CHAPTER C13

PLUMBING PIPING SYSTEMS

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This chapter provides the necessary criteria to enable accurate pipe sizing for various plumbing systems and cost-effective selection of appropriate plumbing piping material.

Plumbing systems directly affect the health and safety of the public, and thus they are distinguished from other piping systems by the following general requirements:

1. The design, materials, and installation of the systems are directly regulated by a plumbing code.
2. System design must be approved by an authorized code official charged with the responsibility of ensuring plumbing code compliance.
3. A permit for installation of the systems must be obtained from the authority having jurisdiction.
4. The systems shall be installed by an individual duly licensed by the authority having jurisdiction for determining the competence of an individual to obtain a plumbing installation license. This may not be required in some jurisdictions.
5. The installed systems are required to be inspected and approved by an authorized code official charged with the responsibility of code enforcement.

The basic plumbing systems are

1. Sanitary drainage systems
2. Sanitary vent systems
3. Stormwater drainage systems
4. Potable water systems
5. Fuel gas systems

CODES AND STANDARDS

Plumbing codes establish minimum acceptable standards for the design and installation of the various plumbing systems and for the components that comprise them.

There are five plumbing codes that are generally accepted in large areas of the country:

Code title	Sponsors
A40 Safety Requirements for Plumbing	Cosecretariats are: • Plumbing, Heating, Cooling Contractors—National Association • Mechanical Contractors Association of America • International Association of Plumbing and Mechanical Officials
International Plumbing Code	International Code Council comprised of the Building Officials and Code Administrators, International, the International Conference of Building Officials, and the Southern Building Code Congress
National Standard Plumbing Code	Plumbing, Heating, Cooling Contractors—National Association
One- and Two-Family Dwelling Code (soon to be called the International Residential Code)	International Code Council comprised of the Building Officials and Code Administrators, International, the International Conference of Building Officials, and the Southern Building Code Congress International
Uniform Plumbing Code	International Association of Plumbing and Mechanical Officials

Some states and large cities have adapted codes separate from these building codes. Because of this nonstandardization, the plumbing code used for each specific project must be obtained from a responsible code official.

Many of the tables and figures in this chapter are used only to illustrate and augment discussions of the system sizing procedures and design methods and should not be used for actual design purposes. The information pertaining to those systems is included in the approved plumbing code and should be the primary criterion for accepted methods and sizes for use on any project.

There are many nationally recognized standards that establish dimensions, manufacturing methods, material composition, tests, and numerous other details specific to individual components of the plumbing system. A partial list of organizations originating such standards adapted by various plumbing codes is as follows:

American National Standards Institute (ANSI)

American Society of Mechanical Engineers (ASME)

American Society of Sanitary Engineers (ASSE)

American Society for Testing and Materials (ASTM)

American Water Works Association (AWWA)

American Welding Society (AWS)

Cast Iron Soil Pipe Institute (CISPI)

National Fire Protection Association (NFPA)

National Sanitation Foundation International (NSFI)

Plumbing and Drainage Institute (PDI)

Underwriters' Laboratories (UL)

FIXTURE UNITS

The *fixture unit* (FU) is an arbitrary, comparative value assigned to a specific plumbing fixture, device, or piece of equipment. FU values represent the probable flow that fixture will discharge into a drainage system or use (demand) from a potable water supply system, compared to other fixtures.

The use of fixture units for plumbing systems was expanded by the late Roy B. Hunter, of the former Bureau of Standards. In the years since the development of the Hunter method, new fixtures, changes in the patterns of water use, and water conservation would now result in oversized water and drainage piping systems if the original criteria were used. Long-term data and modern statistical methods and analyses have resulted in revised figures, which were used in calculating the tables and charts provided for this revision of the handbook.

Since sanitary discharge and water demand FUs are different, the designations *DFU* for drainage fixture unit and *WFU* for potable water fixture unit will be used to differentiate between them.

PLUMBING FIXTURES

A plumbing fixture is any approved receptacle specifically designed to receive human and other waterborne waste and discharge that waste directly into the sanitary drainage system, usually with the addition of water. Ideal fixture materials should be nonabsorbent, nonporous, nonoxidizing, smooth, and easily cleaned.

Plumbing codes usually mandate the number and type of fixtures that must be provided for specific building use, based on the proposed population. Provisions for the handicapped have been made an integral part of code requirements, mandating the number, layout, and barrier-free access to those fixtures.

Potable water discharged from specific plumbing fixtures may be restricted to a maximum flow rate mandated by water conservation requirements. Refer to specific code provisions for these restrictions.

Table C13.1 lists average drainage and vent DFUs, hot and cold water WFUs, gallons-per-minute (gpm) flow, and branch size information for typical fixtures.

EQUIVALENT LENGTH OF PIPING

When one is calculating the pressure loss through a pressurized piping system, one of the factors to be considered is the *equivalent length* of pipe. This is the actual pipe run plus an additional length, expressed as a number of feet of straight pipe, that would have the same friction loss as that occurring through various fittings, valves, and so on. Figure C13.1 gives the straight run of pipe for both water and gas systems equal to various valve types and fittings for different pipe sizes. An often used and generally conservative method of quickly finding the equivalent run is to add 50 percent to the actual measured pipe run.

PIPING MATERIALS: GENERAL

When materials and jointing methods are chosen for use in a project, the plumbing code usually specifies pipe materials permitted to be used for the various systems

TABLE C13.1 Typical Plumbing Fixture Schedule

Fixture type	Drainage			Water			
	DFU	Size trap NPT	Size vent NPT	WFU	Size cold	Size hot	Flow, gpm
Automatic clothes washer	3	2	1½	2	½	½	5
Bathroom group (WC, LAV, SH/BT) FV	8			8			
Bathroom group (WC, LAV, SH/BT) tank	6			6			
Bathtub (BT), with or without SH	2	1½	1½	2	½	½	5
Bidet	1	1¼	1¼	1	½		2
Clinic sink	6	3	1½	2	½	½	3
Dishwasher, domestic	2	1½	1½	1	½	½	3
Dental lavatory, cuspidor, and unit	1	1½	1½	1	½	½	1
Drinking fountain	½	1¼	1¼	½	½		½
Floor drain	5	3	1½				
Kitchen sink and tray, with food grinder	4	2	1½	2	½	½	3
Kitchen sink and tray, single 1½-in trap	2	1½	1½	2	½	½	3
Kitchen sink and tray, multiple 1½-in traps	3	1½	1½	2	½	½	3
Lavatory, private	1	1¼	1¼	1	⅜	⅜	2
Lavatory (LAV), public	2	1¼	1¼	2	⅜	⅜	2
Laundry tray, one or two compartments	2	1½	1½	2	½	½	5
Shower (SH) per head or stall	2	2	1½	2	½	½	3
Sink service (SS), trap standard	3	3	1½	3	¾	¾	4
Sink service, P trap	2	1½	1½	2	½	½	4
Sink pot and scullery	2	1½	2	2	½	½	4.5
Sink bar	1½	1½	1½	1	½	½	2
Sink flushing rim	6	3	1½	5	1		15–30
Sink, surgeon's	3	2	1½	2	½	½	2.5
Sink wash fountain, per faucet	2	1½	1½	2	½	½	2.5
Urinal pedestal, blowout	6	3	1½	10	1		15–40
Urinal washout	4	2	1½	5	¾		10–20
Water closet (WC), private flush valve (FV)	6	3	1½	10	1		15–40
Water closet private tank type	4	3	1½	5	½		3–5
Water closet private pressure tank	4	3	1½	4	½		3–5
Water closet public flush valve	6	3	1½	10	1		15–40
Water closet public tank type	4	3	1½	5	½		3–5
Water closet public pressure tank	4	3	1½	4	½		3–5
Fixture not listed	1	1¼	1¼				
Fixture not listed	2	1½	1½				
Fixture not listed	3	2	1½				
Fixture not listed	5	3	1½				
Fixture not listed	6	4	2				
Hose bibb or sill cock, public				5	¾		5
Hose bibb or sill cock, private				3	½		3
Water supply not listed				1	⅜		
Water supply not listed				2	½		
Water supply not listed				3	¾		
Water supply not listed				10	1		

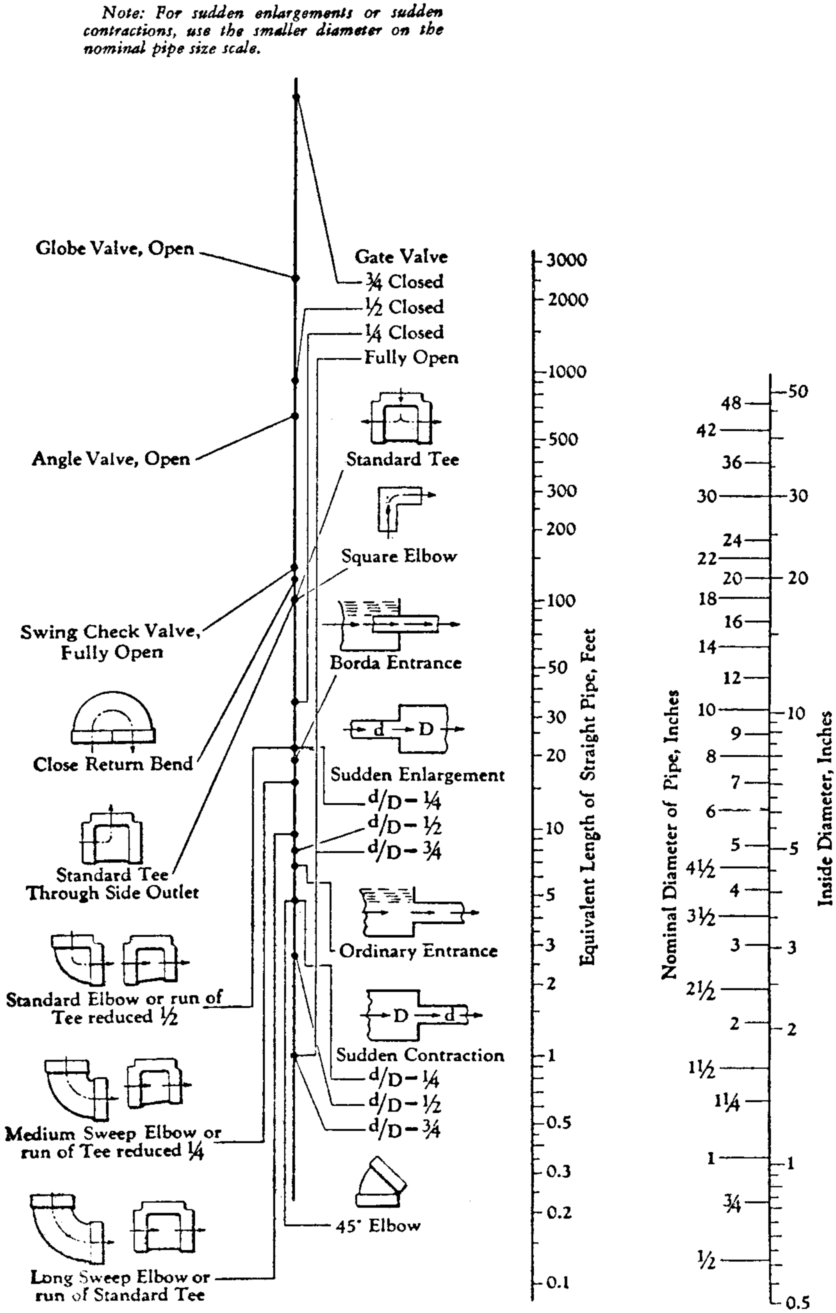


FIGURE C13.1 Resistance of valves and fittings to flow of fluids. (*Courtesy Crane Co.*)

along with any restrictions on their use. The code also may stipulate accepted standards that govern the manufacture of the components, their tolerances, and their installation. The piping materials to be discussed are all accepted for use in various national, regional, and most local codes. Some materials may not be acceptable for use in specific local codes.

When a plumbing system is being renovated or when circumstances require a unique design, it may be necessary to request deviation from the accepted list of materials in order to match existing piping or to obtain special design characteristics. To review such requests, the authorities require enough information to determine whether the intent of the applicable code provisions is adhered to in terms of safety and suitability of the materials for the intended purpose.

The design engineer is ultimately responsible for selecting and specifying the most suitable pipe, fittings, and jointing methods for any project. The following characteristics of pipe and fittings are important considerations in making that selection:

1. Corrosion resistance of the pipe and fittings. This is a measure of their ability to resist both the internal corrosive effects of the fluid likely to flow through the pipe and the effects of soils or ambient conditions on its exterior. Corrosion can be reduced or eliminated by the application of a suitable coating, encasement, lining, and cathodic protection.
2. Total installed cost, which includes the cost of the pipe and fittings, assembly of the joints, handling, and the cost of the support system for the piping.
3. Physical strength of the pipe and fittings, which is the ability to withstand the internal pressure of the liquid and external physical damage that may occur either during installation or after being placed in service.

Metallic Pipe and Fittings

Cast-Iron (CI) Soil Pipe and Fittings. Cast-iron soil pipe is acceptable for any nonpressure, noncorrosive sanitary and stormwater drainage service. Three types of pipe are manufactured: service (or standard) weight, extra heavy, and hubless. Two types of pipe ends are available: hub and spigot, and hubless. Three types of joints are used: caulked and compression gaskets used with hub and spigot pipe, and compression couplings used only for hubless pipe.

Hub and spigot cast-iron soil pipe and fittings shall conform to the following standards:

1. ASTM A 74, Cast-Iron Soil Pipe and Fittings
2. ASTM C 64, Rubber Gaskets for Cast-Iron Soil Pipe and Fittings
3. ASTM HSN, Neoprene Rubber Gaskets for Hub and Spigot Cast Iron Soil Pipe and Fittings
4. CISPI 301, Hubless Cast-Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications
5. CISPI 310, Patented Joint for Use in Connection with Hubless Cast-Iron Sanitary System

Acid-Resistant (AR) Cast-Iron Pipe and Fittings. This pipe material is used for nonpressure drainage service for corrosive liquids whose corrosion potential is too severe for CI pipe. AR pipe is CI pipe containing between 14.25 and 15 percent silicon and small amounts of manganese, sulfur, and carbon. It is manufactured only in extra-heavy grade. It is available with two types of pipe ends: hub and spigot, or hubless. The hub and spigot ends can be joined by caulking. Hubless pipe is joined by the use of compression coupling.

Acid-resistant cast-iron pipe and fittings must conform to the following standards:

1. ASTM A 518, Corrosion Resistant High Silicon Iron Castings
2. ASTM A 861, High Silicon Iron Pipe and Fittings

Ductile-Iron (DI) Pipe and Fittings. DI pipe is suitable for any noncorrosive plumbing service. Ductile-iron pipe is fabricated of a cast-iron alloy in which graphite replaces the carbon that is present in cast-iron soil pipe. It is available for use as either a nonpressure gravity sewer pipe or a pressure pipe. Five pressure classes (PC) 150, 200, 250, 300 and 350 are available. Ductile iron pipe rating is also designated by Special Thickness Classes: 50, 51, 52, 53, 54, 55 and 56, and gravity sewer pipe. Three types of joints are used: mechanical, gasketed, and flanged.

Ductile-iron pipe and fittings must conform to the following standards:

1. ANSI/AWWA C151/A21.51, Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids
2. ANSI/AWWA C115/A21.15, Flanged Ductile-Iron and Gray-Iron Pipe with Threaded Flanges
3. ANSI/AWWA C111/A21.11, Rubber-Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe and Fittings
4. ANSI/AWWA C110/A21.10, Gray and Ductile Iron Fittings, 2 through 48 in for water and other liquids

For other standards refer to Table C1.2 in Chap. C1.

Steel (ST) Pipe. Steel pipe is commonly used in vent systems, in drainage systems where human waste is not discharged, for indirect waste lines, for potable water systems, and for fuel gas piping. Steel pipe can be obtained with threaded ends, plain ends, and beveled ends. Four types of joints are used: screwed, grooved, flanged, and welded. Fitting materials commonly used are steel (for welded joints), malleable iron (either screwed or grooved joints), and cast iron (either screwed or flanged joints). Steel pipe for plumbing systems should be galvanized to retard corrosion.

Steel pipe and fittings used for plumbing systems must conform to the following standards:

1. ASTM A 53, Pipe, Steel, Black, and Hot-Dipped, Zinc-Coated Welded and Seamless
2. ASME B16.1, Cast-Iron Pipe Flanges and Flanged Fittings, Classes 25, 125, 250, and 800
3. ASME B16.3, Malleable-Iron Threaded Fittings; Class 150 and 300
4. ASME B16.5, Pipe Flanges and Flanged Fittings
5. ASME B16.9, Wrought Steel Buttwelding Fittings
6. ASME B16.12, Cast-Iron Threaded Drainage Fittings

Copper Water Tube. Copper tube is used for domestic water service. Copper tube is fabricated of 99.9 percent copper with plain ends, in three types: K, L, and M. Each type has the same outside diameter, with K tube having the greatest wall thickness and pressure rating, and M the least. Each of the three types of copper tube is also available in either drawn (hard) or annealed (soft) forms. Fittings can be either wrought copper or cast bronze. Copper tube can be joined by flared, soldered, or brazed joints.

