges and flanged fittings (ASME B16.24) are made in Classes 150 and 300 and can be used to join copper tube to flanged valves or equipment.

Red Brass Pipe

Red brass pipe is joined in the smaller sizes using cast-bronze threaded fittings (ASME B16.15) which are made in Classes 125 and 250. ASME B16.24 flanges as mentioned above can be used for sizes above NPS 2 (DN 50).

Plastics

Plastic piping is the subject of Part D of this handbook. To aid those reading this chapter, a brief summary of joining methods and fittings is given here.

Solvent cementing is the most common method used for joining PVC (ASTM D2564, D2855), CPVC (F493) pipe, and ABS (D2235). Socket-type fittings are available in Sch 40 (PVC-ASTM D2466, CPVC-ASTM F438) and Sch 80 (PVC-ASTM D2467, CPVC-F439) for pressure systems to at least NPS 8 (DN 200). Check on availability before deciding to use larger sizes. Solvent cement joints are best made when the ambient temperature is between 40 and 100°F (4°C and 38°C).

Threaded fittings up to NPS 4 (DN 100) are available for PVC (ASTM D2464) and CPVC (ASTM F437) piping systems. Only Sch 80 pipe should be threaded, and its pressure rating should be reduced by 50 percent. This type of joint can be taken apart and reassembled.

Flanges are available with solvent cement sockets up to NPS 8 (DN 200) and are made to Class 125 dimensions. Threaded flanges are made up to NPS 4 (DN 100). Flanges can be installed in cemented systems for ease in disassembly. An ASTM standard for thermoplastic flanges has yet to be developed.

Heat joining methods are also available for certain polyolefin joints (ASTM D2657), particularly for polypropylene. Pipe and fittings of this plastic are used for acid-resistant drainage systems. A wire filament is embedded in the socket of the joint then electrically heated with a special timing device to fuse the joint.

Bell and spigot PVC–pressure pipe (AWWA C900) is made for underground water mains. The bell is made to contain an elastomer gasket (ASTM F477), and the joint is assembled by pushing the spigot into the bell. RTRP can be joined using a special taper on the end of the pipe which can be cemented into a matching bell on a coupling or fitting. Refer to Part D of this handbook.

Mechanical joint fittings (AWWA C110/ANSI A21.10) of ductile or cast iron can be used with PVC or RTRP pipe made to AWWA ductile-pipe dimensions (AWWA C151/ANSI A21.51).

Ductile Iron

Ductile iron pipe is used primarily for underground systems. Fittings are rated in pressure classes (AWWA C110/ANSI A21.10).

Bell and spigot fittings are available and made of cast or ductile iron with bell ends. Pipe is made with one end belled. An elastomer gasket fits into a special groove in the bell, and the plain end of the pipe to be joined is pushed into the bell. This can be difficult with large pipe.

Mechanical joint fittings made from cast or ductile iron are available and are easier to work with in larger pipe sizes. The pipe is assembled into the bell before the gasket is in place, which reduces the friction. The gasket is then slid into the bell and a retainer ring is bolted into place to secure the gasket.

Grooved couplings are available and made to fit AWWA ductile-iron pipe diameters (AWWA C151/ANSI A21.51) from NPS 3 to NPS 36 (DN 80–DN 900). Special cut grooves are needed on the pipe. Grooved fittings are not made. Bell and spigot or mechanical joint fittings can be used.

Stainless Steel and Aluminum

Stainless steel and aluminum pipe and fittings are joined using the same methods as those for steel. The availability of fitting sizes is limited and should be investigated before using them in design.

TABLE C4.8 Material Application Chart for Saturated Steam and Condensate*†

Line	Pipe						Fitting					Valve				
Line	Material	ASTM standard	Mfr. process	Weight	Joint	Pressure rating (psig)	Class	Material	Joint	ASTM standard	Pressure rating (psig)	Class	Material	Joint	Type	Pressure rating (psig)
	Low pressure to 15 psig; Medium pressure 16–90 psig															
A. (1)	Steel	A 53 B	Type F(CW)	Std.	Thread	230	125	Cast iron	Thread	B 16.4	125	125	Bronze	Thread	Gate	140
(2)	Steel	A 53 B	Seamless	Std.	Thread	510	300	Ductile iron	Thread	—	430		Bronze	Thread	Ball	150
(3)	Copper	B 88	Drawn	Type L	95-5 Solder	15		Wrought copper	95-5 Solder	B 16.22	15					
(4)	Copper	B 88	Drawn	Type K	Braze	120		Wrought copper	Braze	B 16.22	120					
	NPS 2½–12															
B. (1)	Steel	A 53 B	ERW	Std.	Weld	530	Std	Wrought steel	Weld	B 16.9	580	125	Cast iron	Flange	Gate	150
(2)							150	Wrought steel	Flange	B 16.5	150		Steam trim	Wafer	Butter-fly	150
(3)								Std ERW steel	90° weld branch		375					
	NPS 14–20															
C. (1)	Steel	A 53 B	ERW	Std.	Weld	335	Std	Wrought steel	Weld	B 16.9	395	125	Cast iron	Flange	Gate	100
(2)							150	Wrought steel	Flange	B 16.5	150	150	Ductile iron	Flange	Gate	208
(3)								Std ERW steel	90° weld branch		230		Steam trim	Lug wafer	Butter-fly	150

TABLE C4.8 Material Application Chart for Saturated Steam and Condensate*† (*Continued*)

	Pipe						Fitting					Valve				
Line	Material	ASTM standard	Mfr. process	Weight	Joint	Pressure rating (psig)	Class	Material	Joint	ASTM standard	Pressure rating (psig)	Class	Material	Joint	Type	Pressure rating (psig)
	High pressure 91 to 150 psig at 366°F															
	NPS 2 & smaller															
D. (1)	Steel	A 53 B	ERW	Std.	Thread	645	250	Cast iron	Thread	B 16.4	250	200	Bronze	Thread	Gate	275
(2)		A 53 B	Seamless	XS	Thread	1215	300	Ductile iron	Thread	—	415	300	Bronze	Thread	Gate	410
(3)		A 106 B	Seamless	Std	Socket weld	1385	3000	Forged steel	Socket weld	B 16.11	2600					
(4)	Copper	B 88	Drawn	Type K	Braze	120		Wrought copper	Braze	B 16.22	120	800	Forged steel	Socket weld	Gate	1710
	NPS 2½–12															
E. (1)	Steel	A 53 B	ERW	Std	Weld	530	Std	Wrought steel	Weld	B 16.9	580	250	Cast iron	Flange	Gate	315
(2)		A 53 B	Seamless	Std	Weld	620	300	Wrought steel	Flange	B 16.5	300	150	Ductile iron	Flange	Gate	204
								Std SML steel	90° weld branch		440		Steam trim	Lug wafer	Butter-fly	200
	NPS 14–20															
F. (1)	Steel	A 53 B	ERW	Std	Weld	335	Std	Wrought steel	Weld	B 16.9	395	150	Ductile iron	Flange	Gate	204
(2)		A 53 B	Seamless	Std	Weld	395	300	Wrought steel	Flange	B 16.5	300		Steam trim	Lug wafer	Butter-fly	200
(3)		A 53 B	Seamless	XS	Weld	560		Std ERW steel	90° weld branch		230					
(4)								XH SML steel	90° weld branch		360					

