



Sanitary Drainage Systems

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The purpose of the sanitary drainage system is to remove effluent discharged from plumbing fixtures and other equipment to an approved point of disposal. A sanitary drainage system generally consists of horizontal branches, vertical stacks, a building drain inside the building, and a building sewer from the building wall to the point of disposal.

To economically design a sanitary drainage system, the designer should use the smallest pipes possible according to the applicable code that can rapidly carry away the soiled water from individual fixtures without clogging the pipes, leaving solids in the piping, generating excessive pneumatic pressures at points where the fixture drains connect to the stack (which might cause the reduction of trap water seals and force sewer gases back through inhabitable areas), and creating undue noise.

Since vents and venting systems are described in Chapter 3 of this volume, the following discussion centers only on the design of drain and waste systems.

CODES AND STANDARDS

Plumbing codes establish a minimum acceptable standard for the design and installation of systems, including sanitary drainage. There are various model codes, but some states and large cities have adopted their own plumbing codes, rather than the ones usually associated with the region. Because of this non-standardization, the actual plumbing code used for each specific project must be obtained from a responsible code official.

A variety of different codes are used to lay out and size interior sanitary drainage systems, and the information pertaining to sanitary design for a specific project appears in the approved local plumbing code, which must be the primary method used for the accepted methods and sizing. The tables and charts appearing in this chapter are used only to illustrate and augment discussions of sizing methods, sizing procedures, and design methods and should not be used for actual design purposes.

FLOW IN STACKS

A stack is the main vertical pipe that carries away discharge from water closets and urinals (soil stack) or other clear water waste from equipment and non-sanitary fixtures (waste stack). Flow in the drain empties into the vertical stack fitting, which may be a long-turn tee-wye or a short-turn or sanitary tee. Each of these fittings permits flow from the drain to enter the stack with a component directed vertically downward. Depending on the rate of flow out of the drain into the stack, the diameter of the stack, the type of stack fitting, and the flow down the stack from higher levels (if any),

the discharge from the fixture drain may or may not fill the cross-section of the stack at the level of entry. In any event, as soon as the water enters the stack, the force of gravity rapidly accelerates it downward, and before it falls very far, it assumes the form of a sheet around the wall of the stack, leaving the center of the pipe open for the flow of air.

This sheet of water continues to accelerate until the frictional force exerted by the wall of the stack on the falling sheet of water equals the force of gravity. From that point on, if the distance the water falls is sufficient enough and provided that no flow enters the stack at lower levels to interfere with the sheet, the sheet remains unchanged in thickness and velocity until it reaches the bottom of the stack. The ultimate vertical velocity the sheet attains is called the “terminal velocity.” The distance the sheet must fall to attain this terminal velocity is called the “terminal length.”

Following are the formulae developed for calculating the terminal velocity and terminal length:

Equation 1-1a (terminal velocity)

$$V_T = 3.0(Q/d)^{2/5}$$

Equation 1-1b (terminal length)

$$L_T = 0.052V_T^2$$

where

V_T = Terminal velocity in the stack, feet per second (fps)
(meters per second)

L_T = Terminal length below the point of flow entry, feet
(meters)

Q = Quantity rate of flow, gallons per minute (gpm) (liters per second)

d = Diameter of stack, inches (millimeters)

Terminal velocity is approximately 10 to 15 fps (3.05 to 4.57 meters per second), and this velocity is attained within 10 to 15 feet (3.05 to 4.57 meters) of fall from the point of entry.

At the center of the stack is a core of air that is dragged along with the water by friction. A supply source of air must be provided to avoid excessive pressures in the stack. The usual means of supplying this air are through the stack vent or vent stack. The entrained air in the stack causes a pressure reduction inside the stack, which is caused by the frictional effect of the falling sheet of water dragging the core of air with it.

If the sheet of water falling down the stack passes a stack fitting through which the discharge from a fixture is entering the stack, the water from the branch mixes with or deflects the rapidly moving sheet of water. An excess pressure in the drain from which the water is entering the stack is required to deflect the sheet of water flowing downward or to mix the

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branch water with it. The result is a back-pressure created in the branch, which increases with the flow rate and flow velocity down the stack and with the flow rate out of the drain.

The importance of this knowledge is that it conclusively abolishes the myth that water falling from a great height will destroy the fittings at the base of a stack. The velocity at the base of a 100-story stack is only slightly and insignificantly greater than the velocity at the base of a three-story stack. The concern is the weight of the stack, which must be supported by clamps at each floor level.

Flow in Building Drains

When the sheet of water reaches the bend at the base of the stack, it turns at approximately right angles into the building drain. Flow enters the horizontal drain at a relatively high velocity compared to the flow velocity in a horizontal drain under uniform flow conditions. The slope of the building drain is not adequate to maintain the velocity that existed in the vertical sheet when it reached the base of the stack and must flow horizontally. The velocity of the water flowing along the building drain and sewer decreases slowly and then increases suddenly as the depth of flow increases and completely fills the cross-section of the drain. This phenomenon is called a “hydraulic jump.”

The critical distance at which the hydraulic jump may occur varies from immediately at the stack fitting to 10 times the diameter of the stack downstream. Less hydraulic jump occurs if the horizontal drain is larger than the stack. After the hydraulic jump occurs and water fills the drain, the pipe tends to flow full until the friction resistance of the pipe retards the flow to that of uniform flow conditions.

Flow in Fixture Drains

Determination of the required drain size is a relatively simple matter, since the fixture drain must be adequate only to carry the discharge from the fixture to which it is attached. Because of the problem of self-siphonage, however, it is advisable to select a diameter large enough that the drain flows little more than half-full under the maximum discharge conditions likely to be imposed by the fixture.

For example, a lavatory drain capable of carrying the flow discharged from a lavatory may still flow full over part or all of its length. This occurs for several reasons. The vertical component of the flow out of the trap into the drain tends to make the water attach to the upper elements of the drain, and a slug of water is formed, filling the drain at that point. If insufficient air is aspirated through the overflow, the pipe will flow full for part of its length, with the average flow velocity being less than the normal velocity for the flow rate in the drain at a given slope.

In the past, with a fixture such as a toilet, the surge of water from the toilet continued almost without change even along a very long drain until it reached the stack. This still is generally true, but the use of low-flow and dual-flush toilets requires the design of the horizontal piping to be reconsidered. It cannot be assumed, for all practical purposes, that the surge caused by the discharge of a toilet through a fixture drain reaches the stack or horizontal branch with practically the same velocity it had when it left the fixture.

PNEUMATIC PRESSURES IN A SANITARY DRAINAGE SYSTEM

Due to the pressure conditions in a stack and a building drain, wastewater does not fill the cross-section anywhere, so the air can flow freely with the water. The water flowing down the wall of the stack drags air with it by friction and carries the air through the building drain to the street sewer. The air is then vented through the main street sewer system so dangerous pressures do not build up. The generally accepted pressure is ± 1 inch of water column.

When air enters the top of the stack to replace the air being carried with the water, the pressure inside the stack decreases. However, because of the head loss necessary to accelerate the air and to provide for the energy loss at the entrance, this pressure reduction is negligible, amounting to only a small fraction of an inch of water. Appreciable pressure reductions are caused by the partial or complete blocking of the stack by water flowing into the stack from a horizontal branch.

A small increase in pneumatic pressure will occur in the building drain even if the airflow is not completely blocked by a hydraulic jump or by submergence of the outlet and the building sewer. This is due to the decrease in cross-sectional area available for airflow when the water flowing in the drain has adapted to the slope and diameter of the drain.

FIXTURE DISCHARGE CHARACTERISTICS

The discharge characteristic curves—flow rates as a function of time—for most toilet bowls have the same general shape, but some show a much lower peak and a longer period of discharge. The discharge characteristics for various types of bowls, particularly for low-flow toilets, have a significant impact on estimating the capacity of a sanitary drainage system. Other plumbing fixtures, such as sinks, lavatories, and bathtubs, may produce similar surging flows in drainage systems, but they do not have the same effect as water closets.