Copper tube and fittings must conform to the following ASTM and ASME standards:

1. ASTM B 88, Seamless Copper Water Tube
2. ASME B16.22, Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
3. ASME B16.18, Cast Copper Alloy Solder Joint Pressure Fittings
4. ASME B16.26, Cast Copper Alloy Fittings for Flared Copper Tubes

Copper Tube, Type DWV (Drainage, Waste, and Vent). It is a nonpressure, thin-wall drainage pipe, primarily used in residential buildings, and in commercial buildings for indirect waste lines or local branch lines where human waste is not discharged. It is a seamless tube, made from almost pure copper (99.9 percent), and is available only in drawn form with plain ends. Joints can be either soldered or brazed.

Type DWV copper tube for drainage systems must conform to the following standards:

1. ASTM B 306, Copper Drainage Tube (DWV)
2. ASME B16.29, Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings, DWV
3. ASME B16.23, Cast Copper Alloy Solder Joint Drainage Fittings, DWV

Brass Pipe. It is generally used in local branch drainage lines where this alloy resists specific corrosive drainage effluent, in alterations to match existing work and as a pressure pipe for potable water in sizes larger than NPS 4 (DN 100), where soldering or brazing is impractical. Brass pipe is manufactured from an alloy containing 85 percent copper and 15 percent zinc with plain ends. Joints can be either screwed, soldered, or flanged.

Brass pipe and fittings must conform to the following standards:

1. ASTM B 43, Seamless Red Brass Pipe
2. ASME B16.24, Cast Copper Alloy Pipe Flanges and Flanged Fittings; Classes 150, 300, 400, 600, 900, 1500, and 2500
3. ASME B16.15, Cast Bronze Threaded Fittings, Classes 125 and 250
4. ASME B16.18, Cast Copper Alloy Solder-Joint Pressure Fittings

Plastic Pipe and Fittings

General. Plastic pipe is manufactured in a great variety of compositions, many of which are suitable for plumbing systems. The applicable code is the most important factor in selecting the type of plastic pipe for any specific purpose. All plastic pipe, components, and jointing methods used in potable water systems must be approved by the NSFI. Plastic pipe must be closely integrated with the selection of hangers and the entire pipe support system.

The advantages of plastic pipe include excellent resistance to a wide variety of chemical and waste effluents, resistance to aggressive soils, availability in long lengths, low resistance to fluid flow, and low initial cost. Disadvantages include poor structural stability (requiring additional supports), lower pressure ratings at elevated temperatures, susceptibility of some types of plastics to physical changes due to exposure to sunlight, low resistance to solvents, and production of toxic gases released upon combustion of some types of plastics.

Three designations are used to express pressure rating and wall thickness: schedule (dimensions are outside-diameter-controlled, matching iron pipe size); standard dimensional ratio (SDR) (a pressure rating only); and dimensional ratio (a pressure rating only using nonstandard dimensional ratios). Where the pressure rating is the prime consideration, the abbreviation PR is used.

Polyvinyl Chloride (PVC) Pipe. PVC is used for potable water and drainage systems. It is one of the most widely used of the plastic pipes. It has a low pressure and temperature rating and very poor resistance to solvents.

PVC pipe and fittings must conform to the following standards:

1. ASTM D 1785, PVC Plastic Pipe, Schedules 40, 80, and 120
2. ASTM D 2241, PVC Pressure-Rated Pipe (SDR Series)
3. ASTM D 2466, PVC Plastic Pipe Fittings, Schedule 40
4. ASTM D 2467, Socket-Type PVC Plastic Pipe Fittings, Schedule 80
5. ASTM D 2665, PVC Drain, Waste and Vent Pipe and Fittings

Chlorinated Polyvinyl Chloride (CPVC) Pipe. CPVC is used for potable water and drainage systems. It has the same characteristics as those of PVC and is used where a stronger piping system with higher pressure and temperature ratings is required. CPVC pipe and fittings must conform to the following standards:

1. ASTM F 441, CPVC Plastic Pipe, Schedules 40 and 80
2. ASTM D 2846, CPVC Plastic Hot and Cold Water Distribution Systems
3. ASTM F 439, Socket-Type CPVC Plastic Pipe Fittings, Schedule 80

Polypropylene (PP) Pipe. This material is widely used for chemical drainage piping systems. PP pipe and fittings are manufactured from flame-retardant material and are available in Schedule 40 or 80. Joining methods include solvent cement joints, threaded joints, or mechanical-type joints. (Only Schedule 80 can be threaded.)

Polyethylene (PE) Pipe. It is widely used for underground fuel gas and foundation drainage piping. It is joined by socket and butt heat fusion. Refers to Chap. D1 of this handbook.

Acrylonitrile-Butadiene-Styrene (ABS) Pipe. ABS is widely used as drainage pipe and is available in Schedules 40 and 80 with plain or socket ends. Joints are made by either solvent cement or threaded connections. Only Schedule 80 can be threaded.

ABS pipe and fittings must conform to ASTM Standard D 2661, ABS Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings.

Other Pipe

Glass Pipe. This pipe is primarily used for gravity drainage of various corrosive liquids. Glass pipe is fabricated from a low-expansion borosilicate glass having a low alkali content. Glass pipe is joined by compression couplings.

Vitrified Clay (VC) Pipe. This pipe is suitable for use in underground gravity drainage systems where resistance to a wide variety of corrosive effluent and aggressive soils is required. It is manufactured in standard and extra-strong grades with hub and spigot ends. Clay pipe is joined by mortar joints.

MISCELLANEOUS FITTINGS

Adapters are used to join two different pipe materials or piping with dissimilar joint ends. Most plumbing codes require the use of approved adapters.

Dielectric fittings are used to connect dissimilar metallic pipes together to avoid galvanic corrosion that would quickly weaken the pipe at the joint. The principle of the joint is a gasket that isolates one pipe from the other.

Unions are fittings used to connect two fixed pipes, neither of which is capable of being turned. The union consists of three interconnected pieces: two internally threaded ends and a centerpiece that draws the ends together when rotated.

JOINTS

A *joint* is a connection between one pipe and either another pipe or a fitting. It must be able to withstand the greatest pressure capable of being exerted upon it. Most plumbing codes refer to standards that govern the methods and materials used in forming joints. The selection of the joining methods is determined by the type of pipe and fittings used, the maximum pressure expected in the system, and the need for disassembly.

Caulked Joints

A caulked joint, illustrated in Fig. C13.2, is a rigid, nonpressure-type joint. This joint consists of a rope of oakum or hemp that is packed into the annular space around the spigot end. For acid-resistant cast-iron pipe, hydrous magnesium aluminum silicate, reinforced with fiberglass, is used as a packing material instead of oakum. Molten lead 1 in in depth is then poured into the annular space on top of the rope. The lead is then driven (caulked) farther into the joint. In use, the hemp or oakum swells when it absorbs water and further increases the joint's ability to resist leaking.

Because caulked joints are labor-intensive, they have generally been replaced by either compression coupling or gasketed joints for most cast-iron joint applications where permitted by code.

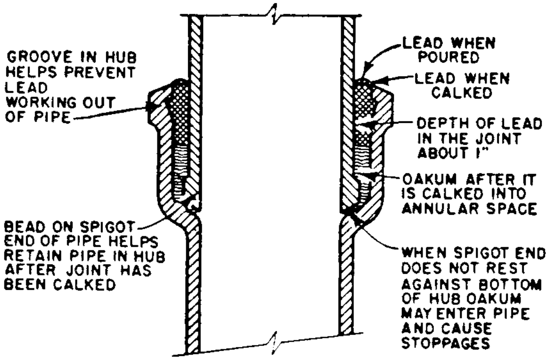


FIGURE C13.2 Caulked joint.

Compression Couplings

The compression coupling, illustrated in Fig. C13.3, is a rigid, nonpressure type of joint that can be easily disassembled. The coupling consists of an inner elastomeric gasket and an outer metallic sleeve with an integral bolt used for tightening and compressing the gasket.

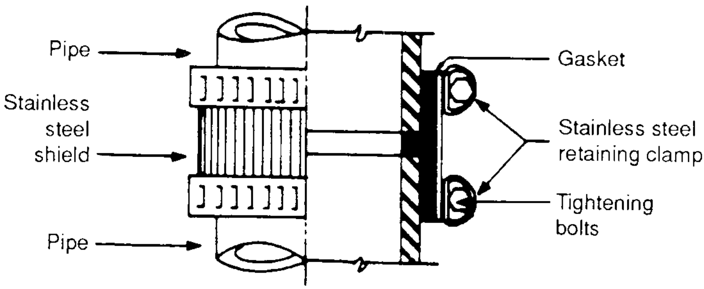


FIGURE C13.3 Compression coupling.

This joint is preferred for aboveground installations because of its ease of assembly and strength. Underground, the metallic sleeve often fails after years of service due to corrosion by surrounding soil or fill. The standard governing the fabrication of this type of joint is Cast Iron Soil Pipe Institute (CISPI) Standard 310.

Screwed Joints

The screwed joint, illustrated in Fig. C13.4, is a rigid, pressure-type joint that can be easily disassembled. Such a joint can be used with any plain-end pipe that has the necessary wall strength and thickness to have threads cut into it. The joint uses threads on two pipe ends (or on a pipe and a fitting) to draw the two pieces together and form a leakproof seal. The threads used for pipe are known as American (tapered) pipe thread (APT). This type of joint is generally limited to NPS 3 (DN 80)

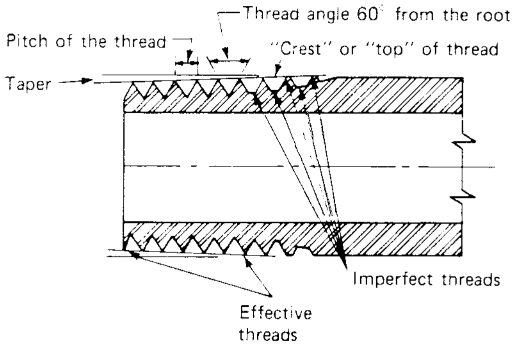


FIGURE C13.4 Screwed joint.

pipe and smaller in diameter, because of the great effort required to turn a pipe of larger size in making a joint.

Applicable plumbing codes usually specify the type of pipe that can be threaded. The standard governing the threads is ASME B1.20.1, Pipe Threads, General Purpose.

Soldered Joints

A soldered joint, illustrated in Fig. C13.5, is a rigid, pressure-type joint made with a filler metal called *solder* that, when heated to its melting point, is drawn by capillary action into the annular space between the pipe and fitting. When the solder cools, it adheres to the walls of both pipe and fitting, creating a joint that is suitable for any installation for which the piping itself is acceptable. This type of joint is generally limited to pipe having diameters no larger than NPS 4 (DN 100) because of the difficulty of applying heat evenly to larger joints.

Solder melts at a temperature of 900°F (482°C) or lower. When used in drainage

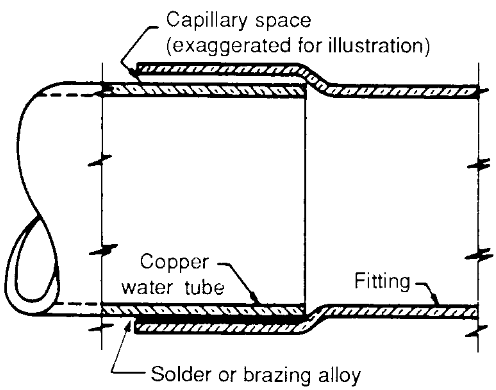


FIGURE C13.5 Soldered joint.

and vent systems, an alloy of tin and lead or tin and antimony is used. Solder and flux used for potable water systems must contain no lead.

The solder material should conform to ASTM Standard B 32, Solder Metal.

Brazed Joints

A brazed joint is similar to a soldered joint, except for the melting point of the filler metal, which is higher than 900°F (482°C). This joint is used where higher pressure ratings are required than are used for solder joints. Various compositions of the filler metal are available for various applications.

Brazing metal should conform to AWS Standard A5.8, Filler Metals for Brazing.

Gasketed Joints

A gasketed joint, illustrated in Fig. C13.6, is a flexible, pressure-type joint using an elastomeric gasket under compression. The joint is capable of being easily disassembled. It is well suited for both aboveground and underground installations.

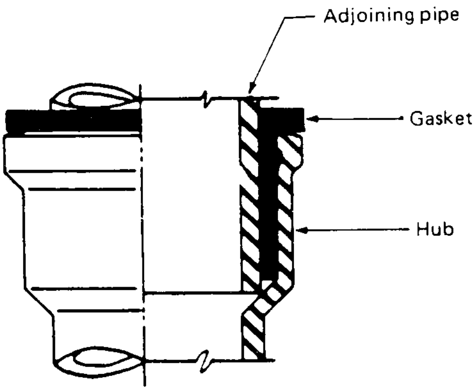


FIGURE C13.6 Gasketed joint.

Various manufacturers produce pipe ends and gasket configurations for different applications that are not compatible with one another.

Standards governing the fabrication of gasketed joints are ASTM C 564, Rubber Gaskets for Cast Iron Soil Pipe and Fittings; ASTM D 3212, Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals; and CISPI HSN, Cast Iron Soil Pipe.

Mechanical Joints

A mechanical joint is a pressure-type joint that can easily be disassembled and uses nuts and bolts to draw together a pipe and gland to compress a gasket around the

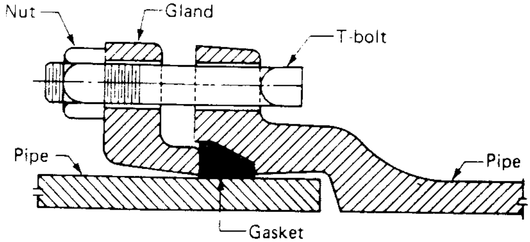


FIGURE C13.7 Mechanical joint.

pipe, forming a leakproof seal. A typical joint is illustrated in Fig. C13.7. Many different kinds of proprietary mechanical joints are available to achieve varying degrees of flexibility and pressure rating.

Grooved Joints

A grooved joint, illustrated in Fig. C13.8, is a pressure-type joint for metallic pipe that can be easily disassembled. The joint consists of an inner elastomeric gasket

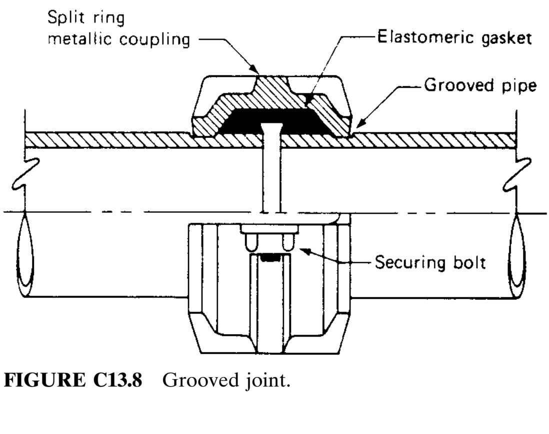


FIGURE C13.8 Grooved joint.

and an outer split metallic sleeve with an integral bolt used for tightening. The outer sleeve has extensions at each end that fit into grooves cut in or rolled into the pipe near the ends to be joined. Roll grooves are used to form joints when the pipe wall is not thick enough to have a groove cut in it. Different styles are available to achieve varying degrees of flexibility and pressure rating. It is highly resistant to being pulled apart.

Standards governing the fabrication of grooved joints are AWWA C606, Grooved and Shouldered Joints; ASTM D 735, Gasket; and ASTM A 193, Bolts.

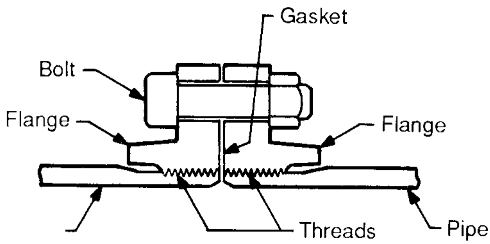


FIGURE C13.9 Flanged joint.

Flanged Joints

A flanged joint, illustrated in Fig. C13.9, is a rigid, pressure-type joint that uses nuts and bolts through a raised projection on the end of a pipe to draw the ends of the pipe together against a gasket, to form a leakproof joint. It can easily be disassembled. Flanges can be cast integrally, or they can be welded or screwed onto a plain-end pipe. The face of the mating flanges can be raised or flat. A variety of proprietary methods of flange attachment to plain-end pipes are also available.