* Pressure ratings for steel pipe are calculated using a mill tolerance of −12.5 percent of the wall thickness, the thread or groove depth, a corrosion allowance of 0.025 in for pipe to NPS 2, and 0.065 in for 2½-in and larger pipe. No pipe reinforcement value is applied for the strength of threaded fittings or grooved couplings.

† Pressure ratings are for the highest temperature and largest pipe size in each group. Higher ratings can be found for lower temperatures and smaller pipe sizes.

TABLE C4.9 Material Application Chart for Water Systems*,†,‡

	Pipe								Fitting	
						Pressure rating				
Line	Material	ASTM standard	Mfr. process	Wall thickness	Joint	@ 75°F (psig)	@ 150°F (psig)	@ 220°F (psig)	Material	Class
	In the building or above ground									
	NPS 2 and smaller									
G. (1)	Steel	A 53 B	Type F(CW)	Std.	Thread	230	230	230	Cast iron	125
(2)	Steel	A 53 B	Type F(CW)	Std.	Groove	275	275	275	D.I. or M.I.	
(3)	Steel	A 53 B	Type F(CW)	Sch 10	Roll groove	400	400	400		
(4)	Copper	B 88	Drawn	Type L	95-5 solder	400	350	220	Wrought copper	
(5)	Copper	B 88	Drawn	Type K	Braze	380	380	300	Wrought copper	
(6)	Steel	A 53 B	Seamless	Std	Thread	510	510	510	Cast iron	250
(7)	Steel	A 53 B	Seamless	Std	Groove	605	605	605	Malleable iron	150
(8)	CPVC	F441	Seamless	Sch 40	Solvent	280	125	NR	CPVC	Sch 40
	NPS 2½–12									
H. (1)	Steel	A 53 B	ERW	Std	Weld	530	530	530	Wrought steel	Std
(2)	Steel	A 53 B	ERW	Std	Groove	310	310	310	D.I. or M.I.	
(3)	Steel	A 53 B	Seamless	Std	Weld	620	620	620	Cast iron	125
(4)	Steel	A 53 B	Seamless	Std	Groove	365	365	365	Wrought steel	150
(5)									Std ERW steel unreinforced 90° weld branch	
(6)									Wrought steel	300
(7)	Copper	B 88	Drawn	Type *L*	95-5 solder	150	150	130	Wrought copper	
(8)	Copper	B 88	Drawn	Type *L*	Braze	260	220	190	Wrought copper	
(9)	Copper	B 88	Drawn	Type *K*	Braze	380	320	285		
(10)	Copper (to 6 in)	B 88	Drawn	Type *L*	Roll groove	300	300	300	Wrought copper	(to 6 in)
(11)	CPVC	F 441	Seamless	Sch 40	Solvent	130	70	NR	CPVC (to 6 in)	Sch 40
(12)	CPVC	F 441	Seamless	Sch 80	Solvent	230	105	NR	CPVC (to 6 in)	Sch 80
	NPS 14–20									
I. (1)	Steel	A 53 B	ERW	Std	Weld	335	335	335	Wrought steel	Std
(2)	Steel	A 53 B	ERW	Std	Groove	195	195	195	D.I. or M.I.	
(3)	Steel	A 53 B	Seamless	Std	Weld	395	395	395	Cast iron	125
(4)	Steel	A 53 B	Seamless	Std	Groove	230	230	230	Wrought steel	150
(5)									Std ERW steel unreinforced 90° weld branch	
(6)									Wrought steel	300

MATERIAL SELECTION

The selection of the material to be used for each system is based on an evaluation of the following factors:

1. Requirements and limitations of the building and piping codes
2. The fluid in the pipe
3. The pressure and temperature of the fluid in the pipe
4. The location and external environment of the pipe

Fitting					Valve						
		Pressure rating							Pressure rating		
Joint	ASTM standard	@ 75°F (psig)	@ 150°F (psig)	@ 220°F (psig)	Class	Material	Type	Joint	@ 75°F (psig)	@ 150°F (psig)	@ 220°F (psig)
Thread	B 16.4	175	175	160	125	Bronze	Gate	Thread	200	200	180
Groove	—	500	500	500		Bronze	Ball	Thread	400	400	400
95-5 solder	B 16.22	375	320	220		Bronze	Ball	95-5 solder	400	350	220
Brazed	B 16.22	445	375	310	200	Bronze	Gate	Thread	400	400	365
Thread	B 16.4	400	400	360							
Thread	B 16.3	300	300	255							
Solvent	F 438	280	125	NR		CPVC	Ball	Socket	150	100	NR
Weld	B 16.9	510	510	510	125	Cast iron	Gate	Flange	150	150	130
Groove	—	500	500	500	150	Ductile iron	Gate	Flange	250	250	230
Flange	B 16.1	200	200	180	250	Cast iron	Gate	Flange	500	500	445
Flange	B 16.5	285	270	250		Buna-N liner	Butterfly	Wafer	150	150	NR
		375	375	375		EPDM liner	Butterfly	Wafer	150	150	150
Flange	B 16.5	720	710	695		Hi-service	Butterfly	Lug	250	250	250
95-5 solder	B 16.22	150	150	130							
Braze	B 16.22	380	320	285	200	Cast iron	Plug	Flange	200	200	180
					500	Cast iron	Plug	Flange	500	500	445
Roll groove	—	300	300	300							
Solvent	F 438	180	80	NR							
Solvent	F 439	280	125	NR							
Weld	B 16.9	400	400	400	125	Cast iron	Gate	Flange	150	150	130
Groove	—	300	300	300	150	Ductile iron	Gate	Flange	250	250	230
Flange	B 16.1	150	150	130	250	Cast iron	Gate	Flange	300	300	275
Flange	B 16.5	275	255	235		Buna-N liner	Butterfly	Wafer	150	150	NR
		230	230	230		EPDM liner	Butterfly	Wafer	150	150	150
Flange	B 16.5	720	710	695		Hi-service	Butterfly	Lug	250	250	250

5. Availability of the material
6. The expected life of the facility where the system is to be installed
7. The installed cost of the system

The first four factors relate to safety and are of primary importance. The last three are related to the economics of the project and are weighted to suit.