Drainage Loads

Single-family dwellings contain certain plumbing fixtures, such as one or more bathroom groups, each consisting of a toilet, lavatory, and bathtub or shower stall, a kitchen sink, dishwasher, and washing machine. Large buildings also have other fixtures, such as slop sinks and drinking water coolers. The important characteristic of these fixtures is that they are not used continuously. Rather, they are used with irregular frequencies that vary greatly during the day. In addition, the various fixtures have quite different discharge characteristics regarding both the average flow rate per use and the duration of a single discharge. Consequently, the probability of all the fixtures in the building operating simultaneously is small.

Assigning drainage fixture unit (dfu) values to fixtures to represent their load-producing effect on the plumbing system originally was proposed in 1923 by Dr. Roy B. Hunter. The fixture unit values were designed for application in conjunction with the probability of simultaneous use of fixtures to establish the maximum permissible drainage loads expressed in fixture units rather than in gpm of drainage flow. Table 1-1 gives the

Table 1-1 Residential Drainage Fixture Unit (dfu) Loads

Fixture	IPC	UPC
Bath tub	2	3
Clothes washer	3	3
Dishwasher	2	2
Floor drain	3	—
1¼-inch trap loading	—	1
1½-inch trap loading	—	3
2-inch trap loading	—	4
3-inch trap loading	—	6
4-inch trap loading	—	8
Laundry tray	2	2
Lavatory, single	1	1
Lavatory, in sets of two or three	2	2
Shower (each head)	2	2
Kitchen sink (including dishwasher and garbage disposal)	3	3
Toilet (1.6-gpf gravity tank)	4	4
Toilet (1.6-gpf flushometer tank)	5	5
Toilet (1.6-gpf flushometer valve)	4	4

recommended fixture unit values. The plumbing engineer must conform to local code requirements.

Dr. Hunter conceived the idea of assigning a fixture unit value to represent the degree to which a fixture loads a system when used at its maximum assumed flow and frequency. The purpose of the fixture unit concept is to make it possible to calculate the design load of the system directly when the system is a combination of different kinds of fixtures, with each having a unique loading characteristic. Current or recently conducted studies of drainage loads on drainage systems may change these values. These include studies of reduced flow from water-saving fixtures, models of stack, branch, and house drain flows, and actual fixture use.

Stack Capacities

The criterion of flow capacities in drainage stacks is based on the limitation of the water-occupied cross-section to a specified fraction (r_s) of the cross-section of the stack where terminal velocity exists, as suggested by earlier investigations.

Flow capacity can be expressed in terms of the stack diameter and the water cross-section.

Equation 1-2

$$Q = 27.8 \times r_s^{5/3} \times D^{8/3}$$

where

Q = Capacity, gpm (liters per second)

r_s = Ratio of the cross-sectional area of the sheet of water to the cross-sectional area of the stack

D = Diameter of the stack, inches (millimeters)

Values of flow rates based on $r = 1/4, 7/24$, and are tabulated in Table 1-2.

Whether or not Equation 1-2 can be used safely to predict stack capacities remains to be confirmed and accepted. However, it provides a definite law of variation of stack capacity with diameter. If this law can be shown to hold for the lower part of the range of stack diameters, it should be valid for the larger diameters. It should be remembered that both F.M. Dawson and Dr. Hunter, in entirely independent investiga-

Table 1-2 Capacities of Stacks

Pipe Size, in. (mm)	Flow, gpm (L/s)		
	$r = 1/4$	$r = 7/24$	$r = 1/3$
2 (50)	17.5 (1.1)	23.0 (1.45)	28 (1.77)
3 (80)	52 (3.28)	70 (4.41)	85 (5.36)
4 (100)	112 (7.07)	145 (9.14)	180 (11.35)
5 (125)	205 (12.93)	261 (16.5)	324 (20.44)
6 (150)	330 (20.82)	424 (26.8)	530 (33.43)
8 (200)	710 (44.8)	913 (57.6)	1,140 (72)
10 (250)	1,300 (82.0)	1,655 (104.4)	2,068 (130.5)
12 (300)	2,082 (131.4)	2,692 (170)	3,365 (212.3)

Table 1-3 Maximum Permissible Fixture Unit Loads for Sanitary Stacks

Diameter of Pipe, in. (mm)	Maximum dfu that May Be Connected			
	Any horizontal fixture branch ^a	One stack of three or fewer branch intervals	Stacks with more than three branch intervals	
			Total for stack	Total at one branch interval
1½ (40)	3	4	8	2
2 (50)	6	10	24	6
2½ (65)	12	20	42	9
3 (80)	20 ^b	48 ^b	72 ^b	20 ^b
4 (100)	160	240	500	90
5 (125)	360	540	1,100	200
6 (150)	620	960	1,900	350
8 (200)	1,400	2,200	3,600	600
10 (250)	2,500	3,800	5,600	1,000
12 (300)	3,900	6,000	8,400	1,500
15 (380)	7,000	—	—	—

^a Does not include branches of the building drain.

^b No more than two water closets or bathroom groups within each branch interval or more than six water closets or bathroom groups on the stack.

tions, came to the conclusion that slugs of water, with their accompanying violent pressure fluctuations, did not occur until the stack flowed one-quarter to one-third full. Most model codes have based their stack loading tables on a value of $r = 1/4$ or $7/24$.

The recommended maximum permissible flow in a stack is $7/24$ of the total cross-sectional area of the stack. By substituting $r = 7/24$ into Equation 1-2, the corresponding maximum permissible flow for the various sizes of pipe in gpm can be determined. Table 1-3 lists the maximum permissible fixture units (fu) to be conveyed by stacks of various sizes. The table was created by taking into account the probability of simultaneous use of fixtures. For example, if 500 fixture units is the maximum loading for a 4-inch (100-millimeter) stack, then 147 gpm (9.3 liters per second) is equivalent to 500 fixture units. This is the total load from all branches.

It should be noted that there is a restriction on the amount of flow permitted to enter a stack from any branch when the stack is more than three branch intervals. If an attempt is made to introduce an overly large flow into the stack at any one level, the inflow will fill the stack at that level and will back up the water above the elevation of inflow, which will cause violent pressure fluctuations in the stack—resulting in the siphoning of trap seals—and also may cause sluggish flow in the horizontal branch. This problem was solved in a study of stack capacities made by Wyly and Eaton at the National Bureau of Standards for the Housing and Home Finance Agency in 1950.

The water flowing out of the branch can enter the stack only by mixing with the stream flowing down the stack or by deflecting it. Such a deflection of the high-velocity stream coming down the stack can be accomplished only if there is a significant hydrostatic pressure in the branch, since a force of some kind is required to deflect the downward flowing stream and change its momentum. This hydrostatic pressure is created by the water backing up in the branch until the head changes the momentum of the stream already in the stack to allow the flow from the branch to enter the stack.

The maximum hydrostatic pressure that should be permitted in the branch as a result of the backing up of the spent water is based on this consideration: The backup should not be of a magnitude that would cause the water to back up into a shower stall or cause sluggish flow. It is half of the diameter of the horizontal branch at its connection to the stack. That is, it is the head measured at the axis of the pipe that will cause the branch to flow full near the exit.

When a long-turn tee-wye is used to connect the branch to the stack, the water has a greater vertical velocity when it enters the stack than it does when a sanitary tee is used. The backpressures should be smaller in this case for the same flows down the stack and in the branch.

Table 1-3 shows the maximum permissible fixture unit loads for sanitary stacks. The procedure for sizing a multistory stack (greater than three floors) is to first size the horizontal branches connected to the stack. This is done by totaling the fixture units connected to each branch and using the corresponding figure in column 2 of Table 1-3. Next, total all the fixture units connected to the stack and determine the size from the same table, under column 4. Immediately check the next column, "Total at One Branch Interval," and determine if this maximum is exceeded by any of the branches. If it is exceeded, the stack as originally determined must be increased at least one size, or the loading of the branches must be redesigned so the maximum conditions are satisfied.