Welded Joints

The welded joint, illustrated in Fig. C13.10, is a pressure-type joint most often used for steel pipe. Welding is accomplished by bringing both pipe walls, at the joint,

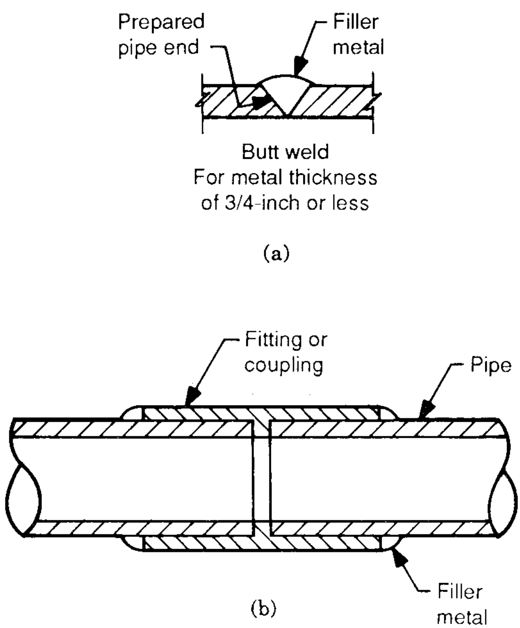


FIGURE C13.10 (*a*) Butt-weld joint. (*b*) Socket weld joint.

to the melting point and fusing them together with the addition of metal to allow for correct wall thickness and strength. The necessary amount of heat for welding is produced by either a high-temperature flame or an electric arc formed between the welding electrode and the pipe. To properly butt-weld pipe, the pipe ends must be specially prepared depending on the pipe thickness, pipe metal composition, and welding method. Two types of joints are possible: butt, illustrated in Fig. C13.10*a*, and socket, illustrated in Fig. C13.10*b*. The four methods of welding are gas tungsten arc welding (GTAW) or TIG welding; gas metal arc welding (GMAW) or MIG welding; shielded metal arc welding (SMAW); and oxyfuel torch welding.

Flared Joints

This is a rigid, pressure-type joint used only with annealed (soft) copper tubing. A flared joint, illustrated in Fig. C13.11, is made by first placing a loose, threaded coupling nut on one end of the pipe, then cold-forming that end with a mandrel that enlarges the pipe end to fit a mating end on a threaded coupling shank. The screwed coupling nut and shank are then turned, drawing the pipe ends together to form a leakproof seal.

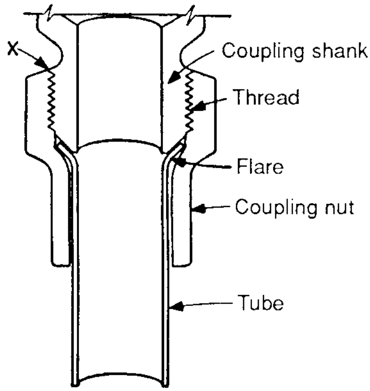


FIGURE C13.11 Piping systems.

JOINTS FOR PLASTIC PIPE

Solvent Cement Joints

This is a rigid, pressure-type joint that is suitable for any type of installation for which the piping itself is acceptable. A solvent cement joint, illustrated in Fig. C13.12, is made by spreading a combination of solvent and cement on the surfaces

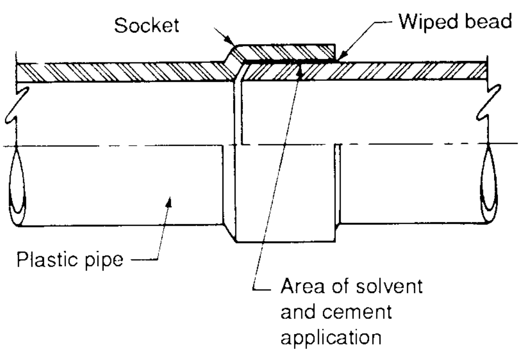


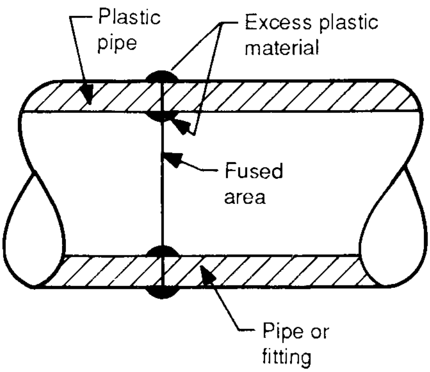
FIGURE C13.12 Solvent cement joint for plastic pipe.

to be joined. They react chemically, dissolving the surface of the pipe and the fitting that it comes in contact with. The two components are put together while wet. After drying, the two components are fused into a homogeneous mass, producing a leakproof joint. Solvent-welded joints can be used only with specific matching types of plastic pipe and fittings with plain and socket ends.

The following standards govern the use of solvent cement, depending on the type of pipe for which the cement will be used: ASTM D 2235, Solvent Cement for ABS Plastic Pipe and Fittings, and ASTM D 2564, Solvent Cements for PVC Plastic Piping Systems.

Heat Fusion Joints

A heat fusion joint is a rigid, pressure-type joint that is only suitable for thermoplastic pipe materials. Heat is used to melt the plastic pipe surfaces and fuse them together into a homogeneous mass. Two types of joints are available: butt, illustrated in Fig. C13.13*a*, and socket, illustrated in Fig. C13.13*b*. Such a joint can be used only with



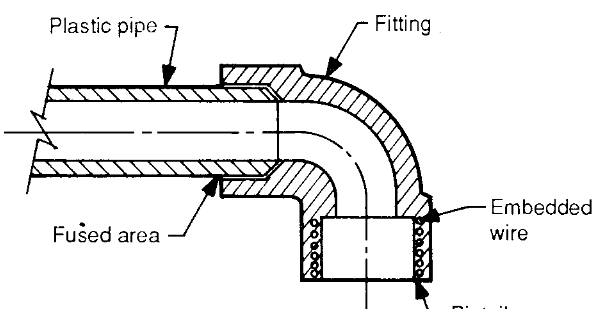


FIGURE C13.13 (*a*) Socket heat-fused joint for plastic pipe. (*b*) Butt heat-fused joint for plastic pipe.

two plain-end plastic pipes (butt joints) or a plain-end pipe and a socket fitting with resistance wire inside the socket manufactured specifically for this purpose. For butt heat fusion, the ends of the pipe are heated to the melting point with an outside source of heat, usually a flat, electrically heated plate. The heated plate is removed, and the two ends of the pipe are brought together. The socket joint is made by placing the plain end of the pipe into the socket, connecting leads from wire embedded inside the fitting to a proprietary electric source, and heating the socket to the melting point to fuse the pipe to the inside of the socket. The manufacturer's instructions must be followed carefully throughout each phase of the process. It is accepted practice to have the mechanics making up the joint certified by the manufacturer as being properly qualified in the correct procedures.

The standard governing the fabrication of heat-fused joints is ASTM D 2657, Heat Joining of Polyolefin Pipe and Fittings.

For more details on nonmetallic piping systems, see Part D of this book.

SANITARY DRAINAGE SYSTEM PIPING

System Description

The sanitary drainage system conveys waterborne effluent discharged from plumbing fixtures and other equipment to an approved point of disposal. The sanitary system receives all liquid waste except stormwater or unacceptably treated process or chemical drainage.

System Components

Major components of the sanitary drainage system are pipe and fittings, joints, valves, traps, cleanouts, drains, interceptors, sewage ejectors, and sump pumps.

Nomenclature

Approved: Accepted for the intended purpose, as an appropriate design or for installation into a plumbing system by a responsible code official or other agency exerting jurisdiction for a specific project.

Backwater valve: A commonly used term for a type of check valve used in a drainage system.

Branch: A horizontal run of pipe not considered a house drain or stack.

Branch interval: The distance measured along the stack, within which horizontal drainage branches are connected to a drain stack. This distance is usually one-story height, but never less than 8 ft, 0 in (2.4 m).

Building drain: The lowest horizontal part of the drainage piping system; considered the principal pipe conveying sanitary effluent by gravity to a point outside the building.

Building sewer: The continuation of the building drain from a point outside the building wall to the actual connection to an adequate and approved point of disposal, such as a public sewer or private sewage disposal system.

Building trap: A trap installed on the house sewer to prevent the circulation of sewer gas between the building sewer and the building drain.

Chemical waste: Any substance that may cause harm to the sanitary piping system, treatment facility, or environment without being treated or neutralized prior to discharge into the sanitary drainage system.

Cleanout: A gas-tight, water-tight pipe fitting with a removable plug that is used to obtain access to the inside of a drainage pipe for cleaning or maintenance.

Combined drainage system: A drainage system that combines sanitary effluent and stormwater runoff in a single piped system.

Fitting: A device used to connect one or more pipes and/or to change the direction of a straight run of pipe.

Floor drain: A plumbing fixture that removes liquid effluent from the surface of floors and other areas.

House drain: A commonly used term for *building drain*.

House sewer: A commonly used term for *building sewer*.

House trap: A commonly used term for *building trap*.

Indirect waste: Any waste pipe not connected directly into the drainage system that discharges through an air gap into a fixture, interceptor, trap, or drain.

Interceptor: A device that separates, retains, and allows removal of specific harmful material suspended in the waste stream, while permitting the remaining acceptable liquid effluent to be discharged into the drainage system.

Invert: The elevation of the inside bottom of a drainage pipe.

Leader: A vertical or horizontal line conveying stormwater.

Offset: Any change in direction of a stack from vertical.

Pitch: The distance that one end of a pipe is lower than the other end, expressed as a percent of the total length of run or as a dimension, in inches or feet per foot of run.

Plumbing fixture: Any approved receptacle or device specifically designed to receive human or other waterborne waste and discharge that waste directly into the sanitary drainage system, often with the addition of water.

Runout: A commonly used term for the first section of horizontal drainage piping from a stack at its lowest level.

Slope: A commonly used term for *pitch*.

Soil line: Any pipe that conveys human waste.

Stack: A vertical drainage line, usually more than three floors in height.

Trap: A device that maintains a water seal, preventing the passage of sewer gas, vermin, air, and odors originating from inside the drainage system, while permitting the unrestricted passage of liquid waste into the drainage system.

Waste line: A drainage pipe conveying liquid waste with no solids.

Major System Components

Cleanouts. Codes mandate that cleanouts generally be provided at the base of stacks before the pipe changes direction from vertical to horizontal, at changes in

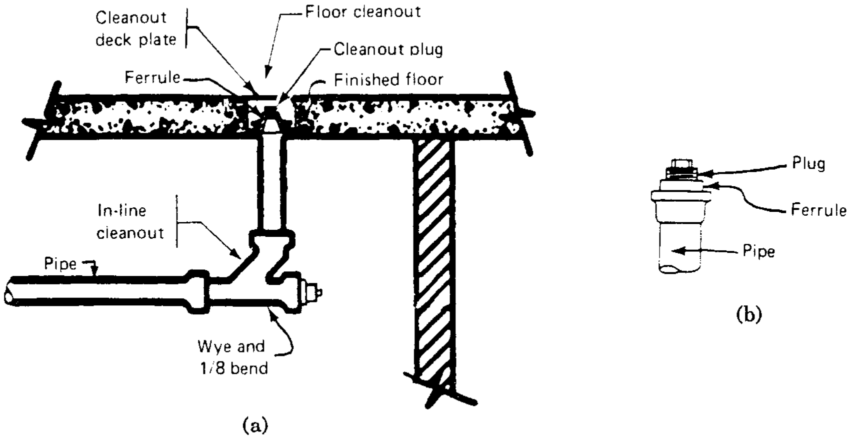


FIGURE C13.14 (*a*) Typical cleanouts. (*b*) Cleanout components.

horizontal pipe direction greater than 45°, and along horizontal runs of pipe every 50 ft (15 m). Typical cleanouts are illustrated in Fig. C13.14*a* and cleanout components in Fig. C13.14*b*.

Floor Drains. A floor drain is a receptacle used to remove liquid effluent from building interior floor areas and other locations. A typical floor drain is illustrated in Fig. C13.15. It provides a receptacle for spills, washdown, and effluent to be collected and routed directly into the sanitary drainage piping system. Code provisions do not specify where a drain should be located. However, most codes regulate the minimum seal requirements for drain traps, the minimum open area of grates and strainers, and the mandatory inclusion of certain individual components (such as removable secondary strainers or sediment buckets) for drains in some locations. A standard commonly cited in the selection of floor drains is ANSI A112.21-1, Floor Drains. Drains consist of the following components:

1. Drain body.

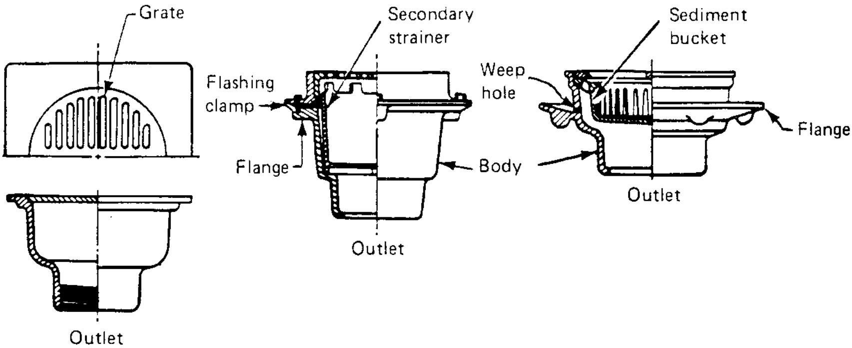


FIGURE C13.15 Typical floor drains.

2. Grates located at the top of a drain permit liquid effluent to enter the drain body while excluding larger solids and foreign matter. Grates are classified as follows:
   a. Light duty: foot traffic only
   b. Medium duty: live wheel loads up to 2000 lb (907.2 kg)
   c. Heavy duty: live wheel loads up to 5000 lb (2268 kg)
   d. Extra-heavy duty: live wheel loads 5000 lb (2268 kg) or more
3. A secondary strainer may be installed below the grate in a drain that does not have a sediment trap.
4. A sediment trap (or bucket) is a removable device inside the drain body that may be installed to trap and retain small solids that pass through the grate.
5. A flashing ring or clamp is a device used to secure flashing directly to the body of the drain.

Interceptors. Plumbing codes require that any substance harmful to the building drainage system, the public sewer, or the municipal sewage treatment process be prevented from being discharged into the public sewer system. Among such materials are grease, flammable liquids, sand, or other substances objectionable to the local authorities.

Traps. A fixture trap, illustrated in Fig. C13.16, is a U-shaped section of pipe of the necessary depth to retain sufficient liquid required by code. All fixtures and equipment directly connected to the sanitary drainage system are required to have traps.

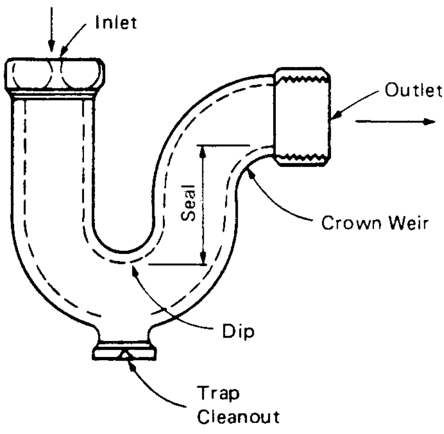


FIGURE C13.16 Typical fixture trap.

In general, traps must (1) be self-cleaning, (2) provide a liquid seal of at least 2 in with larger seals where required, (3) conform to local code requirements in terms of minimum size, (4) provide an accessible cleanout, and (5) be capable of rapidly draining a fixture. All traps must be vented in an approved manner, except for specific conditions waived by local code requirements or authorities.

Traps that are prohibited by code include traps requiring moving parts to maintain the seal; full S-type traps, illustrated in Fig. C13.17; crown vented traps, illustrated in Fig. C13.18; and drum traps, illustrated in Fig. C13.19. Drum traps may be permitted by some codes for use on special-use sinks, such as in laboratories.

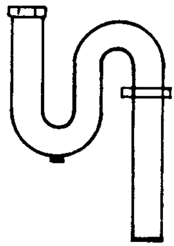


FIGURE C13.17 S trap.

The branch drainage line extending from the trap to the vent is called the *trap arm* and is illustrated in Fig. C13.20. The maximum length of the trap arm is shown in Table C13.2.

Sanitary System Design

The design of the gravity drainage piping system is strictly regulated by the applicable plumbing code. All codes include charts, similar to those presented here, that permit the design engineer to properly size all horizontal and vertical pipes based on the accumulated drainage fixture unit discharge and slope of the pipe.

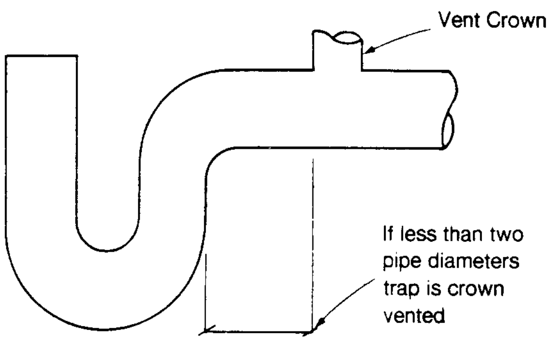


FIGURE C13.18 Crown vented trap.