Steam and Condensate Systems (to 150 psig) (1035 kPa)

Steel pipe is used for steam and condensate systems. Fittings for sizes under NPS 2½ (DN 65) are threaded cast iron. Larger fittings are steel with welding ends.

TABLE C4.9 Material Application Chart for Water Systems*,†,‡ (*Continued*)

Line	Pipe: Material	ASTM standard	Mfr. process	Wall thickness	Joint	Pressure rating @ 75°F (psig)	Pressure rating @ 150°F (psig)	Pressure rating @ 220°F (psig)	Fitting: Material	Fitting: Class
	Below gound (Corrosion protected materials from lines G, H, I may be used underground.)									
	NPS 4–20									
J. (1)	Ductile iron	A 21.51	Cast	Class 50	Mech. jt.	300	300	—	Ductile iron	Class B
(2)	Ductile iron	A 21.15	Cast	Class 50	Flange	250	250	—	Ductile iron	Class B
	NPS 2–16							@ 210°F		
K. (1)	RTRP-11AF	D 2996	Fil. wound	—	B&S adhesive	150	150	150	RTRP-11AF	
	NPS 4–24						@ 100°F			
L. (1)	PVC	AWWA C900	Seamless	Class 100	B&S O-ring	100	60	NR	Ductile iron	Class B
(2)	PVC	AWWA C900	Seamless	Class 150	B&S O-ring	150	90	NR		
(3)	PVC	AWWA C900	Seamless	Class 200	B&S O-ring	200	120	NR		

* Pressure ratings for steel pipe are calculated using (a) a mill tolerance or −12.5% of the wall thickness, (b) the thread or groove depth where used, and (c) a corrosion allowance of 0.025 to NPS 2 and 0.065 for NPS 2½ and larger. No pipe-wall reinforcement value is applied for the strength of threaded fittings or grooved couplings.

† Copper tube pressures are based on the joint strength when soldered or brazed.

‡ Pressure ratings are for the largest pipe size in each group. Smaller pipe sizes have higher ratings.

Bronze valves are used for small sizes and cast or ductile iron, as required by the pressure, for valves NPS 2½ (DN 65) and over. Large gate valves in high-pressure systems should be provided with a bypass to allow warm-up of the downstream pipe before full opening. Equalizing the pressure with a bypass also allows the valve to open.

Ball valves and special steam butterfly valves may be used, but only if the valve has a gear operator so it cannot be opened rapidly. Ball valves can be used for small valves on low-pressure systems.

Copper tubing with brazed joints may be used up to 120 psig (827 kPa). The high energy content of steam makes mechanically restrained joints preferred. However, when space is limited, copper tubing with wrought brazed fittings, which is a much less bulky system than steel, can be used. Welding and brazing should be performed by qualified operators.

Steam condensate piping requires additional attention, since condensate corrodes steel pipe. To lengthen the life of small size pipe, extra heavy weight pipe is often specified. For larger pipe sizes, the increased wall thickness of standard weight pipe provides added material to prolong pipe life. For small low-pressure systems, copper tube with 95-5 solder joints may be used. Fittings and valves for condensate are the same as those used for steam.

Table C4.8 shows some of the materials which can be used for steam and condensate service. Code pressure ratings for the various components or joints are

Fitting					Valve						
		Pressure rating							Pressure rating		
Joint	ASTM standard	@ 75°F (psig)	@ 150°F (psig)	@ 220°F (psig)	Class	Material	Type	Joint	@ 75°F (psig)	@ 150°F (psig)	@ 220°F (psig)
Mech. joint	A 21.10	350	350	350	Same as listed in H and I above.						
Flange	A 21.10	250	250	—							
				@ 210°F							
B&S or T.A.B.		150	150	150	Same as listed in H and I above.						
Mech. joint	A 21.10	350	350	350	Same as listed in H and I above.						

listed. The table should not be read line by line. For example, any of the fittings and valves listed on lines D(1)–(4) may be used with any of the pipe types listed on lines D(1)–(3).

Recirculating Water Piping Systems

Closed recirculating water systems such as chilled water, hot water, and dual temperature water are used for heating and cooling. System temperatures can range from 50 to 200°F (10 to 93°C) and the pressure can be above 200 psig (1380 kPa) on the lower floors of tall buildings.

For pipe NPS 2 ½ (DN 65) and larger the preferred material is steel with welded or grooved joints. The selection of materials for water piping systems NPS 2 (DN 50) and under is usually based on economics. The fluctuating price of materials and the skills of the labor to be used for installation make a number of combinations possible. For pressures above 150 psig (1035 kPa) and temperatures above 200°F (93°C), seamless or extra strong steel pipe with the proper class of threaded fittings or grooved joints can be used. Copper tube with solder or brazed joints is also widely used. For low temperatures, plastic piping systems can be used.

Bronze gate and ball valves are used on small pipe systems, and cast-iron gate, plug, and butterfly valves are used with large pipe.

Table C4.9 lists materials for pipe, fittings, and valves and gives pressure ratings at 75, 150, and 220°F (24, 65, 104°C). The rating at 75°F (24°C) can be used down to 0°F (−17°C). Materials within any letter group can be mixed when a suitable joint can be made.