For example, consider a 4-inch (100-millimeter) stack more than three stories high. The maximum loading for a 4-inch (100-millimeter) branch is 160 fixture units, as shown in column 2 of Table 1-3. This load is limited by column 5 of the same table, which permits only 90 fixture units to be introduced into a 4-inch (100-millimeter) stack in any one-branch interval. The stack would

have to be increased in size to accommodate any branch load exceeding 90 fixture units.

To illustrate the requirements of a stack with an offset of more than 45 degrees from the vertical, Figure 1-1 shows the sizing of a stack in a 12-story building, with one offset between the fifth and sixth floors and another offset below the street floor.

Sizing is computed as follows:

1. Compute the fixture units connected to the stack. In this case, assume 1,200 fixture units are connected to the stack from the street floor through the top floor.
2. Size the portion of the stack above the fifth-floor offset. There are 400 fixture units from the top floor down through the sixth floor. According to Table 1-3, column 4, 400 fixture units require a 4-inch (100-millimeter) stack.

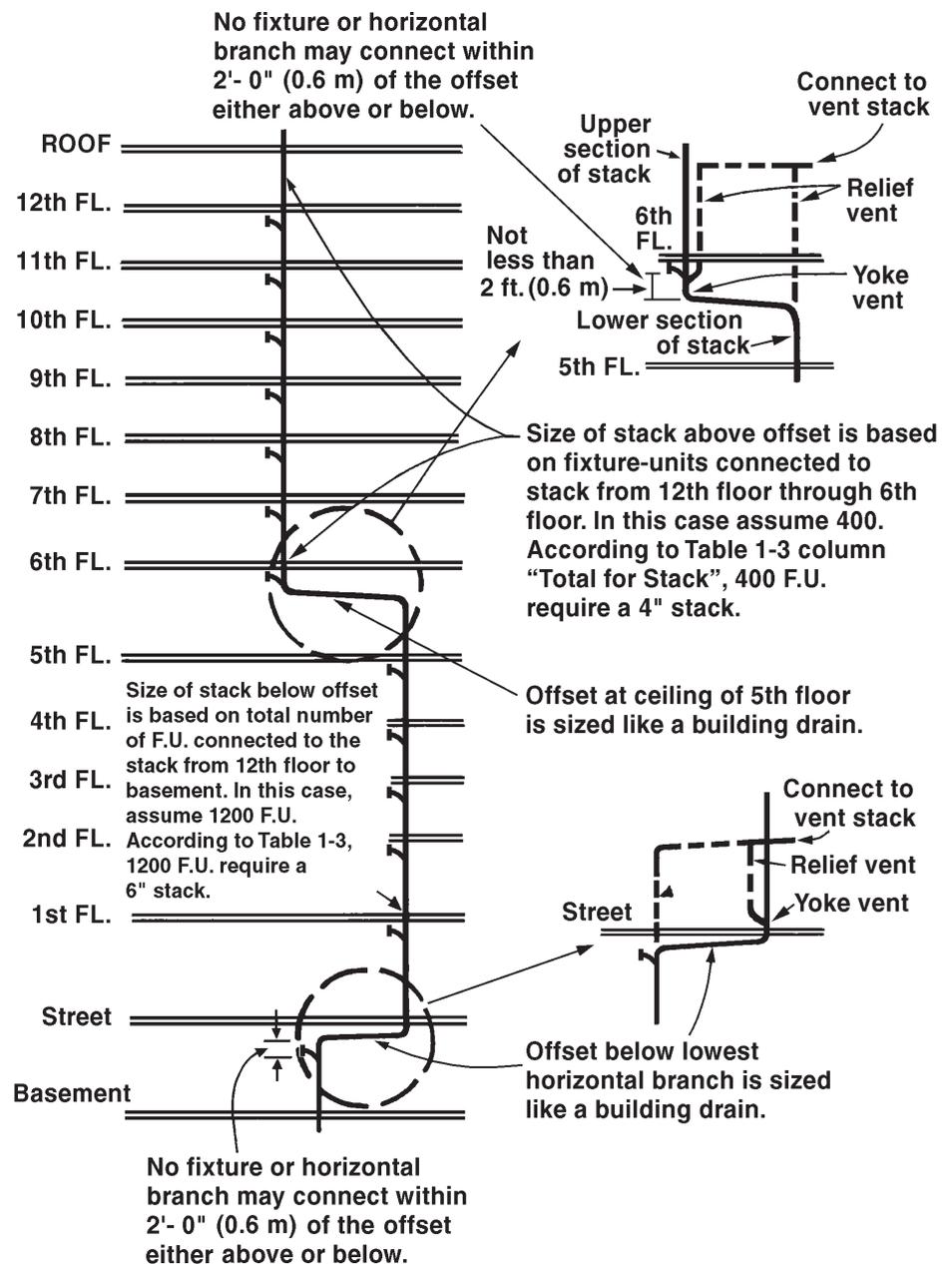


Figure 1-1 Procedure for Sizing an Offset Stack

3. Size the offset on the fifth floor. An offset is sized and sloped like a building drain.
4. Size the lower portion of the stack from the fifth floor down through the street floor. The lower portion of the stack must be large enough to serve all of the fixture units connected to it, from the top floor down (in this case, 1,200 fixture units). According to Table 1-3, 1,200 fixture units require a 6-inch (150-millimeter) stack.
5. Size and slope the offset below the street floor the same as a building drain.

The fixture on the sixth floor should be connected to the stack at least 2 feet (0.6 meter) above the offset. If this is not possible, then connect them separately to the stack at least 2 feet (0.6 meter) below the offset. If this is not possible either, run the fixture drain down to the fifth or fourth floor and connect to the stack at that point.

CAPACITIES OF SLOPING DRAINS

The characteristics of sewage are the same as plain water. The capacities of horizontal or sloping drains are complicated by surging flow.

Determining drain size is based on highly fluctuating or surging flow conditions in the horizontal branches carrying the discharge of fixtures to the soil or waste stack. After falling down the vertical stack, the water is assumed to enter the building drain with surge peaks leveled off somewhat, but still in a surging condition.

A large building covering considerable ground area probably has several primary branches and certainly at least one secondary branch. After the water enters the building drain, the surge continues to level off, becoming more and more nearly uniform, particularly after the hydraulic jump has occurred. If the secondary branch is long enough and if the drain serves a large number of fixtures, the flow may become substantially uniform before it reaches the street sewer.

Steady, Uniform Flow Conditions in Sloping Drains

Although the equations of steady, uniform flow in sloping drains should not be used to determine the capacities of sloping drains in which surging flow exists, flow computations based on these formulas afford a rough check on values obtained by the more complicated methods that are applicable to surging flow. Hence, three of the commonly used formulas for flow in pipes will be considered: Hazen and Williams, Darcy-Weisbach, and Manning.

Hazen-Williams Formula

This formula usually is written as follows:

Equation 1-3

$$V = 1.318 \times C \times R^{0.63} \times S^{0.54}$$

where

V = Mean velocity of flow, fps (meters per second)

C = Hazen and Williams coefficient

R = Hydraulic radius of pipe, feet (meters)

S = Slope of pressure gradient

The exponents of R and S in Equation 1-3 have been selected to make the coefficient C as nearly constant as possible for different pipe diameters and for different velocities of flow. Thus, C is approximately constant for a given pipe roughness.

Darcy-Weisbach Formula

In this formula, the dimensionless friction coefficient f varies with the diameter of the pipe, the velocity of flow, the kinematic viscosity of the fluid flowing, and the roughness of the walls. It usually is written as follows:

Equation 1-4

$$h_f = \frac{fLV^2}{D2g}$$

where

h_f = Pressure drop or friction loss, feet (meters)

f = Friction coefficient

L = Length of pipe, feet (meters)

D = Diameter of pipe, feet (meters)

V = Mean velocity of flow, fps (meters per second)

g = Acceleration of gravity, 32.2 fps² (9.8 m/s²)

Manning Formula

The Manning formula, which is similar to the Hazen and Williams formula, is meant for open-channel flow and usually is written as follows:

Equation 1-5

$$V = \frac{1.486}{n} \times R \times S^{1/2} = \frac{1.486}{n} \times R^{0.67} \times S^{0.50}$$

In this formula, n is the Manning coefficient, which varies with the roughness of the pipe and the pipe diameter.