The pitch of the drainage system must provide sufficient velocity to produce a "scouring action" that will convey all solids along with the liquid stream. The recommended minimum velocity for ordinary sewage is 2 ft/s (0.6 m/s) to prevent the settlement of solids out of the effluent stream. When grease is in suspension, the velocity should be at least 4 ft/s (1.2 m/s).

Accepted practice for low-rise buildings with relatively uniform discharge is to size horizontal drainage lines to flow half full under average design conditions. High-rise buildings produce higher velocities and turbulence in building drains that can fill portions of the piping system as much as three-quarters full, with completely full pipes expected for short distances at stack runouts. This is acceptable, providing that pipe size ultimately allowed for half-full pipes.

The following is a simplified method of sizing the drainage piping system:

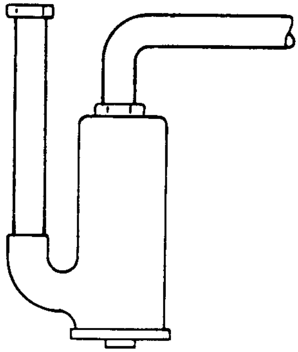


FIGURE C13.19 Drum trap.

1. Establish the location, size, and invert of the point of ultimate disposal of sanitary effluent. Determine whether sump or ejector systems will be required and locate them.
2. Locate and lay out drainage branch lines, stacks, and the house sewer.
3. Start with the individual device or fixture at the farthest and most remote point of the system or branch, for which the code specifies two drainage values. The first is the drainage fixture unit (DFU) value that will be used to size the drainage piping system. The second is a minimum size of the trap, which is the minimum individual branch pipe size. For the minimum trap size, refer to Table C13.1 for typical values. If a fixture or device is not listed, either use the unlisted value based on the size of the discharge or ask the local code official for the accepted value.

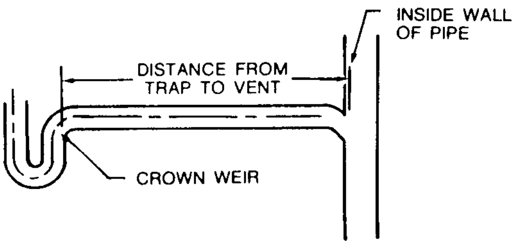


FIGURE C13.20 Trap arm.

4. When more than one fixture or waste line discharges into a horizontal branch pipe, the size of the horizontal drainage line is determined by both the pitch of the drainage line and the accumulated total number of DFUs discharging into it. Refer to Table C13.3 for sizes of branch lines and for the size of building drains and sewers.

TABLE C13.2 Maximum Length of Trap Arm*

Diameter of trap arm, in	Distance from trap to vent†
1¼	3 ft 6 in
1½	5 ft
2	8 ft
3	10 ft
4	12 ft

For use with Fig. C13.20.
* 1 in = 25.4 mm
† 1 ft = 0.304 m

TABLE C13.3 Maximum Permissible Drainage Fixture Unit Loads for Sanitary Drainage Piping

Pipe size		Any horizontal fixture branch	One stack of 3 stories or less in height	Stacks more than three stories high		Building drain and building drain branches from stacks			
						Slope, in/ft (cm/m)			
NPS	DN			Total for stack	Total at one story	¹⁄₁₆ (0.5)	⅛ (1.0)	¼ (2.1)	½ (4.2)
1½*	40	3	4	8	2	np¶	np	np	np
2*	50	6	10	24	6	np	np	21	26
2½*	65	12	20	42	9	np	np	24	31
3	80	20†	48†	72‡	20†	np	np	42†	50†
4	100	160	240	500	90	np	180	216	250
5	125	360	540	1100	200	np	390	480	575
6	150		960	1900	350	np	700	840	1,000
8	200			3600	600	1,400	1,600	1,920	2,300
10	250			5600	900	2,500	2,900	3,500	4,200
12	300					2,900	4,600	5,600	6,700
15	375					7,000	8,300	10,000	12,000

* No water closets permitted.
† Not more than two water closets permitted.
‡ Not more than six water closets permitted.
¶ Not permitted.

TABLE C13.4 Approximate Discharge Rates and Velocities in Sloping Drains (Flowing Half Full*)
(Discharge rate and velocity†)

Pipe size		1/16 in/ft slope		1/8 in/ft slope		1/4 in/ft slope		1/2 in/ft slope	
NPS	DN	Disch., gpm‡	Vel., fps§	Disch., gpm	Vel., fps	Disch., gpm	Vel., fps	Disch., gpm	Vel., fps
1¼	32							3.40	1.78
1½	40					3.91	1.42	5.53	2.01
2	50					8.42	1.72	11.9	2.43
2½	65			10.8	1.41	15.3	1.99	21.6	2.82
3	80			17.6	1.59	24.8	2.25	35.1	3.19
4	100	26.70	1.36	37.8	1.93	53.4	2.73	75.5	3.86
5	125	48.3	1.58	68.3	2.23	96.6	3.16	137.0	4.47
6	150	78.5	1.78	111.0	2.52	157.0	3.57	222.0	5.04
8	200	170.0	2.17	240.0	3.07	340.0	4.34	480.0	6.13
10	250	308.0	2.52	436.0	3.56	616.0	5.04	872.0	7.12
12	300	500.0	2.83	707.0	4.01	999.0	5.67	1413.0	8.02

* *Half full* means filled to a depth equal to one-half of the inside diameter.
† Computed from the Manning formula for half-full pipe, $n = 0.015$.
For one-quarter full: Multiply discharge by 0.274.
Multiply velocity by 0.701.
For three-quarters full: Multiply discharge by 1.82.
Multiply velocity by 1.13.
For full: Multiply discharge by 2.00.
Multiply velocity by 1.00.
For smoother pipe: Multiply discharge and velocity by 0.015 and divide by n value of smoother pipe.

‡ 1 gpm = 0.075 l/s.
§ 1 fps = 0.305 m/s.

5. To determine the size of a horizontal drainage line based on flow given in gallons per minute rather than DFUs, refer to Table C13.4. Use the appropriate pitch and velocity combinations necessary to select a size. When there is a combination flow of both DFUs and gallons per minute into a horizontal line or stack, generally accepted practice is to assign two DFUs for each 1 gpm (0.075 l/s) to allow sizing based on DFUs.

6. The size of a stack is governed by the total DFU discharge into it and its height. Refer to Table C13.3, using the applicable column and the total DFUs for the stack to find the stack size.

7. To size a stack based solely on gallons per minute, refer to Table C13.5. Two generally accepted recommendations regarding the maximum cross-sectional area which may be occupied with water flowing down a stack are ¼ and 7/24, depending on the code used and the requirements of the local authority having jurisdiction. Separate columns are provided for each of these two values. Accepted practice is to use the ¼-full criterion, which closely approximates the allowable flow from a horizontal pipe flowing full at quarter-in (6.3 mm) pitch.

8. If a stack should offset more than 45° from the vertical, the horizontal offset portion of the stack must be sized as a house drain. If the offset size is larger than that portion of the stack higher than the offset, the larger size must be carried down from the offset to the lowest level. The portion of the stack above the offset may remain unchanged.

TABLE C13.5 Drainage Stack Capacity, gpm*

Size			
NPS	DN	¼ full	7⁄24 full
1¼	32	5	6.5
1½	40	8.1	10.5
2	50	17.5	22.6
2½	65	31.8	41
3	80	52.1	67.2
4	100	111	143
5	125	202	261
6	150	336	423
8	200	709	915

* For SI units 1 gpm = 0.075 l/s.

9. The purpose in differentiating between branch intervals and the actual number of horizontal soil or waste branch lines entering the stack is to prevent overloading the stack in a short distance. Many codes limit the number of DFUs allowed in a branch interval.

Flow conditions in the offset portion of a stack create severe turbulence. Because of the resulting pneumatic effects, all branch connections that normally would be

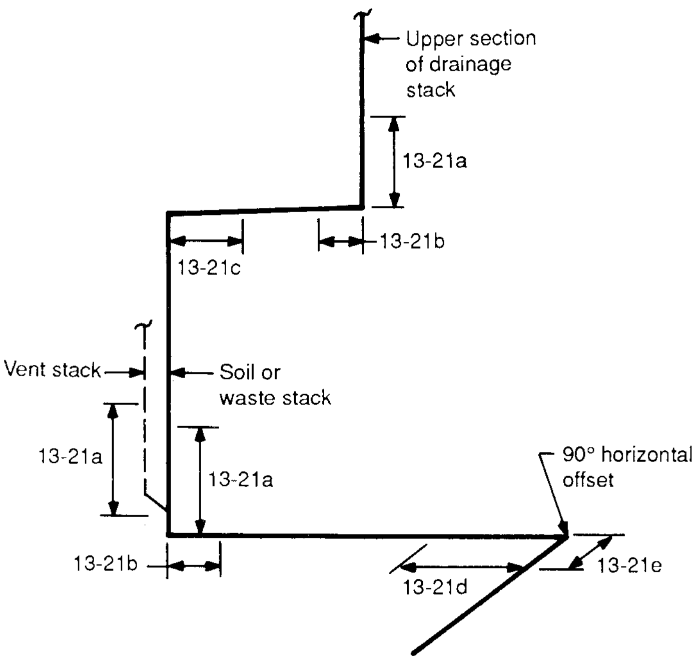


FIGURE C13.21 Suds pressure areas.

made at the level of the offset should be carried down 10 pipe diameters of the stack below the level of the offset.

Suds Pressure Areas. Appliances and fixtures normally using detergents, such as kitchen sinks, bathtubs, showers, dishwashers, and clothes washers, could discharge a large quantity of detergents into the drainage system. During flow through the drainage piping, turbulence causes large amounts of suds to be generated. The suds accumulate in the lower portions of the drainage system and can remain there for a considerable time. When additional liquids flow into these sections of the system, the suds are displaced and will follow the path of least resistance. Enough suds pressure can build up to force the suds through a fixture trap. Suds pressure areas exist in the following parts of the drainage system, as illustrated in Fig. C13.21:

1. For an upper-level stack offset serving fixtures on two or more floors above the offset, there are two suds areas. The first area, C13.21*a*, extends 40 pipe diameters of the stack upward from the base of the offset. The second, C13.21*b,* extends 10 pipe diameters horizontally downstream from the point of change in direction.
2. For an upper-level stack offset turning from horizontal back to vertical, there is one area, C13.21*c,* extending 40 pipe diameters of the stack upstream from the fitting changing direction from horizontal to vertical.
3. In the horizontal runout from a stack when the pipe changes direction horizontally with a fitting greater than 45°, there are two areas. The first, C13.21*d,* extends 40 pipe diameters of the horizontal pipe upstream from the change in direction. The second, C13.21*e,* is 10 pipe diameters downstream.

TABLE C13.6 Suds Pressure Area—Distance Determination
For use with Fig. C13.21.

Nominal pipe size	DN	40 diameters*	10 diameters*
1½	40	5 ft 0 in	1 ft 6 in
2	50	7 ft 0 in	1 ft 6 in
2½	65	8 ft 0 in	2 ft 0 in
3	80	10 ft 0 in	2 ft 6 in
4	100	13 ft 0 in	3 ft 6 in
5	125	17 ft 0 in	4 ft 0 in
6	150	20 ft 0 in	5 ft 0 in

* 1 ft = 0.304 m

When suds pressure areas are anticipated, no pipe shall connect to any of the areas indicated as C13.21*a* to C13.21*e*. Refer to Table C13.6 for actual distances based on pipe size.

SANITARY VENT SYSTEM PIPING

System Description

The sanitary vent system is a network of pipes directly connected to the sanitary drainage piping system for the purpose of limiting air pressure fluctuations within the sanitary drainage piping to ±1 in (±2.54 cm) of water column.

There are two primary reasons why the vent system is an integral and necessary adjunct to any drainage piping network:

1. It prevents the loss of fixture trap seals.
2. It permits the smooth flow of water in the drainage system.

Other lesser problems will be prevented if air pressure in the drainage system is excessive, such as

1. Unsightly movement of water levels in water closet bowls
2. The possibility of sewer gases discharging through a fixture trap
3. Noise in the drainage system due to the gurgling of water

System Components

The components of the vent system consist of pipes directly connected to the drainage piping network. The piping materials are the same as those of the sanitary drainage system, except that the fittings may be of the short-turn type in lieu of the required long-turn fittings of the drainage system. Some codes permit the use of air admittance fittings which do not require termination of vents through the roof.

Code Considerations

Most problems occurring in the drainage system not resulting from blockages are caused by fluctuations in air pressure. These problems can be either eliminated or reduced to a level where they are no longer objectionable, by designing a vent system that limits these variations in the drainage piping network to a generally accepted figure of ±1 in (±2.5 cm) of water column. This basic design criterion has been used to determine vent sizing and allowable lengths that appear in modern codes.

Nomenclature

The following definitions are presented to prevent any differences in terminology between this handbook and any local, regional, and national codes.

Branch vent: A branch vent is a vent that connects one or more individual or common vents to a vent stack or a stack vent.

Circuit vent: A circuit vent is a branch vent that serves two or more traps and extends from a connection to a drainage line, in front of the last fixture connection, to a vent stack.

Common vent: A single vent line serving two fixtures.

Continuous vent: A vertical vent that is a continuation of the waste line from a fixture to which it is connected.

Developed length: The total length of a vent pipe, measured along the centerline of that pipe, from point to point.

Fixture battery: Any group of two or more fixtures that discharge into a common horizontal waste or soil branch.

Individual vent: A vent that connects directly to only one fixture and extends to either a branch vent or a vent stack.

Loop vent: A branch vent that serves two or more traps and extends from a point in front of the last fixture connection to a stack vent.

Main vent: The principal vent of a building, remaining undiminished in size from the connection with the drainage system to its terminal.

Relief vent: An auxiliary vent that connects the vent stack to the soil or waste stack in multistory buildings; used to equalize pressure between them. This connection will occur at offsets and at set vertical intervals determined by code.

Revent: Another name for an individual vent.

Stack vent: The extension of a soil or waste stack above the highest horizontal drainage connection to that stack. It is also the name of a method of venting using the stack as a branch vent connection.

Suds venting: A method of venting in which there is a suds pressure zone.

Trap arm: That portion of the drainpipe between the trap and the vent.

Vent extension: The height of the vent above the roof at its terminal.

Vent header: A single pipe at the highest level of a building connecting the top of vent stacks in order to penetrate the roof only once.

Vent terminal: The open-air location where the end of the vent stack is placed, generally above the roof.

Vent stack: A vertical pipe extending one or more stories and terminating in the outside air.

Wet vent: A vent line that may also serve as a drainpipe.

System Design

General Vent System Design Considerations. Differences in pressure within drainage piping are caused by the flow of water. When water is flowing under design conditions in a horizontal drain (approximately one-half full), the air above the liquid will be forced into movement by the friction between the flowing water and the air. In a stack, the water flows around the perimeter of the pipe, leaving a central core of air (except when overloaded).

The following principles govern the design of the vent system:

1. When design flow is exceeded, the pipes are completely filled with water. This compresses the air ahead of, and creates a vacuum behind, the solid front of water.
2. The air moving in a vent pipe has friction losses similar to those of flowing water. This is why the longer the pipe, the larger the size.
3. The amount of air displaced is proportional to the amount of water flowing in the drainage pipe. The flow is determined by using drainage fixture units (DFUs).
4. The size of a vent stack should be a minimum of one-half the size of a drainage stack. The size of a branch vent should be a minimum of one-half the size of the branch drainage line it serves.
5. In a plumbing code, where the heading for soil or waste size refers to *stack size,* it should also be used for horizontal branch soil and waste stacks. Since the venting requirements for a stack are more severe than those for a horizontal drainage line, there is a small safety factor.

6. All fixture vents must rise above the flood level of the fixture served so as not to act as a waste line in the event the drain line becomes blocked.

Developed Length Measurement. The developed length of an individual or common vent is measured from its point of connection with the fixture trap arm to where it connects with the branch vent or vent stack. The developed length of a branch vent is taken from the farthest connection with a waste branch from the point being sized. The developed length of a vent stack is taken from its connection with the soil or waste stack to its terminal above the roof.

Sizing of Vent Stacks, Vent Branches, and Fixture Vents. Plumbing codes contain the information necessary to size a vent system. A typical vent sizing chart is presented in Table C13.7.

To use Table C13.7, there are three items that must be known: (1) the total DFU count of the soil or waste line associated with the vent being sized, (2) the developed length of the vent being sized, and (3) the size of the soil or waste branch or stack.