TABLE C4.10 Material Application Chart for Air, Gas, and Oil Systems*,†,‡

	Pipe								Fitting	
						Pressure rating				
Line	Material	ASTM standard	Mfr. process	Wall thickness	Joint	@ 75°F (psig)	@ 150°F (psig)	@ 220°F (psig)	Material	Class
	Compress air to 20 psig									
	NPS 2 and smaller									
O. (1)	Same materials as listed in Table C4.9 lines G(1) through (7).									
	NPS 2½–12									
M. (1)	Same materials as listed in Table C4.9 lines H (1) through (6), (8), and (9).									
	Compressed air to 100 psig									
	NPS 2 and smaller									
N. (1)	Same materials as listed in Table C4.9 lines G (1) through (3) and (5) through (7).									
(2)	Line (7), copper with solder joints may be used at or below NPS 4.									
	NPS 2½–12									
O. (1)	Same materials as listed in Table C4.9 lines H (1) through (6) and (8) through (10).									
O. (1)	Same materials as listed in Table C4.9 lines H (1) through (6) and (8) through (10).									
	Fuel gas to 5 psig									
P. (1)	NPS 2 and smaller									
(2)	Steel	A 53 B	ERW	Std	Thread	430	430	430	Malleable iron	150
(3)	Steel	A 106	Seamless	Std	Thread	510	510	510	Ductile iron	300
(4)	Steel tube	A539, A254			Braze	Use mfrs. rating				
(5)	Copper tube	B 88		Type L, K	Braze, flare	315	315	260	Wrought copper	
(6)	Corrugated S.S. Conduit AGA 1-87				System	Use mfrs. rating				
	NPS 2½–6									
Q. (1)	Steel	A 53	ERW	Std	Weld	695	695	695	Wrought steel	Std
(2)	Steel	A 106	Seamless	Std	Weld	815	815	815	Wrought steel	150
	Fuel oil									
	NPS 2 and smaller									
R. (1)	Steel	A 53	Seamless	XH	Thread	1215	1215	1215	Malleable iron	150
(2)	Steel	A 106	Seamless	XH	Thread	1215	1215	1215	Ductile iron	300
(3)	Steel tube	A539, A254			Braze				Forged steel	3000
	NPS 2½–12									
S. (1)	Steel	A 53	Seamless	Std	Weld	620	620	620	Wrought steel	Std
(2)	Steel	A 106	Seamless	Std	Weld	620	620	620	Wrought steel	150

* Pressure ratings for steel pipe are calculated using (a) a mill tolerance or −12.5% of the wall thickness, (b) the thread or groove depth where used, and (c) a corrosion allowance of 0.025 in to NPS 2 and 0.065 for NPS 2½ and larger. No pipe-wall reinforcement value is applied for the strength of threaded fittings or grooved couplings.
† Copper tube pressures are based on the joint strength when soldered or brazed.
‡ Pressure ratings are for the largest pipe size in each group. Smaller pipe sizes have higher ratings.

Condenser Water Systems

Refrigeration condenser water is usually cooled in a cooling tower where the water temperature is reduced by evaporation to the atmosphere. Lake, river, and well water are also used for condensing refrigerant. As oxygen and atmospheric contaminants are regularly induced into the water, corrosion becomes a major problem.

When a cooling tower is used, the same water plus makeup water are recirculated and chemicals must be added to the system to protect the pipe against corrosion.

Fitting					Valve						
		Pressure rating							Pressure rating		
Joint	ASME/ ASTM standard	@ 75°F (psig)	@ 150°F (psig)	@ 220°F (psig)	Class	Material	Type	Joint	@ 75°F (psig)	@ 150°F (psig)	@ 220°F (psig)
Thread	B 16.3	300	300	255	125	Bronze	Gate	Thread	200	200	180
Thread	A 395	500	500	460		Bronze	Ball	Thread	400	400	400
Brazed	B 16.22										
Weld	B 16.9	510	510	510	125	Cast iron	Gate	Flange	150	150	130
Flange	B 16.5	285	270	250	150	Ductile iron	Gate	Flange	250	250	230
					200	Cast Iron	Plug	Flange	200	200	180
Thread	B 16.3	300	300	255	125	Bronze	Gate	Thread	200	200	180
Thread	A 395	500	500	460		Bronze	Ball	Thread	400	400	400
Socket weld	B 16.11	2600	2600	2600							
Weld	B 16.9	510	510	510	150	Ductile iron	Gate	Flange	250	250	230
Flange	B 16.5	285	270	250							

With river water or well water, corrosion-resistant materials must be used for the system or the interior of the pipe must be lined with a corrosion-resistant material. Refer to Chaps. B9, B10, B11, and B12 for lined piping systems.

Steel pipe is most often used for large condenser-water piping systems aboveground. Where chemical treatment is possible it does not have to be lined, but the use of extra heavy pipe should be considered. Where chemicals cannot be used, steel pipe can be cement lined using welded or grooved joints. Plastic lining can also be used with grooved joints (Refer to Chap. B12). Linings do not add to the strength of the pipe and may reduce the flow capacity.

Condenser-water lines are often run below ground. Ductile-iron or plastic water-main pipe can be used, since both the interior and exterior are corrosion resistant. Copper is a good alternative for both aboveground and underground condenser-water piping. Table C4.9 lists some materials suitable for condenser water and the pressures at which they can be used.

Compressed Air

High temperatures are not usually involved, but compressed air contains stored energy, and system failure can result in explosive reactions. Welding or a restrained joint should be used for large sizes. Do not use PVC or CPVC or any material subject to brittle failure for compressed air. Other thermoplastics which are not subject to brittle failure may be used. Check with the manufacturer of the material to be sure it is recommended for compressed air service.

Steel and copper pipe with malleable iron, cast-iron, or copper fittings are suitable materials for compressed air. Ball, butterfly, or gate valves can be used. For large sizes use welded, flanged, or grooved systems. ASME B31.9, Building Services Piping, does not permit the use of copper with soldered joints for sizes above NPS 4 (DN 100) size at pressures exceeding 20 psig (138 kPa). Table C4.10 lists some suitable materials.

Fuel Gas

Pipe material for use in buildings should be standard weight, electric resistance weld, or seamless steel or copper tube Type *K* or *L*. Copper is not to be used if the gas contains more than an average of 0.3 grain of hydrogen sulfide per 100 standard cubic feet of gas. Fittings for steel pipe may be threaded malleable iron or ductile iron for sizes up to and including NPS 3 (DN 80). Some jurisdictions require cast fittings to be galvanized to seal casting-pin holes. For sizes NPS 2½ (DN 65) and over, welded joints should be used with steel fittings and flanges.

Copper tube should be joined by brazing, using a brazing alloy that does not contain phosphorus, or by the use of flared connections. Table C4.10 lists some suitable materials.

Fuel Oil

For piping to boilers operating at or under 15 psig (103 kPa) steam or 30 psig (207 kPa) water, use electric-resistance welded, seamless steel pipe, or copper tube, Type *K* or *L*. When threaded joints are used, malleable-iron, ductile-iron, or forged-steel fittings may be used. A thread-sealing compound suitable for oil should be used when making the joints. Joints in copper tube may be brazed or made by using flared or compression fittings.