The flow quantity is equal to the cross-sectional area of the flow times the flow velocity obtained from the above three equations. This can be expressed as:

Equation 1-5a

$$Q = AV$$

where

Q = Quantity rate of flow, cubic feet per second (cfs) (cubic meters per second)

A = Cross-sectional area of flow, square feet (square meters)

V = Velocity of flow, fps (meters per second)

By substituting the value of V from Manning's formula, the quantity of flow in variously sized drains of the same material can be calculated as:

Table 1-4 Values of R, R^{2/3}, A_F, and A_H

Pipe Size, in. (mm)	R = ¼, ft (mm)	R ^{2/3} , ft (mm)	A _F (Cross-sectional Area for Full Flow), ft ² (m ²)	A _H (Cross-sectional Area for Half-full Flow), ft ² (m ²)
1½ (40)	0.0335 (1.02)	0.1040 (3.17)	0.01412 (0.0013)	0.00706 (0.00065)
2 (50)	0.0417 (1.27)	0.1200 (3.66)	0.02180 (0.0020)	0.01090 (0.0009)
2½ (65)	0.0521 (1.59)	0.1396 (4.24)	0.03408 (0.0031)	0.01704 (0.0015)
3 (80)	0.0625 (1.90)	0.1570 (4.78)	0.04910 (0.0046)	0.02455 (0.0023)
4 (100)	0.0833 (2.54)	0.1910 (5.82)	0.08730 (0.0081)	0.04365 (0.0040)
5 (125)	0.1040 (3.17)	0.2210 (6.74)	0.13640 (0.0127)	0.06820 (0.0063)
6 (150)	0.1250 (3.81)	0.2500 (7.62)	0.19640 (0.0182)	0.09820 (0.0091)
8 (200)	0.1670 (5.09)	0.3030 (9.23)	0.34920 (0.0324)	0.17460 (0.0162)
10 (250)	0.2080 (6.33)	0.3510 (10.70)	0.54540 (0.0506)	0.27270 (0.0253)
12 (300)	0.2500 (7.62)	0.3970 (12.10)	0.78540 (0.0730)	0.39270 (0.0364)
15 (380)	0.3125 (9.53)	0.4610 (14.05)	1.22700 (0.0379)	0.61350 (0.0570)

Equation 1-5b

$$Q = A \times \frac{1.486}{n} \times R \times S^{1/2}$$

This is the formula used by many plumbing engineers to deal with sloping drain problems. The significant hydraulic parameters used in the above equation are listed in Table 1-4.

Slope of Horizontal Drainage Piping

Horizontal drains are designated to flow at half-full capacity under uniform flow conditions to minimize the generation of pneumatic pressure fluctuations. The minimum slopes are as follows:

- Pipe 3 inches (80 millimeters) and smaller: ¼ inch per foot (6.4 millimeters per meter)
- 4- to 6-inch (100- to 150-millimeter) pipe: 1/8 inch per foot (3.2 millimeters per meter)
- Pipe 8 inches (200 millimeters) and larger: 1/16 inch per foot (1.6 millimeters per meter)

These slopes are not a hard and fast rule and might be less under unusual conditions. The designer must confirm the required slopes with the local code authority. These minimum slopes are required to maintain a velocity of flow greater than 2 fps for scouring action. Table 1-5 gives the approximate velocities for given flow, slopes, and diameters of horizontal drains based on the Manning formula for half-full pipe and $n = 0.015$.

A flow velocity of 2 fps will prevent the solids within a pipe from settling out and forming a system stoppage. Table 1-6 has been prepared to give the size of a pipe in conjunction with the flow rate to maintain a self-cleansing velocity of 2 fps.

Loads for Drainage Piping

The recommended loads for building drains and sewers are tabulated in Table 1-7. This table shows the maximum number of fixture units that may be connected to any portion of the building drain or building sewer for given slopes and diameters of pipes. For example, an offset below the lowest branch with 1,300 fu at a slope of ¼ inch per foot (6.4 millimeters per meter) requires an 8-inch (200-millimeter) pipe.

For devices that provide continuous or semi-continuous flow into the drainage system, such as sump pumps, ejectors, and air-conditioning equipment, a value of 2 fixture units can be assigned for each gpm (liter per second) of flow. For example, a sump pump with a discharge rate of 200 gpm (12.6 liters per second) is equivalent to $200 \times 2 = 400$ fixture units.

COMPONENTS OF SANITARY DRAINAGE SYSTEMS

Sumps and Ejectors

The distinction between sump and ejector pumps is more terminology than actual fact. A sump pump is designed to transport clear, non-sanitary wastewater with some turbidity and suspended solids no larger than sand grains. An ejector pump is designed to transport sanitary waste and larger solids suspended in the

effluent. All effluent is a liquid with solids suspended in it, but it has the same hydraulic characteristics as water.

Building drains that cannot flow directly into a sewer by gravity must be discharged into a covered basin. From there, the fluid is lifted into the building's gravity drainage system by automatic pump equipment or by any equally efficient method approved by the administrative authority.

An ejector basin must be of airtight construction and must be vented. It is airtight to prevent the escape of foul odors generated by sanitary waste from the sub-drainage system. Since it is airtight, a vent is required to relieve the air in the basin as wastes discharge into it and also to supply air to the basin while the contents are being discharged to the sanitary gravity drainage system. A duplex pump system shall be used. If one pump breaks down, the control system will alert the second pump to start. Thus, the system will remain in operation, and no damage will be caused by the cessation of system operation. When a duplex unit is used, each pump