TABLE C13.7 Size and Length of Vents

DN	Size of soil or waste stack, NPT*	Drainage fixture units connected	Maximum length of vent, ft† size of vent, required, NPS								
			1¼	1½	2	2½	3	4	5	6	8
40	1½	8	50	150							
50	2	12	30	75	200						
	2	20	26	50	150						
65	2½	42		30	100	300					
	3	10		30	100	100	600				
80	3	30			60	200	500				
	3	60			50	80	400				
	4	100			35	100	260	1000			
100	4	200			30	90	250	900			
	4	500			20	70	180	700			
	5	200				35	80	350	1000		
125	5	500				30	70	300	900		
	5	1100				20	50	200	700		
	6	350				25	50	200	400	1300	
150	6	620				15	30	125	300	1100	
	6	960					24	100	250	1000	
	6	1900					20	70	200	700	
	8	600						50	150	500	1300
200	8	1400						40	100	400	1200
	8	2200						30	80	350	1100
	8	3600						25	60	250	800
	10	1000							75	125	1000
250	10	2500							50	100	500
	10	3800							30	80	350
	10	5600							25	60	250

* 1 in = 25.4 mm.
† 1 ft = 0.304 m.

Having calculated these items, enter the table with the most severe condition of soil pipe size or DFUs. Then read horizontally across until you come to the figure that meets or exceeds the developed length that you calculated. Read up to find the correct size of the vent. Use the following as a guide to sizing:

1. For vent stacks, use the total DFU load for the drainage stack and the full developed length of the vent to find the size. Vent stacks must be undiminished in size for their entire length.
2. For branch vents, use the longest developed length from the point where the size is being determined to the farthest connection to the waste line.
3. For individual fixture vent size, refer to Table C13.1.
4. For building trap vents and fresh-air inlets, the size should be a minimum of one-half the size of the building drain.

Vent Terminals. The vent pipe passing through the roof must remain open under all circumstances. The two conditions that would cause the exposed pipe to become blocked are frost closure and snow closure. Local codes and authorities will specify or require the minimum extension of the vent pipe to avoid closure by accumulated snow on a roof.

In the absence of specific code requirements, the following can be used as a guide to locating vent extensions. The vent extension shall not be located under, or within 10 ft 0 in (3.0 m) of any window, door, or ventilating opening unless it is 2 ft 0 in (0.6 m) above that opening. If the terminal is through a building wall, it shall be located a minimum of 10 ft 0 in (3.0 m) from the property line, a minimum of 10 ft 0 in (3.0 m) above grade, and not under any overhang.

Experience has shown that an NPS 4 (DN 100) pipe will prevent frost closure.

Relief Vents. Soil or waste stacks with no offsets, in buildings having more than 10 branch intervals, shall be provided with a relief vent at each tenth interval, strarting at the top floor. Offsets in the drainage stacks may also be required to have relief vents.

There are several acceptable configurations allowed by various codes. In general, the lower end of the relief vent shall connect to the soil or waste stack below the horizontal branch serving the floor required to have the relief vent. The upper end of the relief vent shall connect to the vent stack no less than 3 ft (1 m) above that same floor level. The size shall be equal to that of the vent stack to which it is connected or the drainage stack, whichever is smaller.

Circuit and Loop Vents. These venting schemes are intended to provide a more economical means of venting than the individual vent. It is allowed only for venting of floor-mounted fixtures such as water closets, shower stalls, and floor drains and may not be acceptable in all code jurisdictions. Circuit venting is illustrated in Fig. C13.22.

Circuit venting requires a uniformly sized drainage line with at least two, but not exceeding eight, fixtures connected in a battery arrangement. The circuit vent connects to the vent stack from the horizontal drain line from a point between the two most remote fixtures. In addition to the circuit vent, a relief vent is required to be connected to the horizontal drain line at the end of the battery, or every eight fixtures. The sizes of each shall be one-half the size of the horizontal drainage line or the full size of the vent stack, whichever is smaller.

Loop venting is the same as circuit venting except for the connection of the

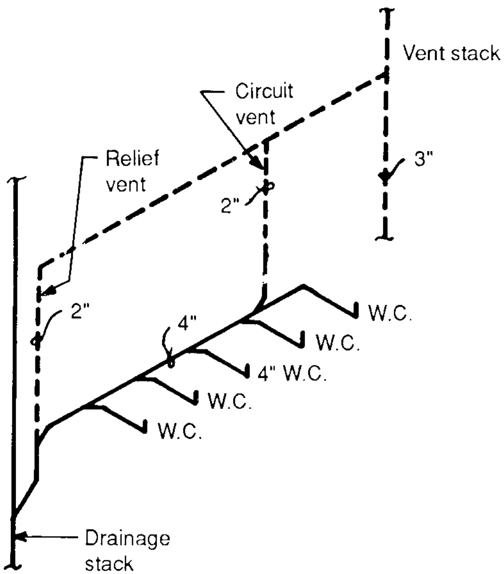


FIGURE C13.22 Detail of circuit vent.

branch vent to the building system. The loop vent "loops" back to the stack vent instead of the vent stack. This is illustrated in Fig. C13.23.

Wet Vents. A wet vent is a combined vent-drain line that receives drainage from fixtures in addition to serving as a vent pipe. Wet vents are primarily used in residential-type projects and are permitted only in a limited number of codes. Wet vents shall conform to the guidelines provided in each respective code.

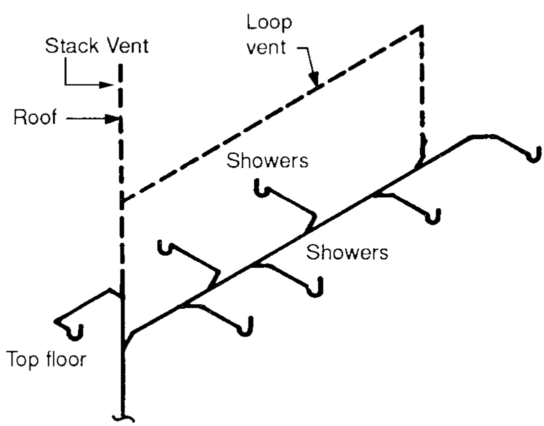


FIGURE C13.23 Detail of loop vent.

Suds Relief Vents. Suds pressure zones are illustrated in Fig. C13.21. If a drainage connection to these zones is made, a relief vent must be installed from the base of the suds pressure zone of the drainage stack to a nonpressure zone. Typical suds pressure relief vent sizes are shown in Table C13.8.

TABLE C13.8 Suds Pressure Relief Vents

Drain stack size		Relief vent size	
NPS	DN	NPS	DN
1½	40	2	50
2	50	2	50
2½	65	2	50
3	80	2	50
4	100	3	80
5	125	4	100
6	150	5	125
8	200	6	150

Sump and Ejector Vents. All codes require the venting of ejector pits, since they are gasketed and airtight. Many codes may also require the venting of sump pits. The vent pipe size is determined from the gpm discharge of the pump and the developed length from the pit to its connection with the building vent system or vent terminal. Table C13.9 shows a typical method of sizing such vents.

TABLE C13.9 Size and Length* of Sump Vents

Discharge capacity of sump pump		Maximum equivalent length of vent, ft size of vent, NPS					
gpm	l/s	1¼	1½	2	2½	3	4
10	3.04	NL†	NL	NL	NL	NL	NL
20	6.08	270	NL	NL	NL	NL	NL
40	12.16	72	160	NL	NL	NL	NL
60	18.24	31	75	270	NL	NL	NL
80	34.32	16	41	150	380	NL	NL
100	30.4	10‡	25	97	250	NL	NL
150	45.6	NP§	10^{3}	44	110	370	NL
200	60.8	NP	NP	20	60	210	NL
250	76.0	NP	NP	10	36	132	NL
300	91.2	NP	NP	10‡	22	88	380
400	121.6	NP	NP	NP	10^{3}	44	210
500	142.0	NP	NP	NP	NP	24	130

* Developed length plus an appropriate allowance for effects of entrance losses and friction due to fittings, changes in direction, and changes in diameter. Suggested allowances may be obtained from NBS Monograph 31 or other acceptable sources. An allowance of 50 percent of the developed length may be assumed if a more precise value is not available.

† No limit; actual values greater than 500 ft (152.5 m). 1 ft = 0.304 m.

‡ Less than 10 ft (3 m).

§ Not permitted.

TABLE C13.10 Nominal Pipe Cross-Sectional Area, Schedule 40 Pipe

NPS	DN	in^2
1½	40	1.767
2	50	3.1416
2½	65	4.908
3	80	7.068
4	100	12.566
5	125	19.635
6	150	28.274

Vent Headers. When several vent stacks are combined into a common header at the highest level to penetrate the roof only once, various codes require that the combined vent pipe be sized using the combined DFUs of all the connected vents and the single longest developed length of all the vent stacks being combined. Other codes require that the combined vent stacks have a minimum cross-sectional area of all the separate vent pipes being combined. Table C13.10 lists the cross-sectional area for Schedule 40 steel pipe in square inches.

INTERIOR STORMWATER DRAINAGE SYSTEM PIPING

Purpose

The purpose of the stormwater drainage system is to collect stormwater runoff from building roofs and ancillary areas exposed to the weather, and to convey the runoff to an approved point of disposal. Ancillary areas of a building include areaways, walkways, canopies, and balconies.

Components

Major components of the stormwater drainage system are drains and the pipe itself. Drain manufacturers make various types of roof and specialty drains as well as accessories used for the installation of drains in all areas of a project. Any pipe material suitable for the sanitary drainage system is also acceptable for use in the stormwater drainage system.

Nomenclature

Areaway: An enclosed excavated area below grade level and open to the weather.

Canopy: A small roof protecting a window or entrance.

Conductor: Stormwater piping inside a building.

Design point: The specific point in the piping network where pipe size is calculated.

Downspout: A vertical pipe attached to gutters installed on the outside of a building.

Drain: A receptacle for the collection and removal of stormwater from surfaces exposed to the weather into the stormwater drainage piping network.

Duration: A commonly used term for time of concentration.

Flow rate: The measurement of a volume of water over time, such as cubic feet per second.

Frequency: The estimated number of years that elapse between the recurrence of storms with a specific intensity.

Gutter: An open horizontal channel used to collect stormwater, usually made of sheet metal or wood, attached to the lowest point of a pitched roof.

Imperviousness factor: A number indicating the percent of rainfall available as runoff and not absorbed into the ground, absorbed by plants, left as puddles, or lost to evaporation during the rainstorm, expressed as a decimal.

Inlet time: A frequently used term for overland flow time.

Intensity: The rate at which rain falls for design purposes, measured in inches per hour.

Leader: A vertical pipe carrying stormwater either inside or outside the building.

Overflow: A positive and fail-safe outlet for removal of stormwater that has reached a predetermined height above the roof level.

Overland flow time: The time rainwater takes to travel on the ground from the farthest point of an outside area to a drain, measured in minutes.

Piping network: The entire stormwater drainage system, including all drains and pipe, to the point of disposal.

Rate of rainfall: A commonly used term for intensity.

Return period: A commonly used term for frequency.

Runoff: The actual flow rate of stormwater discharging into the piping network.

Scupper: A penetration through a parapet above the roof level serving as an overflow.

Sidewall area: Vertical surfaces that contribute runoff to the stormwater system.

Stormwater: Liquid effluent resulting from any form of precipitation, such as rain, snow, hail, or sleet.

Time of concentration: The length of time a rainstorm will persist for design purposes, usually calculated by adding the overland flow time to the time in pipe.

Time in pipe: The length of time stormwater will take to reach one design point from another design point while inside the piping network.

Tributary area: The entire area contributing runoff into any portion of the piping network.

General System Criteria

General Information. The design of the stormwater drainage system requires that the following information be obtained to establish design criteria:

1. Local climatic conditions
2. Local building and plumbing code restrictions
3. Building use
4. Building construction and pitch of roof
5. Location, size, depth, type, and availability of the ultimate point of disposal
6. Total size of roof and ancillary tributary areas
7. Method of connecting to public sewers
8. Allowable methods of disposal and permits required if public sewers are not available
9. Client standards and preferences

Design Storm. The stormwater system is designed to remove the maximum expected runoff in a given period. The ability to calculate the flow rate is complicated by not being able to accurately predict many of the factors affecting the actual amount of runoff resulting from any given storm. To calculate the estimated maximum runoff, an artificial ''design storm'' must be created. This storm will serve as a simulation capable of predicting runoff volume accurately enough to provide a basis for the design of the piping network.

The design storm is based on actual rainfall records and is plotted in convenient form by the National Oceanic and Atmospheric Administration/National Weather Service (NOAA).

Special consideration should be given to the degree of protection provided for the building and its contents by the stormwater drainage system. This depends on the importance of the facility or the space below the roof, the importance of uninterrupted service, and the value of the equipment or material installed or stored. Since a severe thunderstorm or hurricane may produce rainfall rates larger than those that the code has been based on, the property value may require the design engineer to select a rainfall rate greater than the minimum provided for by the code.

Roof Overflows. A fail-safe method must be provided to immediately remove excess runoff from a roof before the water level rises to a point where damage could result. The most commonly used method employs scuppers that will allow the excess runoff to be discharged directly off the roof and down the side of the building. Codes often stipulate the height that scuppers shall be installed above the roof level and the size of the opening. One disadvantage of scuppers is that wave action may allow water to spill out of the scuppers before the design depth is reached.

Various codes mandate the use of a separate overflow piping network in addition to the regular stormwater drainage system. This network could connect either to the regular system independently outside a building or directly to the point of disposal. Another type of overflow protection is the use of separate overflow pipes or drains, in addition to the regular drains, connecting to the regular stormwater drainage piping. Applicable codes and local authorities will provide the information required for design.

Sidewall Area Calculation. Precipitation falling on vertical walls located on roofs and other areas, such as penthouse walls and stair towers, will add to the total runoff calculated for the horizontal area. Therefore, it is necessary for these vertical areas to be added to the horizontal tributary area. To calculate the amount of sidewall area to add to the horizontal roof segment, determine the square foot area of the single or two largest adjacent walls that would contribute runoff to any one roof drain. Divide this area in half, because less rain falls on vertical surfaces than on horizontal surfaces. Add the calculated vertical sidewall area to the horizontal tributary area for each roof drain to obtain the total tributary area.

Roof Drainage Systems. There are two types of systems used to remove stormwater runoff: conventional and limited discharge. The conventional system removes runoff as quickly as it accumulates. The limited-discharge system removes only a portion of the runoff, storing the remainder temporarily on the roof. Selection of the appropriate method depends on the capacity and/or availability of disposal facilities and acceptance of the proposed method by local code and authorities.

Roof Drainage Design Procedures

Conventional Roof Drainage Procedure. Design of the conventional roof drainage system consists of the following general steps:

1. Locate drains on roofs and ancillary areas throughout all areas of the project discharging into the system.
2. Determine the code overflow requirements.
3. Route the stormwater piping and overflow systems.
4. Select the rainfall intensity. This figure is generally provided in the code.
5. Size the piping network by first calculating the total tributary area for each individual drain located in each specific section of the roof and other areas. For horizontal pipe, the sizing procedure starts at the remotest part of the system. Determine the pipe pitch and total tributary area for each horizontal pipe section from design point to design point.
6. Use the appropriate charts to size the roof drains and the piping network. Enter the charts provided in the applicable code with the intensity, pitch, and total tributary area. Select the figure at the intersection of the criteria used for that specific chart, and choose a pipe size corresponding to a figure equal to or greater than the calculated tributary area. Notes associated with different chart types allow conversion to another rainfall rate if different from that of the chart. For vertical piping, use the tributary area discharging into the vertical leader, increasing the size as areas are added. Table C13.11 is a typical table used to size both roof drains and the vertical leaders. Table C13.12 enables sizing of horizontal pipes depending upon pitch and tributary area. Table C13.13 allows the sizing of gutters. These tables are from the National Standard Plumbing Code which uses 4 in/h (100 mm/h) as the basis for the tables. Local rates shall always take precedence over a regional value.
7. When a very large building, such as a warehouse or factory, has a total tributary area in excess of that appearing in the code, other methods must be used to

TABLE C13.11 Size of Vertical Conductors and Leaders*

Diameter of leader or conductor,† in	Maximum projected roof area	
	ft^2	gpm
2	544	23
2½	987	41
3	1,610	67
4	3,460	144
5	6,280	261
6	10,200	424
8	22,000	913

* Based upon a maximum rate of rainfall of 4 in/h (100 mm/h) and on the hydraulic capacities of vertical circular pipes flowing between one-third and one-half full at terminal velocity, computed by the method of NBS Monograph 31. Where maximum rates are more or less than 4 in/h (100 mm/h), the figures for drainage area shall be adjusted by multiplying by 4 and dividing by the local rate in inches per hour.