Oil piping to boilers operating at steam pressures from 16 to 150 psig (110 to 1035 kPa) should be seamless steel, standard weight, when welded or extra strong if threaded. Threaded joints using ductile-iron or forged-steel fittings may be used if unavoidable. Valves should be made of ductile iron or brass.

Outside the boiler room malleable-iron threaded fittings may be used. Type *K* or *L* copper tube with brazed joints may also be used outside the boiler room. Table C4.10 lists some suitable materials.

WELDING

Welding Qualification

To comply with the B31 Pressure Piping Code sections, all welding procedures and welders must be qualified as required by Sec. IX of the ASME Boiler and Pressure Vessel Code. B31.9, Building Services Piping, also permits qualification to AWS D10.9, Qualification of Welding Procedures and Welders for Piping and Tubing.

A welding procedure specification is written to outline a method for making a weld. It lists the conditions under which the weld must be made. The procedure is qualified by making a weld following the specification. If the weld passes the prescribed tests, the procedure is qualified as being able to make a sound weld.

Welders and welding operators are tested to see that they have the necessary skills by making a weld using a qualified weld procedure specification. If the weld passes the required test, the welder can be termed qualified by his employer.

Boiler External Piping

For boilers operating at pressures higher than 15 psig (103 kPa), the ASME Boiler and Pressure Vessel Code has administrative control over the welding on boiler external piping (BEP), which is broadly defined as the piping between the boiler and (1) the first steam stop valve, (2) the second feedwater valve, and (3) the second blowdown valve. When multiple boilers are connected to a header, the BEP extends to the second steam valve.

The boiler external piping must be fabricated and installed by an organization holding an ASME certificate and must be provided with data reports, inspection, and stamping as required by the boiler code.

The ASME Pressure Piping Code B31.1, Power Piping, does not require nondestructive examination of welds unless the pressure is above 1025 psig (7067 kPa) with a temperature above 350°F (177°C) or the temperature is above 750°F (400°C) at all pressures. If radiography or other nondestructive examination is desired in excess of code requirements, it should be clearly spelled out in the contract or specification.

HANGERS AND SUPPORTS

This section gives a brief outline of the use of hangers, supports, anchors, and guides. See Part B of this handbook for a detailed discussion of hangers and hanger loads.

Hangers support the pipe from above; supports bear the load of the pipe from below; anchors restrain pipe movement; guides allow only axial movement of the pipe and direct expansion forces.

Buildings are built to provide usable floor space; therefore, piping is usually hung from the structure above. Hangers are concentrated loads; an allowance of extra distributed–dead load in the structure above mechanical rooms will not necessarily be sufficient to support the point loads of large pipelines or suspended equipment. Piping should be arranged to allow the use of major structural elements for hanging pipelines. Major loads that pipe hangers impose on a structure should be reviewed by a structural designer.

Hanger loads are calculated according to B31.9 by taking the following elements into account:

1. The dead weight of the pipe, fittings, valves, insulation, and the hanger itself.
2. The weight of liquid in the pipe.
3. Occasional loads, such as ice, wind, earthquake, a test liquid, and water hammer. Occasional loads need not be considered as acting concurrently.

The forces acting on pipe anchors are

1. The hanger loads listed above.
2. Forces caused by expansion and contraction of the pipe.
3. Expansion joint forces needed to overcome joint friction and separation. The separation force is the product of the line pressure and the largest inside cross-section area of the joint.

When supporting a riser, the entire weight of the riser pipe and the fluid or test liquid in that vertical section of the pipe must be carried by the base elbow or anchor.

Hanger design is based on using one-fifth of the minimum tensile stress of the hanger material. If the minimum tensile strength of a material is not known, a value of 9500 (65 MPa) psi may be used. During hydrostatic testing this value may be increased to 24,000 (165 MPa) psi. Allowable stress values for shear are 80 percent and for bearing are 160 percent of the values determined above.

The carrying capacity of threaded rod is based on the rod area at the root of the thread. The allowable stress is reduced by 25 percent for cut threads. See Table C4.11 for rod-carrying capacities.

TABLE C4.11 Capacities of Threaded Steel Rods

Rod diameter (in)	Root area of thread (in^2)	Unknown steel rolled threads, S = 9.5 ksi (lb)
¼	0.027	260
⅜	0.068	650
½	0.126	1200
⅝	0.202	1900
¾	0.302	2900
⅞	0.419	4000
1	0.551	5200
1⅛	0.693	6600
1¼	0.889	8400
1⅜	1.054	10000
1½	1.294	12300

Hangers should be designed to permit vertical adjustment. When this is done with threaded elements, double nuts or other locking devices should be used to prevent vibration from working the nut loose.

Hangers are attached to the structure by welding, beam clamps, concrete inserts, and metal-deck inserts and by drilling expansion anchors directly into the concrete. Loads on inserts in, or attachments to, concrete should be limited to one-fifth of the ultimate strength of the attachment as determined by the manufacturer's tests.

TABLE C4.12 Pipe Spans for Standard Weight Steel Pipe for Straight Runs with No Valves or Components

	Pipe and insulation						Pipe, water, and insulation					
	ASTM A53 type F butt weld S = 11,250			ASTM A53B Smls or ERW S = 15,000			ASTM A53 type F butt weld S = 11,250			ASTM A53B Smls or ERW S = 15,000		
	Pressure in pipe			Pressure in pipe			Pressure in pipe			Pressure in pipe		
Pipe size NPS (DN)	300 psig (ft)	15 psig (ft)	Hanger load (lb)	400 psig (ft)	15 psig (ft)	Hanger load (lb)	300 psig (ft)	15 psig (ft)	Hanger load (lb)	400 psig (ft)	15 psig (ft)	Hanger load (lb)
½ (15)	6	6	5	6	6	5	6	6	6	6	6	6
¾ (20)	7	7	9	7	7	9	7	7	11	7	7	11
1 (25)	9	9	16	9	9	16	9	9	19	9	9	19
1¼ (32)	11	11	26	11	11	26	11	11	32	11	11	32
1½ (40)	12	12	34	12	12	34	12	12	45	12	12	45
2 (50)	14	14	56	14	14	56	13	14	75	14	14	77
2½ (65)	16	16	96	16	16	96	15	16	128	16	16	129
3 (80)	17	17	139	17	17	139	16	17	189	17	17	195
4 (100)	20	20	224	20	20	224	18	19	317	20	20	334
5 (125)				22	22	338				22	22	530
6 (150)				24	24	478				23	24	782
8 (200)				28	28	829				25	28	1431
10 (250)				31	31	1309				28	31	2369
12 (300)				34	34	1746				28	33	3301
14 (350)				36	36	2038				29	34	3929
16 (400)				38	38	2500				29	35	5015
18 (450)				40	40	2993				28	36	6223
20 (500)				43	43	3515				28	36	7561
24 (600)				46	47	4638				27	37	10603