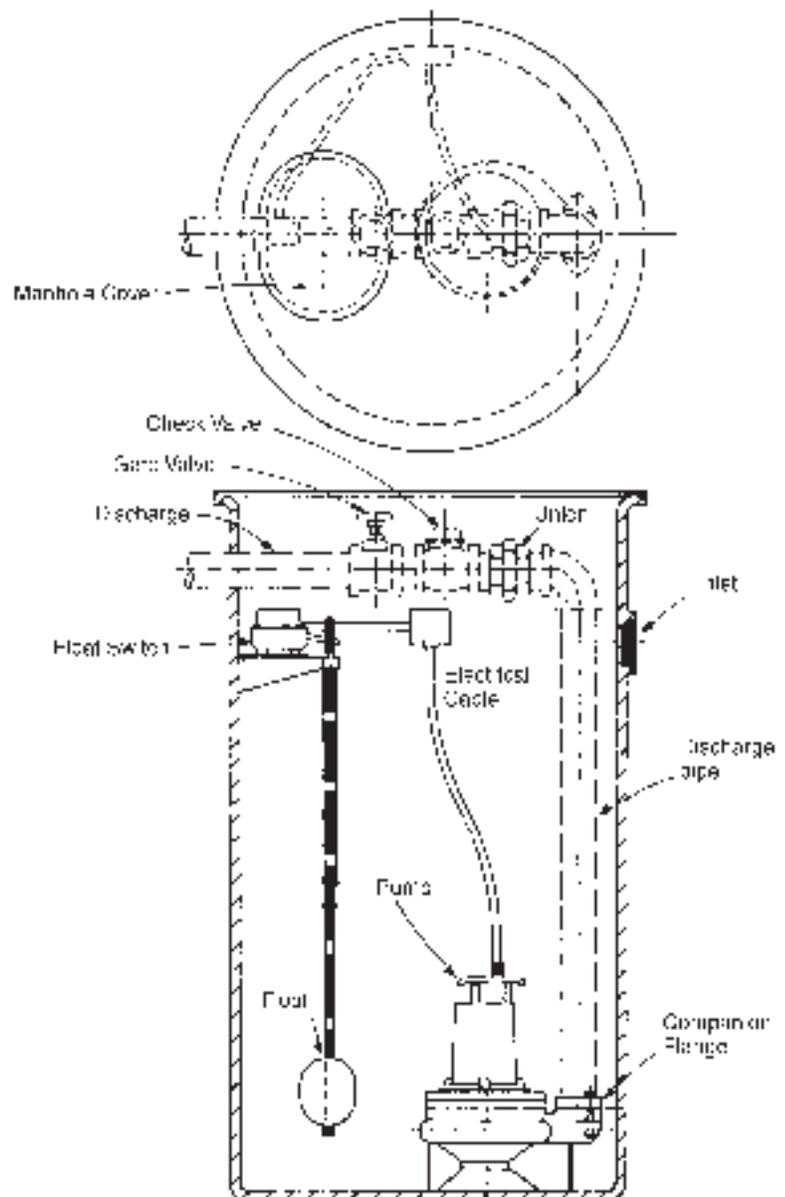


Figure 1-2 Typical Ejector Pump Installation

Table 1-5 Approximate Discharge Rates and Velocities in Sloping Drains, n = 0.015^a

Actual Inside Diameter of Pipe, in. (mm)	Actual Inside Half-full Flow Discharge Rate and Velocity							
	1/16 in./ft (1.6 mm/m) Slope		1/8 in./ft (3.2 mm/m) Slope		1/4 in./ft (6.4 mm/m) Slope		1/2 in./ft (12.7 mm/m) Slope	
	Discharge, gpm (L/s)	Velocity, fps (mm/s)	Discharge, gpm (L/s)	Velocity, fps (mm/s)	Discharge, gpm (L/s)	Velocity, fps (mm/s)	Discharge, gpm (L/s)	Velocity, fps (mm/s)
1 1/4 (31.8)							3.40 (0.21)	1.78 (45.5)
1 3/8 (34.9)					3.13 (0.20)	1.34 (0.41)	4.44 (0.28)	1.90 (48.3)
1 1/2 (38.9)					3.91 (0.247)	1.42 (0.43)	5.53 (0.35)	2.01 (51.1)
1 5/8 (41.28)					4.81 (0.30)	1.50 (0.46)	6.80 (0.38)	2.12 (53.9)
2 (50.8)					8.42 (0.53)	1.72 (0.52)	11.9 (0.75)	2.43 (61.8)
2 1/2 (63.5)			10.8 (0.68)	1.41 (0.43)	15.3 (0.97)	1.99 (0.61)	21.6 (1.36)	2.82 (71.7)
3 (76.3)			17.6 (1.11)	1.59 (0.49)	24.8 (1.56)	2.25 (0.69)	35.1 (2.21)	3.19 (81.1)
4 (101.6)	26.70 (1.68)	1.36 (34.6)	37.8 (2.38)	1.93 (0.59)	53.4 (3.37)	2.73 (0.83)	75.5 (4.76)	3.86 (98.2)
5 (127)	48.3 (3.05)	1.58 (40.2)	68.3 (4.30)	2.23 (0.68)	96.6 (6.10)	3.16 (0.96)	137 (8.64)	4.47 (113.7)
6 (152.4)	78.5 (4.83)	1.78 (45.3)	111 (7.00)	2.52 (0.77)	157 (10)	3.57 (1.09)	222 (14.0)	5.04 (128.2)
8 (203.2)	170 (10.73)	2.17 (55.2)	240 (15.14)	3.07 (0.94)	340 (21.5)	4.34 (1.32)	480 (30.3)	6.13 (155.9)
10 (256)	308 (19.43)	2.52 (64.1)	436 (27.50)	3.56 (1.09)	616 (38.9)	5.04 (1.54)	872 (55.0)	7.12 (181.0)
12 (304.8)	500 (31.55)	2.83 (72.0)	707 (44.60)	4.01 (1.22)	999 (63.0)	5.67 (1.73)	1,413 (89.15)	8.02 (204.0)

^an = Manning coefficient, which varies with the roughness of the pipe.
 For full flow: Multiply discharge by 2.
 For full flow: Multiply velocity by 1.
 For smoother pipe: Multiply discharge and velocity by 0.015 and divide by n of another pipe.

Table 1-6 Slopes of Cast Iron Soil Pipe Sanitary Sewer Required to Obtain Self-cleansing Velocities of 2.0 and 2.5 ft/sec. (based on Manning formula with n = 0.012)

Pipe Size (in.)	Velocity (ft/sec.)	1/4 Full		1/2 Full		3/4 Full		Full	
		Slope (ft/ft)	Flow (gpm)						
2.0	2.0	0.0313	4.67	0.0186	9.34	0.0148	14.09	0.0186	18.76
	2.5	0.0489	5.04	0.0291	11.67	0.0231	17.62	0.0291	23.45
3.0	2.0	0.0178	10.71	0.0107	21.46	0.0085	32.23	0.0107	42.91
	2.5	0.0278	13.47	0.0167	26.62	0.0133	40.29	0.0167	53.64
4.0	2.0	0.0122	19.03	0.0073	38.06	0.0058	57.01	0.0073	76.04
	2.5	0.0191	23.79	0.0114	47.58	0.0091	71.26	0.0114	95.05
5.0	2.0	0.0090	29.89	0.0054	59.79	0.0043	89.59	0.0054	119.49
	2.5	0.0141	37.37	0.0085	74.74	0.0067	111.99	0.0085	149.36
6.0	2.0	0.0071	43.18	0.0042	86.36	0.0034	129.54	0.0042	172.72
	2.5	0.0111	53.98	0.0066	101.95	0.0053	161.93	0.0066	215.90
8.0	2.0	0.0048	77.20	0.0029	154.32	0.0023	231.52	0.0029	308.64
	2.5	0.0075	96.50	0.0045	192.90	0.0036	289.40	0.0045	385.79
10.0	2.0	0.0036	120.92	0.0021	241.85	0.0017	362.77	0.0021	483.69
	2.5	0.0056	151.15	0.0033	302.31	0.0026	453.46	0.0033	604.61
12.0	2.0	0.0028	174.52	0.0017	349.03	0.0013	523.55	0.0017	678.07
	2.5	0.0044	218.15	0.0026	436.29	0.0021	654.44	0.0026	872.07
15.0	2.0	0.0021	275.42	0.0012	550.84	0.0010	826.26	0.0012	1101.68
	2.5	0.0032	344.28	0.0019	688.55	0.0015	1032.83	0.0019	1377.10

Table 1-7 Building Drains and Sewers^a

Diameter of Pipe, in. (mm)	Maximum Permissible Fixture Units for Sanitary Building Drains and Runouts from Stacks			
	Slope, in./ft (mm/m)			
	1/16 (1.6)	1/8 (3.2)	1/4 (6.4)	1/2 (12.7)
2 (50)			21	26
2 1/2 (65)			24	31
3 (80)		20	42 ^b	50 ^b
4 (100)		180	216	250
5 (125)		390	480	575
6 (150)		700	840	1,000
8 (200)	1400	1600	1,920	2,300
10 (250)	2500	2900	3,500	4,200
12 (300)	2900	4600	5,600	6,700
15 (380)	7000	8300	10,000	12,000

^aOn-site sewers that serve more than one building may be sized according to the current standards and specifications of the administrative authority for public sewers.
^bNo more than two water closets or two bathroom groups, except in single-family dwellings, where no more than three water closets or three bathroom groups may be installed. Check the local codes in the area served for exact requirements or restrictions.

should be sized for 100 percent flow, and it is good practice to automatically alternate the operation of the pumps.