† The area of rectangular leaders shall be equivalent to that of the circular leader or conductor required. The ratio of width to depth of rectangular leaders shall not exceed 3 to 1.

calculate the volume of runoff and size of pipe. The most commonly used method for the calculation of runoff is the rational formula

$$Q = AIR \tag{C13.1}$$

where Q = quantity (flow rate) of stormwater runoff, ft^3/s (cfs) (1 ft^3/s = 448 gpm)
A = tributary area, acres (1 acre = 43,560 ft^2)
I = imperviousness factor: use a value of 1.0
R = rate (intensity) of rainfall, in/h (select the rainfall rate based on information contained in the previous discussion)

The design procedure is the same as that described for a conventional drainage system, except that Eq. (C13.1) is used to calculate the flow rate in horizontal system piping. Determine the slope of the pipe, and use Table C13.12 to find the pipe size up to the largest areas in the chart. When a larger area is reached, use Table C13.14, entering the chart with the gpm value and the pitch. Table C13.15 provides a direct conversion in both gallons per hour (gph) and gpm per square foot of tributary area for various rainfall rates. For rates not shown, add any lesser rate together to find the new rate.

In some areas of the country, the public sewer is a combined sanitary and stormwater system. This requires the sanitary and stormwater systems to be combined either inside or outside the building wall. The combined system is usually sized on the basis of DFUs. To size the combined system, the number of square feet of tributary area of the stormwater system is converted to DFUs, to calculate the size of the combined building drainage network. Table C13.16 can be used as a guide for the conversion of square feet to DFUs.

TABLE C13.12 Size of Horizontal Storm Drains*

Diameter of drain, in	Maximum projected area for drains of various slopes					
	⅛-in slope		¼-in slope		½-in slope	
	ft^2	gpm	ft^2	gpm	ft^2	gpm
3	822	34	1,160	48	1,644	68
4	1,880	78	2,650	110	3,760	156
5	3,340	139	4,720	196	6,680	278
6	5,350	222	7,550	314	10,700	445
8	11,500	478	16,300	677	23,000	956
10	20,700	860	29,200	1,214	41,400	1,721
12	33,300	1,384	47,000	1,953	66,600	2,768
15	59,500	2,473	84,000	3,491	119,000	4,946

* Based upon a maximum rate of rainfall of 4 in/h (100 mm/h). Where maximum rates are more or less than 4 in/h (100 mm/h), the figures for drainage area shall be adjusted by multiplying by 4 and dividing by the local rate in inches per hour.

1 ft^2 = 0.093 m^2

1 gpm = 0.075 l/s

Limited-Discharge Roof Drainage Systems

There are two reasons to select a limited-discharge roof drainage system: voluntarily for economic reasons or by necessity. The voluntary use of the limited-discharge system will allow smaller piping throughout the entire network, resulting in savings on the total installed cost of the piping. Job conditions may mandate the use of a

TABLE C13.13 Size of Roof Gutters*

Gutter diameter		Maximum projected roof area for gutters†			
		1⁄16-in slope‡			
in	DN	ft^2	m^2	gpm	l/s
3	80	170	16	7	0.5
4	100	360	33	15	1.1
5	125	625	58	26	1.9
6	150	960	91	40	3.0
7	175	1380	128	57	4.3
8	200	1990	185	83	6.2
10	250	3600	335	150	11.3

* Based upon a maximum rate of rainfall of 4 in/h (100 mm/h). Where maximum rates are more or less than 4 in/h (100 mm/h), the figures for drainage area shall be adjusted by multiplying by 4 and dividing by the local rate in inches per hour.

† Gutters other than semicircular may be used provided they have an equivalent cross-sectional area.

‡ Capacities given for slope 1⁄16 in/ft shall be used when designing for greater slopes.

TABLE C13.14 Capacity of Vertical and Various Sloped Horizontal Stormwater Conductors and Rainwater Leaders, gpm (l/s)

Pipe size		Roof drains and vertical piping	Horizontal piping slope, in/ft (cm/m)		
NPS	DN		⅛ (1.0)	¼ (2.1)	½ (4.2)
3	80	92 (5.8)	34 (2.1)	48 (3.0)	69 (4.3)
4	100	192 (12)	78 (4.9)	110 (6.9)	57 (9.9)
5	125	360 (23)	139 (8.8)	197 (12)	278 (18)
6	150	563 (35)	223 (14)	315 (20)	446 (28)
8	200	1208 (76)	479 (30)	679 (43)	958 (60)
10	250		863 (54)	1217 (77)	725 (109)
12	300		1388 (87)	1958 (123)	2775 (175)
15	375		2479 (156)	3500 (220)	4958 (312)

limited discharge system. Urban areas may have overloaded sewers, allowing only a small portion of the runoff to be discharged into the public sewer in order to prevent additional overloading.

To limit the discharge, install roof drains with factory-preset grate openings that allow only a predetermined amount of stormwater to enter the drain. The allowable amount to be discharged must be given to the manufacturer in order to have the

TABLE C13.15 Rainfall Conversion Data

Rainfall, in/h	gph per 1 ft^2	gpm per 1 ft^2
3.0	1.870	0.0312
2.9	1.808	0.0302
2.8	1.745	0.0291
2.7	1.683	0.0281
2.6	1.621	0.0270
2.5	1.558	0.0260
2.4	1.496	0.0250
2.3	1.434	0.0239
2.2	1.371	0.0229
2.1	1.309	0.0218
2.0	1.247	0.0208
1.9	1.184	0.0198
1.8	1.122	0.0187
1.7	1.060	0.0177
1.6	0.997	0.0166
1.5	0.935	0.0156
1.4	0.873	0.0146
1.3	0.810	0.0135
1.2	0.748	0.0125
1.1	0.686	0.0114
1.0	0.623	0.0104

1 gph = 0.0012 l/s   1 ft^2 = 0.093 m^2

TABLE C13.16 Fixture Unit Drainage Square-Footage Equivalent

Drainage area, ft^2	Fixture unit equivalent
180	6
260	10
400	20
490	30
1,000	105
2,000	271
3,000	437
4,000	604
5,000	771
7,500	1,188
10,000	1,500
15,000	2,500
20,000	3,500
28,000	5,500
Each additional 3 ft^2	1 fixture unit

1 ft^2 = 0.093 m^2 1 gpm = 19 ft^2

drain openings set correctly at the factory. The runoff not discharged must be temporarily stored on the roof or on site.

A simplified design procedure for the limited-discharge roof drainage system consists of the following general steps:

1. Determine whether the code and local authorities will permit limited-discharge roof drainage for the project.
2. Establish the maximum allowable flow rate, in gallons per minute, permitted to discharge into the ultimate point of disposal from all sources of water for the entire site. If the system is voluntary, some iterations will be necessary after the piping is run to find the optimum pipe size for the amount of stormwater stored on the roof. If discharge is into a sewer, the authorities having jurisdiction will provide the allowable discharge amount. If discharge is into a waterway, the existing site conditions should be calculated. The difference between the existing and proposed discharge volumes is the volume of water that should be stored on the roof. If drains in areas other than the roof are present, it is not generally possible to store water from those areas. The discharge from these drains will have to be separated from the total roof discharge to find the actual discharge allowed from the roof alone.
3. Decide on the length of time that water is to remain on the roof. Generally accepted practice is to allow between 12 and 18 h, starting with as short a time as possible. Lengthen the time as necessary to obtain the calculated rate of discharge.
4. Since the structural engineer must design the roof to support the additional load of stored water, a mutual agreement between the plumbing and structural engineers must be made to determine the depth. If the roof is flat, the generally

accepted depth is 3 in. If the roof is pitched, add 3-in water depth above the high point of the roof. Table C13.17 gives the weight for each inch of water.

TABLE C13.17 Weight of Rainfall

Amount of rain, in	Weight of water, lb/ft^2
6	31.21
5	26.01
4	20.81
3	15.61
2	10.40
1	5.20

1 in = 25.4 mm
1 lb/ft^2 = 4.88 kg/m^2

5. Find the total amount of rainfall, in inches, that will fall on the roof for the time established in step 3. The amount is obtained from Fig. C13.24, which is a 24-h, 10-yr return rainfall. A 10 percent reduction in the 24-h figure approximates an 18-h rainfall.
6. Divide the figure found in step 5 by the time found in step 3 (e.g., 8 in divided by 12 h equals 0.67 in/h). Then determine the gpm discharge, using Table C13.15. Compare this figure with the maximum allowable discharge from the roof found in step 2. Adjust the retention time as required to match the allowable discharge rate.
7. Consideration must be given for a heavy rainfall occurring after the design storm ends, while some water remains on the roof during the drain-down time. This rainfall should be the actual 1-h duration, with the same return period selected for the project. This 1-h rainfall will deposit a number of inches of rain. The actual drainage rate will be the figure selected in step 2. By subtracting the drainage rate figure (in inches per hour) from the 1-h rainfall figure, the actual total allowable rainfall depth is found. This depth must not exceed the depth established in step 4. If it does, additional depth of storage is required, or the client must be willing to accept rainwater spilling out of the emergency overflow once during the return period selected.
8. Locate drains on roof, and find the total number of drains required.
9. Route the stormwater piping and overflow systems.
10. Divide the number of drains into the total roof discharge allowed to find the gpm flowing out of each drain. Using Table C13.14, size the individual drains and branches, using the gpm and pitch of the pipe. Limited-discharge roof drains are set at the factory for the specified maximum flow rate established by the engineer.
11. Size the piping network based on accumulated gpm flow at each design point and the pitch of the pipe.

Conventional Roof Drainage System Considerations

1. It is important that the local codes and authorities be consulted for the method used to connect to the public sewers.

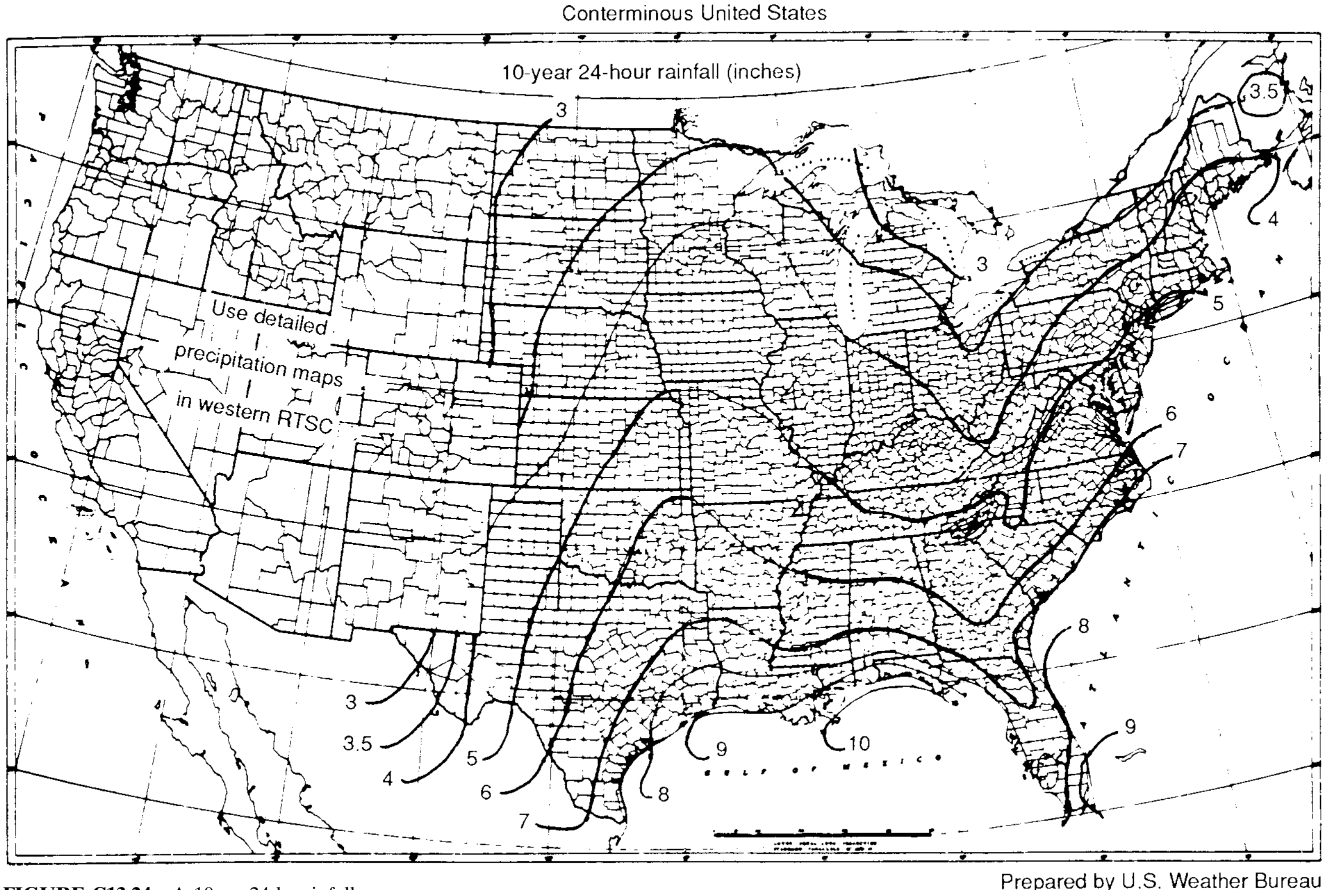


FIGURE C13.24 A 10-yr, 24-h rainfall.

2. It is good practice to place two roof drains in any area (except very small areas) to provide at least one drain to accept flow if the other is blocked by debris.
3. Limit the square footage of any individual roof drain to a maximum of 5000 ft^2 (464.5 m^2) of tributary area.

Limited-Discharge Roof Drainage System Considerations

1. Drains should be no greater than 200 ft (60 m) apart.
2. Drains should be no greater than 50 ft (15 m) from the end of a tributary area.

POTABLE WATER SUPPLY SYSTEMS AND PIPING

Purpose

The purpose of the potable water system is to provide water suitable for human consumption that has adequate purity, pressure, temperature, and volume to satisfy all applications for a specific project or purpose.

Components

The total potable water system consists of cold water, hot water, and hot water temperature maintenance subsystems. Major components of the various subsystems are water meters, treatment facilities, backflow preventers, storage tanks, pumps, pressure-reducing devices, water heating equipment, temperature maintenance wiring, hot water circulating pumps, system valves, and piping.

Nomenclature

Air gap: An unobstructed separation between a source of potable water and any source of contamination.

Backflow: Any reversal of the flow of water from its intended direction.

Back pressure: Backflow caused by an increase of normal pressure.

Back siphonage: Backflow caused by a lowering of normal pressure.

Booster hot water system: A secondary water heating system used to heat water to a higher temperature than that of the primary water heating system.

Cavitation: A phenomenon of flowing water caused by the rapid formation and collapse of air cavities, which results in the pitting of surfaces on which they occur.

City water: A commonly used term for potable water.

Contaminant: Any impurity or toxic substance which, when introduced into a potable water supply, will create a health hazard or threaten the well-being of a consumer.

Cross-connection: Any physical connection between a potable water system and any potential source of contamination not protected by an approved device specifically designed to prevent flow between the two.

Demand: Estimated flow rate expected under normal operating conditions, most often expressed in gallons per minute (gpm).

Direct-fired: A water heater whose primary heat source is an integral part of the water heater assembly.

Domestic water: Potable water primarily intended for direct human use, such as that supplied to plumbing fixtures.

Evacuation-type plumbing fixtures: Plumbing fixtures, such as water closets and urinals, used to receive and discharge waterborne human bodily waste.

Hot water: Water at a temperature higher than ambient, established by generally accepted practice or code as being suitable for a specific application.

Hydraulically remote: Farthest from the source of supply in terms of total pressure lost through the entire water supply piping system.

Impurity: Any physical, chemical, or biological substance found in water making it undesirable for a specific use or degrading the purity of potable water.

Indirect-fired: A water heater whose primary heat source is generated remotely from the water heater.

Ion: Atoms, either singly or in groups, that have an electric charge.

Maximum acceptable pressure: The highest pressure that will not cause a nuisance or produce premature and accelerated damage to any component.

Maximum building demand: The estimated flow of water from the maximum fixture demand plus highest water demand from various equipment throughout a building.

Maximum fixture demand: The greatest estimated flow of water resulting from the probable maximum simultaneous use of intermittently operated plumbing fixtures.

Minimum acceptable pressure: The lowest water pressure permitting safe, efficient, and satisfactory operation of the most hydraulically remote fixture or component.

Normal pressure: The design or expected force per unit area at any point in a water system, usually expressed as pounds per square inch.

Point-of-use heater: Locations immediately adjacent to the fixtures and/or equipment requiring hot water, compared to a remote, centralized location serving an entire building, area, or project.

Pollutant: Any impurity that may create a hazard to the water supply.

Potable water: Water of sufficient purity to meet various standards established as being fit for human consumption.

Pressure zone: A water distribution system within any area of a building having a common source of water supply or pressure origin.

Raw water: Water received directly from the supply source.

Recovery rate: The amount of water capable of being heated to the design temperature per unit of time in a water heater.