1. Spans based on lesser of (1) half that permitted by allowable stress in simple beam formula or (2) deflection of 0.1 × NPS to 0.2 in max. for empty pipe and fiberglass insulation.
2. Formulas used: Deflection span, ft = $[(384\ EIG/W)^{0.25}]/12$. Simple beam span, (ft) = $[\{8Z(S - SL)/W\}^{0.5}]/12$, where E = modulus of elasticity, I = moment of inertia, G = permitted deflection, Z = section modulus, S = allowable stress, SL = longitudinal stress caused by pressure, W = weight.
3. Hanger loads listed are the full weight of the longer span in each category.
4. For DN equivalents refer to Chap. A1 or App. E2.
5. 1 psi = 6.895 kPa.
6. 1 lb = 2.24 kg.

TABLE C4.13 Pipe Spans for Copper Tube Type *L* for Straight Runs with No Valves or Components

	Pipe and insulation			Pipe, water, and insulation		
	ASTM B88 type *L* hard drawn $S = 11{,}300$ to 250°F			ASTM B88 type *L* hard drawn $S = 11{,}300$ to 250°F		
	Pressure in tube			Pressure in tube		
Nominal pipe size NPS (DN)	300 psig (ft)	15 psig (ft)	Hanger load (lb)	300 psig (ft)	15 psig (ft)	Hanger load (lb)
½ (15)	4	4	1	4	4	2
⅝ (18)	5	5	2	5	5	3
¾ (20)	5	5	3	5	5	4
1 (25)	7	7	6	7	7	8
1¼ (32)	8	8	8	8	8	13
1½ (40)	9	9	12	9	9	19
2 (50)	11	11	22	10	11	37
2½ (65)	12	12	33	10	12	56
4 (100)	14	14	52	12	13	88
3½ (90)	15	15	70	12	14	124
4 (100)	16	16	93	13	15	167
5 (125)	18	18	147	14	17	269
6 (150)	20	20	216	15	18	400
8 (200)	23	23	473	18	21	854
10 (250)	25	25	791	20	23	1480
12 (300)	28	28	1175	21	25	2214

1. Spans based on (1) lesser of half that permitted by allowable stress in simple beam formula or (2) deflection of 0.1 × NPS to 0.2 in max.

2. Formulas used: Simple beam span (ft) = $[\{8Z(S - SL)/W\}^{0.5}]/12$; Deflection span (ft) = $[(384\ EIG/W)^{0.25}]/12$, where E = modulus of elasticity, I = moment of inertia, G = permitted deflection, Z = section modulus, S = allowable stress, SL = longitudinal stress caused by pressure, W = weight (lb/in).

3. Hanger loads listed are the full weight of the longest span in each category.

If the compressive strength of the concrete is unknown, it can be assumed to be 2500 psi (17250 kPa) and the results of the manufacturer's test derated proportionally. Explosively actuated fasteners should not be used where a group of pins is needed to support a load.

Spring hangers should be used where expansion can cause vertical movement of a pipeline. For example, if a branch line is connected to a vertical heating-cooling riser on the 12th floor of a high-rise building, the connection point could be 1 in (25 mm) above its ambient elevation during the heating season and 1 in (25 mm) below in the summer. Using spring hangers on the branch near the riser connection will provide support under both conditions.

Hanger spacing is often determined by the building steel available for suspending the pipe. Tables C4.12, C4.13, C4.14, and C4.15 show maximum spans for steel, copper, aluminum, and plastic pipe. These tables are calculated using a simple beam formula to determine stress and deflection. The basic allowable stress of the pipe will not be exceeded at double the span shown in the tables. The usable stress for bending is that which remains after the stresses due to longitudinal pressure have been deducted from the basic allowable stress of the material. The tables also have

TABLE C4.14 Pipe Spans for Standard Weight Aluminum Pipe for Straight Runs with No Valves or Components

	Pipe and insulation			Pipe, water, and insulation		
	ASTM B241 A93003-0 S = 3,400 to 200°F			ASTM B241 A93003-0 S = 3,400 to 200°F		
	Pressure in pipe			Pressure in pipe		
Nominal pipe size NPS (DN)	180 psig (ft)	15 psig (ft)	Hanger load (lb)	180 psig (ft)	15 psig (ft)	Hanger load (lb)
½ (15)	6	6	2	6	6	3
¾ (20)	7	7	4	7	7	5
1 (25)	8	8	6	8	8	9
1¼ (32)	10	10	10	8	9	14
1½ (40)	12	12	13	9	10	19
2 (50)	13	14	19	9	10	31
2½ (65)	14	15	33	10	12	51
3 (80)	16	17	47	11	12	77
4 (100)	18	20	74	12	14	132
5 (125)	19	22	108	12	14	207
6 (150)	21	24	149	13	15	304
8 (200)	22	27	252	13	17	550
10 (250)	25	31	383	14	18	901
12 (300)	26	33	534	14	19	1329

1. Spans based on (1) lesser of half that permitted by allowable stress in simple beam formula or (2) deflection of 0.1 × NPS to 0.2 in max.

2. Formulas used: simple beam span (ft) = $[\{8Z(S - SL)/W\}^{0.5}]/12$; deflection span (ft) = $[(384\ EIG/W)^{0.25}]/12$, where E = modulus of elasticity, I = moment of inertia, G = permitted deflection, Z = section modulus, S = allowable stress, SL = longitudinal stress caused by pressure, W = weight (lb/in).

3. Hanger loads listed are the full weight of the longest span in each category.

the deflection limited to the smaller of 0.2 in or 10 percent of the nominal pipe diameter at the listed span.

The tables show the effect of internal pressure on pipe spans. In general the deflection is the governing factor in the smaller sizes. The weights and spans have been calculated based on mineral-fiber insulation.

EXPANSION AND FLEXIBILITY

Expansion in building-service piping must be recognized and allowed for. The temperature extremes may run from 40°F (4°C) for chilled water, which will result in the contraction of a pipe installed at 70°F (21°C), to 360°F (182°C) for 150 psig (1035 kPa) steam; which will give rise to a much greater expansion of a pipe. Part B of this handbook gives a detailed discussion on expansion and flexibility as well as tables giving coefficients of expansion and the actual expansion for various materials between given temperatures.