A sump basin need not be airtight or vented because of the lack of objectionable odors. Incoming water is collected in the sump before it is pumped to the gravity drain pipe. Heavy-flow drains require large sumps to retain greater-than-usual amounts of water, thereby creating more head pressure on the pipe inlet. It is good practice to install the sump basin's rim a minimum of 1 inch above the finished floor in case the sanitary building drain backs up. This will prevent sewerage infiltration into the clear water system. Most manufacturers make their basins with bottom, side, or angle inlets and with inside caulk, no-hub, push-on, spigot, or screwed connections. Outlet connections are made to accept pressure-type pipe joints. No-hub pipe and fittings are not acceptable on pumped discharge piping due to the pressure limitations of the pipe joints.

Sump and ejector systems normally use a wet pit, with the pumps either above the slab or submerged. They are controlled with a float switch or electronically with control switches mounted inside the basin. A typical ejector pump installation is illustrated in Figure 1-2. A typical submerged sump pump installation is illustrated in Figure 1-3.

Cleanouts

A cleanout provides access to horizontal and vertical lines to facilitate inspection and provide a means of removing obstructions such as solid objects, greasy wastes, and hair. Cleanouts, in general, must be gas- and water-tight, provide quick and easy plug removal, allow ample space for the operation of cleaning tools, have a means of adjustment to finished surfaces, be attractive in appearance, and be designed to support whatever traffic is directed over them.

Some cleanouts are designed with a neoprene seal plug, which prevents it from “freezing,” or binding, to the ferrule. All plugs are machined with a straight or running thread and a flared shoulder for the neoprene gasket, permitting quick and certain removal when necessary. A maximum opening is provided for tool access. Recessed covers are available to accommodate carpet, tile, terrazzo, and other surface finishes and are adjustable to the exact floor level established by the adjustable housing or by the set screws.

Waste lines typically are laid beneath the floor slabs at a distance sufficient to provide adequate backfill over the joints. Cleanouts then are brought up to floor level by pipe extension pieces. Where the sewer line is at some distance below grade and not easily accessible through extensions, small pits or manholes with access covers must be installed. When cleanouts are installed in traffic areas, the traffic load must be considered when the construction materials are selected.

The size of the cleanout within a building should be the same size as the piping, up to 4 inches (100 millimeters). For larger size interior piping, 4-inch (100-millimeter) cleanouts are adequate for their intended purpose; however, 6-inch (150-millimeter)

cleanouts are recommended to allow for a larger variety of access needs such as for sewer video equipment.

Cleanouts should be provided at the following locations:

- Five feet (1.5 meters) outside or inside the building at the point of exit
- At every change of direction greater than 45 degrees
- At every change of direction and every 150 feet (45.7 meters) for underground sanitary sewer piping larger than 10 inches (250 millimeters) in diameter
- At the base of all stacks—it is good practice to install cleanouts a minimum of 6 inches above the flood rim of the highest fixture served on the lowest level
- To comply with applicable codes
- Optional locations include:
 - At the roof stack terminal
 - At the end of horizontal fixture branches or waste lines

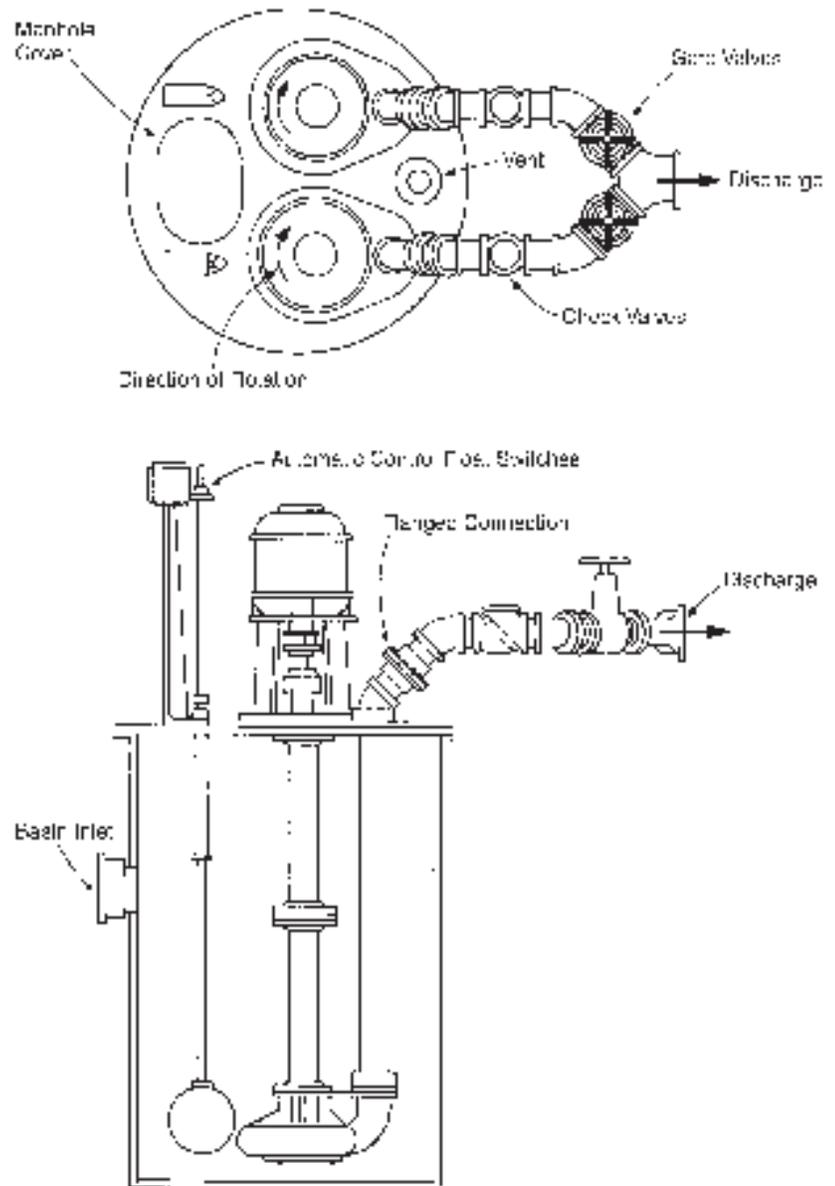


Figure 1-3 Typical Submerged Sump Pump Installation

- At fixture traps, which can be pre-manufactured with cleanout plugs, although some codes prohibit the installation of this kind of trap
- A maximum distance between cleanouts of 50 feet (15.1 meters) should be maintained for piping 4 inches (100 millimeters) and smaller and of 75 feet (22.9 meters) for larger piping. Greasy waste piping shall have a maximum distance of 40 feet (12.2 meters) between cleanouts.

Floor Drains and Floor Sinks

A large-diameter drain with a deep sump connected to a large-diameter pipe passes more water faster than a smaller drain. However, economics do not allow the designer to arbitrarily select the largest available drain when a smaller, less-expensive unit will do a satisfactory job. High-capacity drains are intended for use primarily in locations where the flow reaches high rates, such as malls, wash-down areas, and certain industrial applications. Table 1-8, which shows the minimum ratio of open grate area based on pipe diameter, is offered as a guide for the selection of drains where the drain pipe diameter is known.

The only drawback to using the open-area, pipe-diameter ratio method is that all drain manufacturers do not list the total open areas of grates in their catalogs. However, this information usually can be obtained upon request.

When sizing floor drains for most indoor applications, the capacity of a drain is not extremely critical because the drain’s primary function is to handle minor spillage or fixture overflow. The exceptions are, of course, cases where equipment discharges to the drain, where automatic fire sprinklers may deluge an area with large amounts of water, and where flushing of the floor is required for sanitation.

Floor drains or drains installed to anticipate a failure may not receive sufficient water flow to prevent the protective water seal or plumbing trap from evaporating. If the seal does evaporate, sewer gases will enter the space. Thus, automatic or manual trap primers should be installed to maintain a proper trap seal. (A small amount of vegetable oil

will dramatically reduce the evaporation rate of infrequently used floor drains and floor sinks.)

Figure 1-4 shows the basic components of a floor drain.