Residual water pressure: The pressure of water available in a piping system when water is flowing.

Service hot water: Hot water intended for commercial, industrial, or domestic use within a building.

Static water pressure: The pressure of water in a piping system during the time no water is flowing.

Street pressure system: A pressure zone supplied from a public water main, using only the pressure available in that main.

Toxic substance: A commonly used term for pollutant.

Ultra low flush (ULF): Used to describe water closets requiring low volume of water (1.6 gpm or 0.12 l/s) for discharge into the sanitary drainage system in lieu of the 3.5 gpm (0.26 l/s) which is currently the standard.

Usable storage volume: The gallons of hot water available for use before the introduction of water into the tank faster than it can be heated lowers the water temperature below acceptable limits. A generally accepted value is 70 percent.

Water hammer: A sharp, instantaneous rise in pressure of water in a pipe and the resulting shock wave caused by a sudden stoppage of moving water.

Water Meters

When water is provided by a utility company, meters are required for billing purposes. The utility company will usually require a specific location for the meter, such as inside the building or in a pit adjacent to the property or building; clearance around the meter needed for reading the meter; piping arrangement; and other regulations to discourage any attempt to bypass the meter.

The water meter is usually a part of a water meter assembly that could include shutoff valves, strainers, a test tee for testing the accuracy of the meter by the local authorities, and a meter bypass.

The selection of a meter type, if not mandated by the utility company or local authorities, is based on accuracy and pressure loss through the meter at the intended flow rates. Water meter types include the disk meter, turbine meter, and compound meter.

Contamination Prevention

Impurities found in potable water are divided into three general classifications: severe, moderate, and minor. It is necessary to evaluate each facility as a whole and also at specific points of use to protect against potential hazards. Local health and building codes and ordinances must be consulted for specific requirements, and for the suitability of any device for a specific application.

There are five basic methods of preventing the contamination of a potable water system from cross-connections with, and backflow from, a potentially contaminated source:

1. *Air gap*. Suitable for severe hazards, the air gap is passive and is the only fail-safe method of preventing backflow. The allowable air gap dimension is provided in local codes and is usually 2 in (50 mm).
2. *Pressure-type vacuum breaker.* Suitable for minor hazards, the pressure-type vacuum breaker is a mechanical device designed to prevent backflow caused

only by back-pressure conditions. It is designed to operate under continuous pressure on both sides of the device.

3. *Atmospheric-type vacuum breaker.* Suitable for minor hazards, the atmospheric-type vacuum breaker is a mechanical device designed to prevent backflow caused only by back-siphonage conditions. It is designed to operate with pressure on only one side of the device.

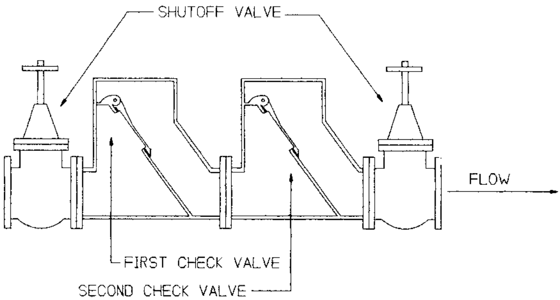


FIGURE C13.25 Double check valve backflow preventer.

4. *Double check valve.* Suitable for moderate hazards, a double check valve, illustrated in Fig. C13.25, is a mechanical device consisting of two independently operating, soft seat, swing check valves. It prevents backflow from back-siphonage and back-pressure conditions.

5. *Reduced-pressure zone.* Suitable for severe hazards, a reduced-pressure zone backflow preventer, illustrated in Fig. C13.26, is a mechanical device consisting of two independently operating, soft seat, spring-loaded check valves with the

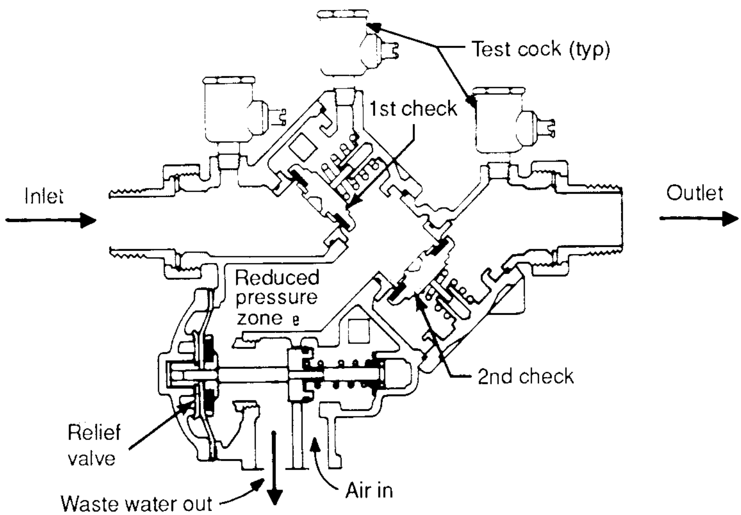


FIGURE C13.26 Reduced pressure zone backflow preventer.

addition of an independent, differential-pressure relief valve installed between the check valves, in the region of the assembly called the *reduced-pressure zone*. The relief valve will open under backflow conditions and discharge all the upstream water under pressure until the condition is corrected. With the potential for large flows, it is accepted practice to direct the discharge outside a facility.

The supplier of public potable water is responsible for protecting the public distribution system from contamination by a nearby contaminated water source, such as a pond or stream that may be used by a fire department to fight a fire at the project location. Depending on local regulations, it may be neccessary to provide backflow protection on the site main before it connects to the public source of water.

Another aspect of contamination protection is the disinfection of the entire interior potable water system. A commonly referenced standard is AWWA C651, Standard for Disinfecting Water Mains.

Water Velocity

The velocity of water flowing through the piping system should be kept low enough to prevent objectionable noise, water hammer, and accelerated component wear due to erosion or nuisance splashing of water from fixtures. To avoid excessive

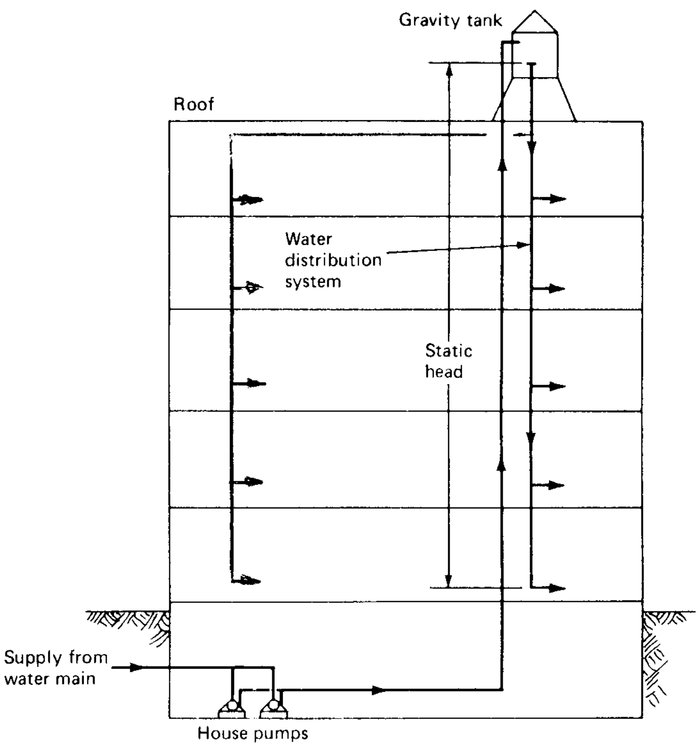


FIGURE C13.27 House tank and downfeed water distribution system.

noise, generally accepted practice for commercial buildings is to limit water velocity to between 6 and 8 fps. For industrial projects, 10 fps is acceptable in work areas where the noise is not noticeable. If the water supply is controlled by a quick-closing valve, the velocity should be limited to approximately 4 fps to avoid water hammer.

Water Distribution Systems

The purpose of a water distribution system is to deliver both hot and cold water, in an acceptable range of pressure and temperature, to fixtures and devices in all parts of a building. All distribution systems can be divided into either upfeed or downfeed systems.

In the downfeed system, illustrated in Fig. C13.27, water is supplied down through vertical pipes to the lowest point in the pressure zone. In an upfeed system, illustrated in Fig. C13.28, the water is supplied upward through vertical pipes to the highest point in the pressure zone.

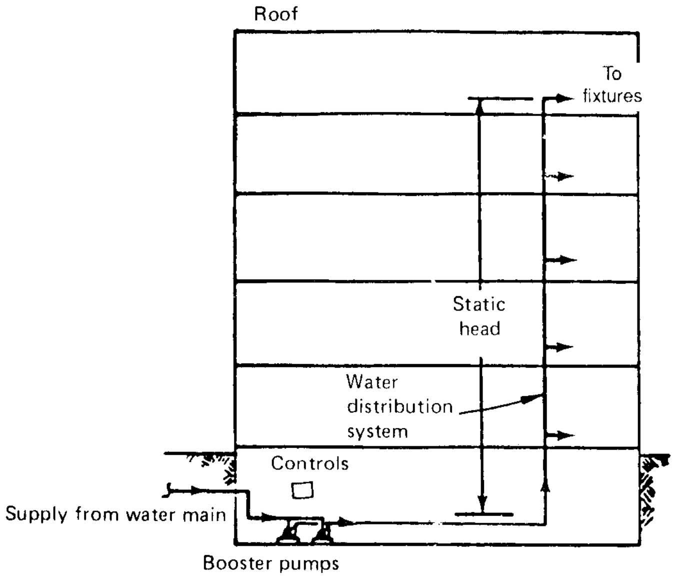


FIGURE C13.28 Booster pump system and upfeed water distribution system.

The decision as to which system to use is based on several factors, such as where enough room exists to run the hot and cold water distribution mains, origin of the source of supply, and economics. A downfeed system generally has smaller pipe sizes and is usually more economical than an upfeed system.

Estimating Water Demand

The calculation of maximum demand is approximate because it is not possible to predict exactly how many fixtures or pieces of equipment may be in use at the same time. This estimate should allow for the probability that the calculated flow will be exceeded occasionally but not permit wasteful oversizing because the estimate will be rarely exceeded.

The method used to calculate the maximum probable demand is based on the water fixture unit (WFU). Refer to Table C13.1 for WFU values for typical fixtures. Table C13.18 permits determination of the estimated flow rate in gallons per minute for accumulated WFUs at any point in the system. Interpolate to find intermediate values.

Table C13.18 is divided into two columns, one for systems containing flush valve-operated water closets in addition to other fixtures, and the other for flush tank water closets and any other fixtures. Use the appropriate column for the specific

TABLE C13.18 Maximum Probable Flow, gpm (l/s)

Water supply fixture units	Tank-type water closets	Flushometer-type water closets	Water supply fixture units	Tank-type water closets	Flushometer-type water closets
1	1 (0.07)		120	25.9 (2.0)	76 (5.7)
2	3 (0.21)		125	26.5 (2.0)	76.5 (5.7)
3	5 (0.38)		130	27.1 (2.1)	77 (5.8)
4	6 (0.45)		135	27.7 (2.1)	78 (5.8)
5	7 (0.53)	27.2 (2.2)	140	28.3 (2.1)	78.5 (5.8)
6	8 (0.60)	29.1 (2.2)	145	29.0 (2.2)	79 (5.9)
7	9 (0.68)	30.8 (2.4)	150	29.6 (2.2)	80 (6.0)
8	10 (0.70)	32.3 (2.5)	160	30.8 (2.3)	81 (6.1)
9	11 (0.83)	33.7 (2.5)	170	32.0 (2.4)	83 (6.2)
10	12.2 (0.92)	35 (2.6)	180	33.3 (2.5)	84 (6.3)
12	12.4 (0.94)	37.3 (2.6)	190	34.5 (2.5)	85 (6.4)
14	12.7 (0.96)	39.3 (2.8)	200	35.7 (2.6)	86 (6.5)
16	12.9 (0.98)	41.2 (3.1)	220	38.1 (2.8)	88 (6.7)
18	13.2 (1)	42.8 (3.2)	240	40.5 (3.0)	90 (6.8)
20	13.4 (1.01)	44.3 (3.3)	260	43.0 (3.2)	92 (7.0)
22	13.7 (1.02)	45.8 (3.5)	280	45.4 (3.4)	94 (7.2)
24	13.9 (1.03)	47.1 (3.6)	300	47.7 (3.6)	96 (7.2)
26	14.2 (1.07)	48.3 (3.7)	400	59.6 (4.5)	102 (7.4)
28	14.4 (1.09)	49.4 (3.8)	500	71.2 (5.3)	108 (8.2)
30	14.7 (1.1)	50.5 (3.9)	600	82.6 (6.3)	113 (8.6)
35	15.3 (1.1)	53.0 (4.0)	700	93.7 (7.1)	117 (8.9)
40	15.9 (1.2)	55.2 (4.1)	800	105 (8.0)	120 (9.1)
45	16.6 (1.3)	57.2 (4.2)	900	115 (8.7)	123 (9.3)
50	17.2 (1.3)	59.1 (4.3)	1,000	126 (9.5)	126 (9.5)
55	17.8 (1.4)	60.8 (4.5)	1,500	175 (13.3)	175 (13.3)
60	18.4 (1.4)	62.3 (4.6)	2,000	220 (16.7)	220 (16.7)
65	19.0 (1.5)	63.8 (4.7)	2,500	259 (19.7)	259 (19.7)
70	19.7 (1.5)	65.2 (4.9)	3,000	294 (22.3)	294 (22.3)
75	20.3 (1.5)	66.4 (5.0)	3,500	325 (24.7)	325 (24.7)
80	20.9 (1.6)	67.7 (5.1)	4,000	352 (26.7)	352 (26.7)
85	21.5 (1.6)	68.8 (5.2)	4,500	375 (28.5)	375 (28.5)
90	22.2 (1.7)	69.9 (5.3)	5,000	395 (30)	395 (30)
95	22.8 (1.7)	71.0 (5.3)	6,000	425 (32.3)	425 (32.3)
100	23.4 (1.8)	72.0 (5.4)	7,000	445 (34)	445 (34)
105	24.0 (1.8)	73.0 (5.5)	8,000	456 (34.6)	456 (34.6)
110	24.6 (1.9)	73.9 (5.6)	9,000	461 (35)	461 (35)
115	25.3 (1.9)	74.8 (5.7)	10,000	462 (35)	462 (35)

branch or system under design, with a value of 75 percent of the WFU value for fixtures using both hot and cold water.

Design of the Water Supply Distribution System

The water supply system must achieve the following basic objectives:

1. Deliver an adequate volume of water to the most hydraulically remote fixture during minimum pressure and maximum flow conditions.
2. Provide adequate water pressure to the most hydraulically remote fixture during minimum pressure and maximum flow conditions.
3. Prevent excessive water velocity during maximum flow conditions.

The process of pipe sizing and component selection is an iterative one, requiring the design engineer to first assume initial values and recalculatc if necessary, using new values if the initial assumptions prove wrong. Use the following simplified method as a guide to sizing. Additional criteria regarding system components are presented later in this chapter.

The basic method of system design is to first establish values that are fixed, such as fixture operating pressure and the difference in static height of that fixture from the pressure source. The pipe size, which is adjustable, is then selected so that the remaining system pressure, in the form of friction loss of the water flowing through the pipe, will be used while not exceeding recommended velocity figures. For a pumped system, the design engineer has the ability to increase the total dynamic head of the pump, to provide additional pressure to the piping network if desired. A simplified design of a street pressure system proceeds as follows:

1. Find the static and residual source water pressures and the elevation at which the pressures are obtained. The residual pressure is the basis of the sizing procedure.
2. Determine by rough calculation whether water pressure booster or reducing systems are necessary. If pressure adjustment is required, select the appropriate system.
3. Locate main runs, and route the water distribution system piping.
4. Calculate pressure losses in the distribution system as follows:
   - ***a.*** Estimate the maximum flow in the building water service. This is done by adding all WFUs and converting them to gpm, using Table C13.18.
   - ***b.*** Calculate the loss of pressure in the building water service from the source into the building. Add (or subtract) the height difference between source and height of main distribution piping inside building, friction loss of the service line, meter, BFP, valves, and all equipment contributing to the loss of pressure. Allow 5 to 10 psi (35 to 70 kPa) for future losses in water supply source pressure, if applicable.
   - ***c.*** Find the height of the most hydraulically remote fixture from the height of main distribution piping.
   - ***d.*** Find the pressure required to operate the most hydraulically remote fixture from Table C13.19.
5. Add the results of steps *b, c,* and *d,* and subtract from the figure obtained from step 1.
6. Calculate the total equivalent run of water piping to the farthest fixture.
7. Divide the pressure calculated in step 3 into the pipe run calculated in step 4 to find the friction loss allowable for the piping system.