Uncontrolled expansion forces can be harmful at equipment connections by imposing loads on the equipment. Manufacturers will provide the allowable forces

TABLE C4.15 Pipe Spans for Sch 40 CPVC, PVC, ABS, and Sch 80 PP Thermoplastic Pipe, Including Water and Insulation

	CPVC ASTM F441 #4120 Cell no. 23447						PVC ASTM D1785 #1120 Cell no. 12454				ABS ASTM D1517 Des. no. 1210				Polypropylene Schedule 80 pipe					
	Pipe pressure (psig)						Pipe pressure (psig)				Pipe pressure (psig)				Pipe pressure (psig)					
	73°F		100°F		180°F		73°F		100°F		73°F		100°F		73°F		100°F		180°F	
Nominal pipe size NPS (DN)	100 (ft)	15 (ft)	100 (ft)	15 (ft)	100 (ft)	15 (ft)	100 (ft)	15 (ft)	100 (ft)	15 (ft)	100 (ft)	15 (ft)	100 (ft)	15 (ft)	100 (ft)	15 (ft)	100 (ft)	15 (ft)	100 (ft)	15 (ft)
½ (15)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3
¾ (20)	4	4	3	3	2	3	4	4	4	4	3	3	3	3	3	3	3	3	EX	3
1 (25)	4	4	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4		3
1¼ (32)	5	5	5	5	EX	4	5	5	3	5	5	5	4	5	5	5	5	5		3
1½ (40)	6	6	6	6		4	6	6	6	6	5	6	4	5	6	6	5	6		3
2 (50)	7	7	7	7		4	7	7	7	7	5	6	4	5	6	7	5	6		4
2½ (65)	8	8	8	8		5	8	8	8	8	6	7	5	6	7	7	6	7		4
3 (80)	9	9	8	9		5	9	9	8	9	6	8	5	7	8	8	6	7		4
4 (100)	10	10	8	10		5	10	10	9	10	6	8	EX	7	8	9	6	8		5
5 (125)	10	11	9	10		5	10	12	9	11	EX	8		7						
6 (150)	11	12	9	11		6	11	12	9	11		9		8	9	11	7	9		5
8 (200)	11	13	9	12		6	11	13	9	12		9		8	9	12	EX	10		6
10 (250)	12	14	10	13		7	12	14	10	13		10		9						
12 (300)	12	15	10	13		7	12	15	10	14		11		9						

1. Spans based on lesser of (1) half that permitted by allowable stress in simple beam formula or (2) deflection of $0.1 \times$ NPS to 0.2 in max. For empty pipe and glass fiber insulation.

2. Formulas used: Deflection span (ft) = $[(384EIG/W)^{0.25}]/12$; simple beam span (ft) = $[\{8Z(S - SL)/W\}^{0.5}]/12$, where E = modulus of elasticity, I = moment of inertia, G = permitted deflection, Z = section modulus, S = allowable stress, SL = longitudinal stress caused by pressure, W = weight.

EX—At this pressure the hoop stress in the pipe exceeds the allowable stress for this size and larger.

and moments. When necessary these forces can be controlled by providing an anchor or restraint on the piping at or near the connection.

Long straight runs of pipe with no offsets, or very short offsets, need to be checked for total linear expansion. These are found most often as risers in vertical buildings and mains in horizontal buildings. If the amount of expansion encountered cannot be absorbed by the flexibility in the pipe configuration at take-offs from a main, or at the end of a main, an expansion joint or pipe loop must be used.

There are three categories of expansion joints: corrugated bellows, packed slip joints, and rotary or ball joints. All expansion joints must be placed between anchors to direct the forces and in some cases to keep the joint from separating due to the internal pressure.

1. Corrugated joints have no packing, which is an advantage since they do not develop leaks. The pipe leading to this type of joint must be provided with adequate guiding to keep the pipe axially aligned and direct the expansion forces into the joint. If the pipe is improperly guided the joint may squirm, which results in misalignment and possible catastrophic failure.
2. Packed slip joints have the disadvantage of packing, which must be maintained. They must also be guided, but catastrophic failure is unlikely unless an anchor fails.
3. Ball joints are used in pairs in branch pipes, or in the main after an elbow, to take up the expansion offset. These are packed swivel joints which need maintenance but will not separate.

Flexibility is inherent in a building system due to the elbows and offsets usually necessary to get from the source to the destination. An unrestrained piping system will find its own point of least stress and have the lowest end forces. If an inspection of the pipe route does not reveal any places where the expected expansion will interfere with walls, columns, ducts, or other pipes, it is advisable not to introduce anchors. Detailed flexibility analysis methods can be found in Part B of this handbook.

TESTING

Before putting a system in service it should be tested for leakage or proof tested to demonstrate its ability to withstand the design pressure. This can be done by several methods.

Hydrostatic Testing

Hydrostatic testing is the preferred method of testing, since leaks are detectable and the stored energy in the pipe is low. All joints should be exposed and uninsulated. Before initial filling, the following precautions should be observed:

1. A survey of the entire pipeline should be made to ensure that there are no open ends; all hangers, anchors, and guides are in place; and all joints are properly made.
2. All equipment that will be damaged by the test pressure should be isolated from the system.

3. Expansion joints and anchors in the pipeline should be checked for their ability to withstand the test pressure.
4. If the test pressure is to be left on the system for an extended period, a relief valve should be installed to prevent overpressurization due to expansion of the fluid caused by an increase in temperature.
5. Vents should be used to release air from high points of the system. Drains should be provided to remove the test liquid.

Test Medium. The test medium should be water unless there is a risk of freezing or water will damage the system. A glycol solution can be used if provisions are made to flush the system and properly dispose of the glycol at the end of the test. The system should be filled gradually and examined to detect leaks as the filling progresses.

Test Pressure. The test pressure required by B31.9 is 1.5 times the design pressure at all points of the system. For vertical systems the pressure at the bottom should not exceed the lower of

1. 90 percent of the minimum yield strength of the material
2. 1.7 times the SE value of brittle materials
3. The rated pressure of valves or equipment which will be subjected to the pressure

Examination. Examination of the entire system for leaks should be made after the test pressure has been on the system for at least 10 minute. If leaks are found they should be repaired and the test repeated until no leakage is detected.

Pneumatic Testing

Pneumatic testing is dangerous and should only be used within the following conditions:

1. There are no soldered joints in the system over NPS 4 (DN 100).
2. If brittle plastic, no pipe is larger than NPS 2 (DN 50).
3. Water will be detrimental to the system.
4. The test pressure does not exceed 150 psig (1035 kPa).