Floor drains shall connect to a trap that can be readily cleaned and sized to efficiently serve the purpose for which it is intended. A deep-seal trap or an approved automatic priming device should be provided. The trap shall be accessible either from the floor-drain inlet or by a separate cleanout within the drain. Figure 1-5 illustrates several types of drains that meet these conditions.

Grates/Strainers

The selection of grates is based on use and the amount of flow. Light-traffic areas may have a nickel-bronze grate, while mechanical areas may have a large, heavy-duty, ductile iron grate.

The wearing of spike-heeled shoes prompted the replacement of grates with a heel-proof, ¼-inch (6.4-millimeter) square grate design in public toilet rooms, corridors, passageways, promenade decks, patios, stores, theaters, and markets. Though this type of grating has less drainage capacity than typical grates, its safety feature makes it well worth the change.

Table 1-8 Recommended Grate Open Areas for Various Floor Drains with Outlet Pipe Sizes

Nominal Pipe Size, in. (mm)	Recommended Minimum Grate Open Area for Floor Drains	
	Transverse Area of Pipe, in. ^{2a} (× 10 mm ²)	Minimum Inside Area, in. ² (× 10 mm ²)
1½ (40)	2.04 (1.3)	2.04 (1.3)
2 (50)	3.14 (2.0)	3.14 (2.0)
3 (80)	7.06 (4.6)	7.06 (4.6)
4 (100)	12.60 (8.1)	12.06 (8.1)
5 (125)	19.60 (12.7)	19.60 (12.7)
6 (150)	28.30 (18.3)	28.30 (18.3)
8 (200)	50.25 (32.4)	50.24 (32.4)

^aBased on extra-heavy soil pipe, nominal internal diameter.

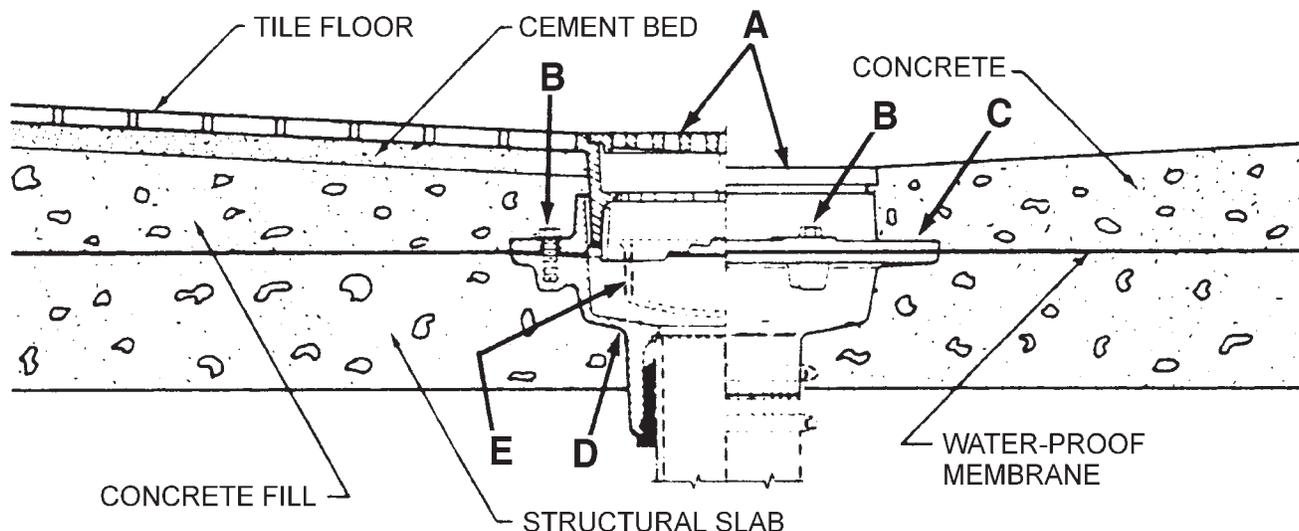


Figure 1-4 Basic Floor-Drain Components:
 (A) Removable Grate; (B) Rust-resistant Bolts; (C) Integral, One-piece Flashing Ring; (D) Cast Drain Body with Sump; (E) Sediment Bucket (optional)

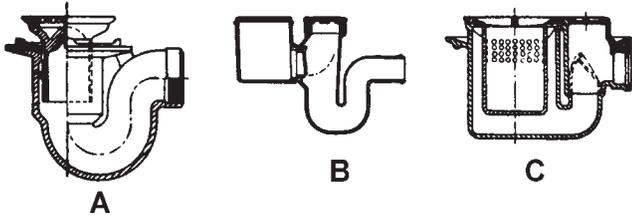


Figure 1-5 Types of Floor Drain:
(A) Typical Drain with Integral Trap that May Be Cleaned Through Removable Strainer at Floor Level;
(B) Floor Drain with Combination Cleanout and Backwater Valve, for Use Where Possibility of Backflow Exists;
(C) Drain with Combined Cleanout, Backwater Valve, and Sediment Bucket

Grates or strainers should be secured with stainless-steel screws in nickel-bronze tops. If the public may access the roof, consideration must be given to protecting vent openings from vandals, and vandal-proof fasteners are available from most manufacturers.

In school gymnasium shower rooms, where the blocking of flat-top shower drains with paper towels can cause flooding, dome grates in the corners of the room or angle grates against the walls can be specified in addition to the regular shower drains. Shower-room gutters and curbs have become undesirable because of code requirements and the obvious dangers involved. Therefore, the passageways from shower areas into locker areas need extended-length drains to prevent runoff water from entering the locker areas.

Where grates are not secured and are subject to vehicular traffic, it is recommended to install non-tilting and/or tractor-type grates. With these grates, when it moves out of position the skirt catches the side of the drain body, and the grate slides back into its original position. Ramp-drain gratings should be slightly convex because rapidly flowing ramp water has a tendency to flow across flat grates. A better solution to this problem is to place flat-top grates on a level surface at the bottom of the ramp, rather than on the ramp slope.

Flashing Ring

This component makes an effective seal, which prevents water from passing around the drain to the area below.

Sediment Bucket

A sediment bucket is an additional internal strainer designed to collect debris that gets by the regular strainer. It is required wherever the drain can receive solids, trash, or grit that could plug piping, such as the following situations:

- Toilet rooms in industrial/manufacturing buildings should be equipped with floor drains with sediment buckets to facilitate cleaning.
- Floor drains with sediment buckets must be provided in mechanical equipment rooms, where pumps, boilers, water chillers, heat exchangers, and HVAC equipment regularly discharge and/or must be periodically drained for maintenance and repairs. HVAC equipment requires the drainage of condensate from cooling coils using indirect drains.

- Boilers require drains with sediment buckets. Strategically located floor drains also are required in buildings with wet sprinkler systems to drain water in case the sprinkler heads are activated. The maximum temperature of liquids discharged should be 140°F (60°C).
- Where a residential garage requires a floor drain, a sediment bucket shall be used.

Accessories

A variety of accessories are available to make the basic drain adaptable to various types of structures. The designer must know the construction of the building, particularly the floor and deck structures, to specify the appropriate drain accessories.

Backwater Valves

A backwater valve can be installed on a building sewer/house drain when the drain is lower than the sewer line, when unusual sewer discharges may occur due to combined storm water and sanitary sewer systems, or when old municipal sewers incur high rates of infiltration.

A backwater valve reacts similarly to a check valve. The device consists of a mechanical flapper or disc, which requires a certain amount of maintenance; therefore, these devices must be placed to provide a free area and access for maintenance. Sediment can accumulate on the flapper valve seat, preventing the flapper from closing tightly. Also, many valves employ a spring or mechanical device to exert a positive pressure on the flapper device, which requires occasional lubrication. Most manufacturers of backwater valves provide an access cover plate for maintenance, which also may be used as a building sewer cleanout.

Figure 1-6 illustrates two types of backwater valves that may be installed where there is a possibility of backflow.