TABLE C13.19 Minimum Acceptable Operating Pressures for Various Plumbing Fixtures

Fixture	Pressure, psi
Basin faucet	8
Basin faucet, self-closing	12
Sink faucet, ⅜-in (0.95-cm)	10
Sink faucet, ½-in (1.3-cm)	5
Dishwasher	15–25
Bathtub faucet	5
Laundry tub cock, ¼-in (0.64-cm)	5
Shower	12
Water closet ball cock	15
Water closet flush valve	15–20
Urinal flush valve	15
Garden hose, 50-ft (15-m), and sill cock	30
Water closet, blowout type	25
Urinal, blowout type	25
Water closet, low-silhouette tank type	30–40
Water closet, pressure tank	20–30

1 psi = 6.89 kPa

8. Using appropriate pipe friction loss charts or tables and the estimated water demand, size the piping at each design point.

For a pumped system, steps 1, 3, 4*a,* and 4*b* will determine the suction pressure at the inlet to the pump. Steps 4*c* and 4*d* will establish the fixed-pressure requirements, and the design engineer then selects a pump with enough pressure to allow a reasonable friction loss in the piping system.

Adjusting Water Pressure

If the pressure in the water source is sufficient to adequately supply the most hydraulically remote fixture in a building, a street pressure system is the most economical selection.

When the pressure is not adequate, it must be increased. Systems used are elevated water tank, booster pumps, or hydropneumatic tank systems. Sizing should be based on accepted practices, such as those published by the American Society of Plumbing Engineers (ASPE). If the pressure is excessive, it must be reduced to an acceptable level.

Excessive Water Pressure. Water pressure in a water distribution system is considered excessive if it will damage, or create conditions that will damage, components of the water distribution system or create a nuisance such as by having water splash out of a fixture during use.

There is no precise value of water pressure below which the pressure will never damage a water distribution system, and above which it will always damage the system. A widely accepted value is 70 psi (483 kPa). Often, the maximum permissible water pressure is stipulated by code.

A *pressure-regulating valve (PRV)* is a device used to lower a variable inlet pressure and automatically maintain the outlet pressure of water within predetermined design parameters for both dynamic flow and static conditions. This is done by a closure device that opens and closes an orifice in response to fluctuations in outlet (regulated) pressure. The degree of closure depends upon the ability of a sensing mechanism to detect changes in water pressure at the outlet side of the valve.

Pressure-regulating valves fall into two general categories: direct-operated and pilot-operated.

The direct-operated PRV has the closure member controller in direct contact with water pressure in the outlet (regulated) side of the valve. When the outlet pressure varies, the differing pressure causes the closure member to open or close by an amount necessary to achieve the desired outlet pressure. Direct-operated valves are lowest in initial cost and provide the least accuracy in regulating the outlet pressure. They produce a pressure reduction in proportion to the flow—the larger the flow, the less the pressure in the discharge line.

A pilot-operated valve is a combination of two pressure-regulating valves in a single housing. It consists of a primary valve (or pilot), which is in direct contact with water pressure in the outlet (regulated) side of the valve, and the main valve, which contains the closure member. The pilot valve senses variations in the outlet pressure and magnifies closure member travel to achieve the desired outlet pressure.

The pilot-operated valves are the highest in initial cost but provide the greatest degree of accuracy over a wider range of pressure and flow conditions than a direct-operated PRV.

Selecting a Pressure-Regulating Valve

Various manufacturers offer different types of PRVs. The different valves represent a compromise between price, capacity, accuracy, and speed of response. Such information is provided by the manufacturers for use in valve selection.

The following considerations affect the selection of a pressure-regulating valve:

1. *Minimum flow rate:* The minimum rate of flow (other than zero) expected in the piping section under design.
2. *Maximum flow rate:* The maximum rate of flow expected in the piping section under design.
3. *Nature of flow:* Whether the flow rate is reasonably constant or intermittent.
4. *Location of the pressure-regulating valve:* Is the valve located at the beginning or end of a branch?
5. *Maximum inlet pressure:* The highest pressure expected at the inlet of the pressure-regulating valve.
6. *Outlet pressure:* The pressure that the regulating valve must maintain.
7. *Falloff:* The difference between the design pressure at which the system has been set and the actual outlet pressure found in the piping—a difference usually limited to approximately 15 psi (104 kPa).

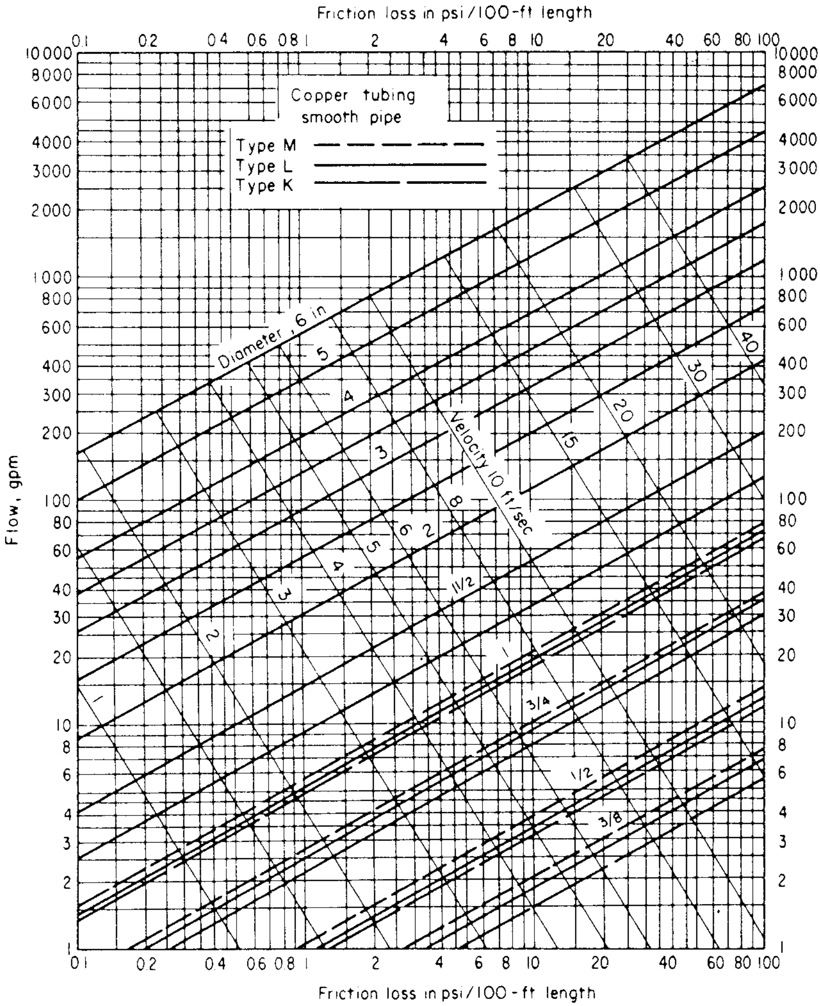


FIGURE C13.29 Friction loss for smooth pipe.

8. *Pressure differential:* The difference in pressure between the inlet and outlet of the pressure-regulating valve. If this difference is excessive, cavitation may result.
9. *Accuracy of pressure regulation:* The degree of accuracy desired to be maintained within the regulated water distribution system.
10. *Speed of response to changes in pressure:* If this response is too rapid, a noise called *chatter* may result. If the response is too slow, an unacceptably wide variation of pressure may occur at the outlet.
11. If flow requirements are beyond the recommended capacity of a single PRV,

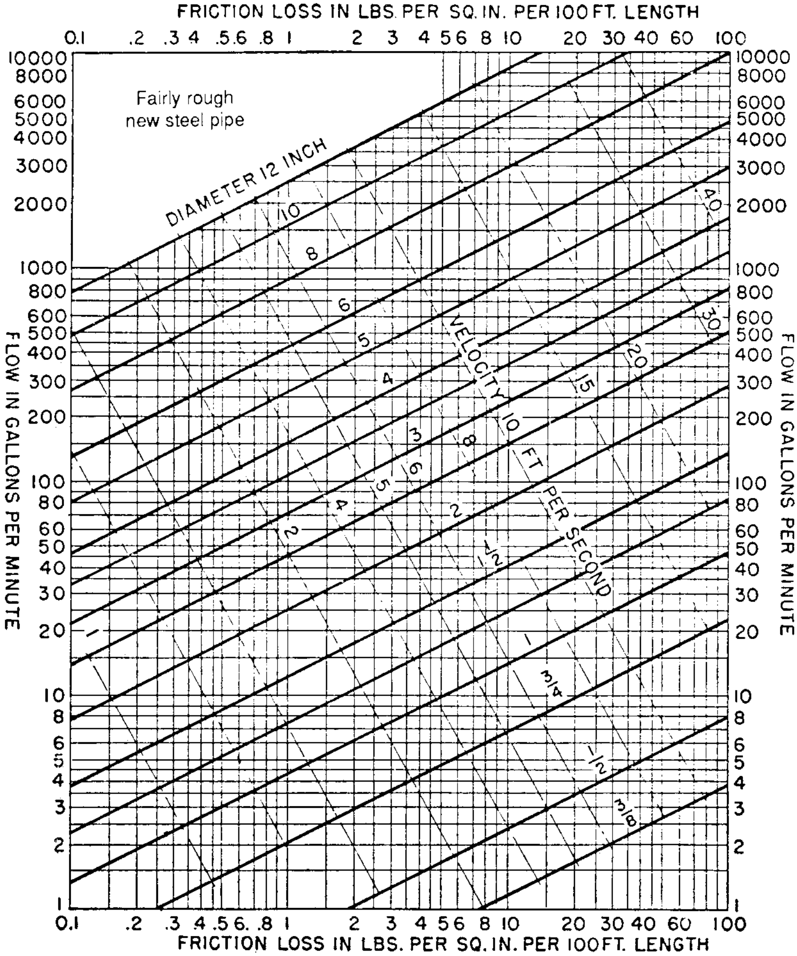


FIGURE C13.30 Friction loss for fairly rough pipe.

multiple PRVs in parallel are commonly used to allow for low and high flows in a single supply branch.

Pipe Size Selection

Pipe sizing is accomplished by using maximum allowable pressure loss, demand, and velocity at the design point. Two methods of determining these values are available. The first uses prepared tables for each pipe size, with the velocity and pressure loss for various flow rates. The second method uses nomographs, where on a single graph, all the information is displayed. The tables are regarded as more accurate, and the nomographs are more convenient. The nomographs in Figs.

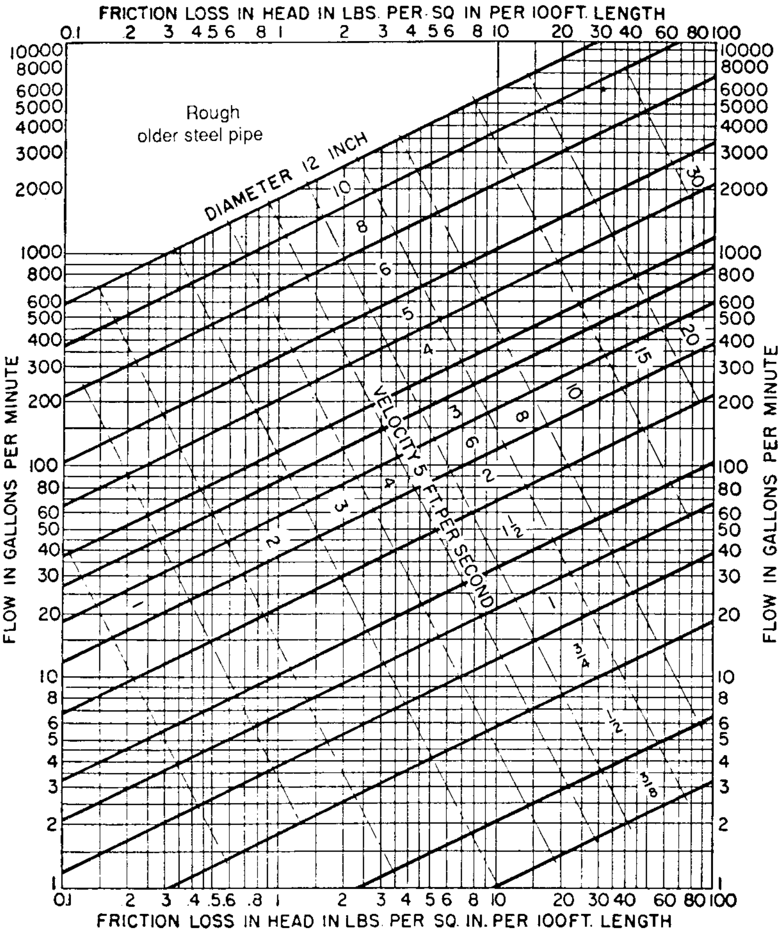


FIGURE C13.31 Friction loss for rough pipe.

C13.29, C13.30, and C13.31 are provided for smooth, fairly rough, and rough pipes. Charts have been made for specific plastic pipe materials, but space limitations prevent reproduction in this handbook. Use Fig. C13.29 for plastic pipe.

SERVICE HOT WATER SYSTEM

Purpose

The purpose of the service hot water system is to heat raw water from ambient temperature to a desired higher temperature and to deliver hot water to terminal points with a delay of less than 20 s. A booster hot water system heats primary service hot water to a higher temperature for a specific purpose.

Water Heating Methods and Equipment

Water heaters are categorized as instantaneous, semi-instantaneous, or storage. They can be either directly or indirectly fired. Fuels most freqently used to heat water are electricity, steam, fuel oil, fuel gas, and solar energy.

Instantaneous-type heaters consist of a unit that heats water as quickly as the demand flow rate requires. They have no storage and a high recovery rate. Advantages include little floor space required, low initial cost, and factory preassembly into a package ready to install. Disadvantages are difficult control of outlet water temperature and high Btu requirements for the heating medium. For instantaneous-type heaters, an accurate approximation for steam can be calculated by multiplying the gpm requirements by 50 lb/h. This type of heater is almost always indirectly fired, using either steam or hot water supplied from a central heating plant, steam utility system, or a boiler.

Semi-instantaneous-type heaters are similar to the instantaneous type except for having a limited water storage capacity, which permits easier control of outlet water temperature. This type of heater can be either directly or indirectly fired and is preferred to the instantaneous type. The far greater majority of installations are of the indirect-fired type.

Storage-type heaters have a large storage capacity and lower recovery rate. This system consists of either a combination storage tank and a direct- or indirect-type immersion heater inside the tank, or separate water heater and storage tank. This system should be considered when high peak surge loads are encountered for short periods and when a limited source of heat energy exists. Disadvantages include large amount of floor space and high initial cost. Advantages include a low instantaneous heat energy demand rate.

Point-of-use heaters are used for isolated and remote locations where it is not economical to run piping from the primary service hot water system.

The choice of a primary fuel for heating water depends on the following considerations:

1. Availability of fuel
2. Cost
3. Availability of heating equipment using the desired fuel
4. Space requirements and cost for equipment vents or flues
5. Client preferences

Acceptable Hot Water Temperature

Generally accepted practice requires a hot water temperature to a maximum of 140°F (60°C) at the heater to eliminate leagonella bacteria. Codes and standards, particularly for hospitals, schools and health care facilities, may further restrict the allowable temperature of the hot water supplied for various uses.

Water Heater Sizing

Hot water use and flow rates are characterized by intermittent periods of peak, sustained, and low to no-flow conditions. The pattern and use requirements vary depending on building type, population, time of day, and commercial process requirements.

When one is designing a project for a client or an agency with a preference for specific heater types and sizing criteria, such as cities and states, the federal government, and the Department of Defense, the design engineer must follow the methods established by the client. When no criteria exist, sizing should be based on accepted practices, such as those published by the ASPE and ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers).

Safety Devices

The heating of water produces pressures in the hot water piping network and equipment higher than those in the cold water system. This pressure may exceed the rating of the various components if not relieved. To accomplish this, three devices are provided. Temperature relief valves discharge water from the system in the event that water temperature is excessive; pressure relief valves discharge water from the system if the design pressure is exceeded; and energy cutoff devices are provided to stop the flow of fuel or heating medium to the heater if the temperature or pressure value is exceeded anywhere in the system. It is common practice to combine the temperature and pressure relief into a single safety device. The hot water discharged must be routed to a safe location. In addition, expansion tanks are installed in the hot water piping to accommodate the increased volume of water.

Hot Water Temperature Maintenance

Generally accepted practice requires that hot water delivered to terminal points of the system reach utilization temperature in 20 s or less. To accomplish this, two methods are used to maintain the water temperature. The first uses a separate water circulation pipe to return the cooler hot water from the end of the system to the heater for reheating, thereby keeping the primary water hot. The second method uses a self-regulating electric heater wire attached directly to the hot water pipe. This heater wire becomes hot only in response to a drop in temperature of the water pipe to a predetermined point.

The electric heater strip has become the preferred method of temperature maintenance because of its lower initial and operating costs compared to those of a recirculated system.

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