The test medium should be air, nitrogen, or any other innocuous gas.

Test Pressure. The test pressure for a pneumatic test is limited by B31.9 to a maximum of 1.25 times the design pressure. The pressure should be introduced gradually with the first increment not more than 10 psig (69 kPa), at which time an inspection can be made for major leaks. The pressure can then be raised in increments of 25 percent, pausing at each increment to allow system equalization.

Examination. Examination for leaks should be made after the full test pressure has been on the system for 10 minute or more. Leaks can be detected by soap bubbles, special testing fluids, ultrasonic means, or test-gauge monitoring.

Service Testing

Service testing can be used in place of the above tests for low-pressure systems that operate below 15-psig (103 kPa) steam pressure or 30-psig (207 kPa) water pressure. Proof testing is not needed, and an examination for leaks can be made when the system is placed in initial operation for the service intended.

PROBLEMS AND SOLUTIONS

Some of the problems occurring most often with piping systems are discussed below.

The cost of the installation is too high. If this comment is heard, check the following:

1. Has seamless pipe been used when furnace butt-weld or electric resistance-weld pipe will be adequate?
2. Has Type K copper tubing been called for when Type L is adequate?
3. Have steel valves been used when ductile-iron or cast-iron valves are strong enough?
4. Has radiography of welds been called for when it is not required by the piping code?
5. Are too many anchors and expansion joints called for when the system has inherent flexibility?
6. Have factory-made tees or reinforced outlet fittings been used when welded branch connections are suitable?
7. Has the use of grooved-type joints been permitted where they are economical?
8. Has the use of plastic materials been considered?
9. Are pipe sizes too large? This requires analysis of the long-term pumping costs, since smaller pipe sizes will result in greater friction.
10. Has the hanger spacing been checked to make sure the most economical spacing has been allowed?
11. Has the system configuration been reviewed to be sure the most direct route possible has been selected?

The system does not circulate the proper GPM. Look for the following:

1. Are all of the valves open?
2. Is the system fully vented?
3. Are all the strainers clean?
4. Is the pump providing the proper pressure differential?
5. Is there an obstruction in the piping? Check pressures along the system to find an unpredicted drop.

The system is noisy. Look for the following causes:

1. Has the system been fully vented? Air in the system is noisy.
2. Is the pump circulating too much fluid? If the required system head has been

predicted higher than the actual one, the pump is circulating too much fluid and causing velocity noise. Throttle a pump-balancing valve to introduce more pressure drop in the system. If this solves the problem, the pump impeller should be changed for long-term economy.

The chilled water expansion tank overflows. Investigate the following:

1. The makeup level in the tank is set too high and water is added when the system is operating cold.
2. The tank does not have the capacity for the expansion volume.
3. There is a cross connection to another system.

The steam pipes make knocking noises. Investigate the following:

1. The steam pipe has not been pitched in the direction of condensate flow.
2. The distance between drip legs on long runs is too great. If the knocking only occurs on warmup, look for a slower warmup method.

The water pipes hammer or shake. Water hammer can be caused by the following:

1. The sudden opening or closing of a valve. Automatic valves can be made to operate slower to prevent water hammer. Manual valves should always be operated slowly.
2. The starting or stopping of a pump. A spring-loaded or hydraulically operated check valve should always be installed at the discharge of large pumps.
3. Air can be sucked into a piping system at a cooling-tower basin and cause violent pipe movement. Install a vortex breaker in the basin.

Is the system ready to be placed in operation?

1. The pressure test should be performed and all blanks removed.
2. The system should be flushed, and the water treatment system should be operable.
3. A visual inspection should be made to be sure all open ends have been secured, all block valves are in the proper position for operation, all safety and relief valves are installed, and if a water system, the system is full and vented.
4. A visual inspection should be made to be sure adequate pipe expansion room is available. Some approximations that can be used for visual inspection are as follows per 100 ft (30.5 m) of straight pipe per 100°F (38°C) from ambient temperature (do not use for exact calculations):

Ductile iron	Expands	1 in
Steel	Expands	1 in
Stainless steel	Do	1¼ in
Copper or brass	Do	1½ in
Aluminum	Do	2 in
RTRP	Do	2 in
PVC & CPVC	Do	5 in
Polypropylene	Do	6 in
ABS	Do	7 in
PB	Do	9½ in

5. Check that all anchors and guides are in place.

Life Expectancy. Piping in power plants, refineries, industrial plants, and so on, where the piping is a part of the process, is subjected to extreme service conditions and is therefore closely monitored. Building piping, while necessary to the operation of a building, is not subject to severe service and therefore not watched as closely. Because the pipe is built into walls and shafts, it is expensive to replace and is generally designed to last as long as the building.

The corrosion of steel pipe is the biggest concern. Closed recirculating systems such as chilled water or heating water can circulate for years with very little corrosion, since no new oxygen is introduced into the system. Cooling tower piping systems require very close monitoring, and alternative materials should be considered.

BIBLIOGRAPHY

ASHRAE Handbook, American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, GA.

ASME Boiler & Pressure Vessel Code, ASME, New York.

Section I, Power Boilers

Section IV, Heating Boilers

Section VI, Recommended Rules for Care and Operation of Heating Boilers

Section IX, Welding and Brazing Qualifications

ASME Code for Pressure Piping B31, ASME, New York.

B31.1, Power Piping

B31.3, Chemical Plant and Petroleum Refinery Piping

B31.5, Refrigeration Piping

B31.9, Building Services Piping

ASTM Annual Book of ASTM Standards, ASTM, Philadelphia, PA.

Volume 01.01, Steel-Piping, Tubing, Fittings

Volume 02.01, Copper and Copper Alloys

Volume 08.04, Plastic Pipe and Building Products

Piping Engineering, Tube Turns Division of Chemetron Corporation, Louisville, KY.

Copper Tube Handbook, Copper Development Association Inc., Greenwich, CT.

Victaulic Mechanical Piping Systems General Catalog, Victaulic Company of America, Easton, PA.

MSS Standard Practices, Manufacturers Standardization Society, Inc., Vienna, VA.

SP-58, Pipe Hangers and Supports—Materials, Design and Manufacture

SP-69, Pipe Hangers and Supports—Selection and Application

PFI Technical Bulletin, Pipe Fabrication Institute, Springdale, PA. TB2, Reinforcement Tables for Branch Connections