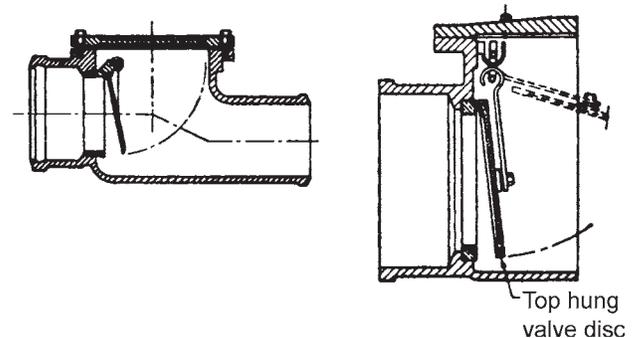


Figure 1-6 Types of Backwater Valve

Oil Interceptors

In commercial establishments such as service stations, garages, auto repair shops, dry cleaners, laundries, industrial plants, and process industries having machine shops, metal-treating process rooms, chemical process or mixing rooms, etc., flammable or volatile liquids may enter the drainage system, which can contaminate the sewer line and cause a serious fire or explosion.

Oil interceptors are designed to separate and collect oils and other light-density, volatile liquids, which would otherwise be discharged into the drainage system. An oil interceptor is required wherever lubricating oil, cutting oil,

kerosene, gasoline, diesel fuel, aircraft fuel, naphtha, paraffin, tri-sodium phosphate, or other light-density and volatile liquids are present in or around the drainage system.

The interceptor is furnished with a sediment bucket, which collects debris, small parts, chips, particles, and other sediment frequently present in industrial waste and could clog the drainage system. A gasketed, removable cover permits access for cleaning. To eliminate pressure buildup inside the interceptor, a connection on each side of the body allows venting of the interceptor.

Oil interceptors are sized in accordance with the maximum anticipated gpm (liter per second) flow rate of wastewater that could be discharged through a tailpiece and typically are protected from back-siphonage by a vacuum breaker mounted at the tailpiece entrance.

Fixture Wastewater Type

These devices are mounted on the trap of frequently used fixtures. A tapping at the overflow line will allow small amounts of wastewater to enter an adjacent, infrequently used drain as the trap surges during use.

Automatic trap primers can be obtained as pre-engineered devices, which have widely accepted approval. All direct connections between the sewer system and the potable water system must be protected from potential contamination. Primers can be manufactured or fitted with devices that are approved to prevent cross-contamination.

Supports

The location of pipe supports usually is specified by code. They are located to maintain a slope that is as uniform as possible and will not change with time. In this regard, the rigidity of pipe and joints and the possibility of creep and bedding settlement are primary considerations. When building settlement may be significant, special hanging arrangements may be necessary. Underground piping should be continuously and firmly supported, but blocking below metal pipe is usually acceptable. Consult the manufacturer for recommendations for piping materials not covered in the code and for special problems.

Hangers should be designed adequately. To protect them from damage by building occupants, allow at least a 250-pound (113.4-kilogram) safety factor when designing hangers. See *Plumbing Engineering Design Handbook, Volume 4*, Chapter 6 for further information on hangers and supports.

Seismic restraint also must be considered.

PIPING MATERIALS

The materials recommended for soil and waste piping, installed aboveground within buildings, are copper alloy, copper, cast iron (hub-and-spigot or hubless), galvanized steel, and PVC. Underground building drains should be cast iron soil pipe, hard-temper copper tube, ABS, PVC, PVDF, or DWV pattern Schedule 40 with compression joints or couplings, installed with a minimum cover of 12 inches (300 millimeters). Corrosive wastes require suitably acid-resistant materials such as high-silicon cast iron, borosilicate glass, or polypropylene. (Note: Some blood analyzers discharge sodium azide, which forms a very dangerous, explosive com-

pound with copper pipes. Other piping must be used, or the sodium azide must be kept out of the system.)

The materials used for the pipe fittings must be compatible with the piping materials. Fittings should slope in the direction of flow and have smooth interior surfaces without ledges, shoulders, or reductions that may obstruct the flow in the piping.

Drains specified with cast iron or PVC bodies should be suitable for most installations. Where extra corrosion resistance is required, high-silica cast iron, polypropylene, borosilicate glass, stainless steel, galvanized iron, or other acid-resisting material should be selected. Where a sediment bucket is used, it should be bronze, galvanized, or stainless steel. Enameled sediment buckets are impractical because they chip when cleaned.

In the selection of materials for top surfaces, such as grates, where floor drains are visible in finished areas, appearance is a prime consideration. As cast iron will rust and galvanizing and chrome plating eventually will be worn off by traffic, the preferred material is solid, cast nickel-bronze, which maintains its attractive appearance. In a swimming pool, however, chlorine necessitates the use of chlorine-resistant materials. For large grates that will be subject to hand-truck or forklift traffic, a ductile iron grate with or without a nickel-bronze veneer is recommended.

Polished brass or bronze for floor service will discolor unless there is constant traffic over it. Cast aluminum has also been found inadequate for certain floor-service applications due to excessive oxidation and its inability to withstand abrasion.

JOINING METHODS

Drain and cleanout outlets are manufactured in five basic types.

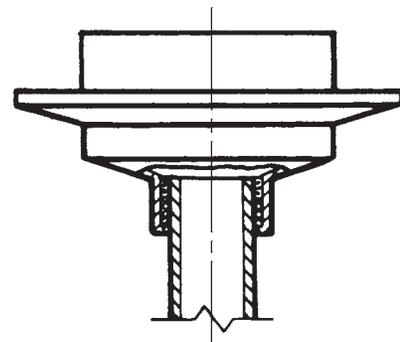


Figure 1-7 Inside Caulk Drain Body

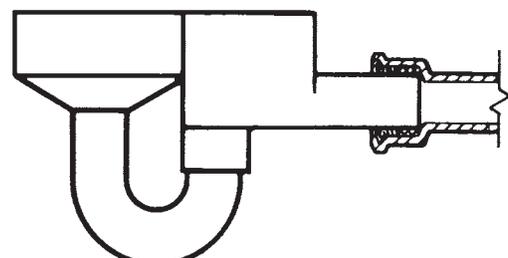


Figure 1-8 Spigot Outlet Drain Body

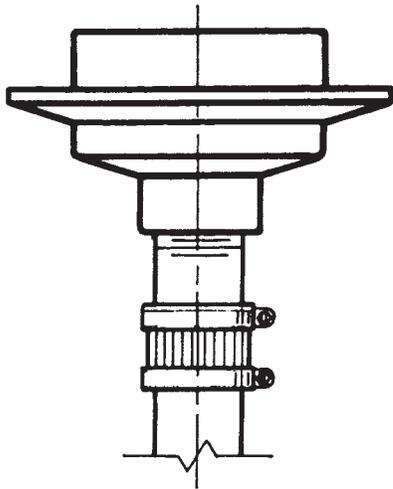


Figure 1-9 No-hub Outlet Drain Body

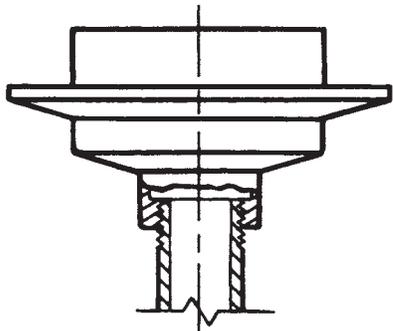


Figure 1-10 IPS or Threaded Outlet Drain Body

Inside Caulk

In the inside caulk arrangement, the pipe extends up into the drain body, and oakum is packed around the pipe tightly against the inside of the outlet. Molten lead then is poured into this ring and later stamped or caulked to correct for lead shrinkage. Current installation methods use a flexible gasket for the caulking material. See Figure 1-7.

Spigot Outlet

The spigot outlet utilizes the caulking method as outlined above for the inside caulk, except that the spigot outlet is caulked into the hub or bell of the downstream pipe or fitting. See Figure 1-8.

Push-seal Gasketed Outlet

The push-seal gasketed outlet utilizes a neoprene gasket similar to standard ASTM C564 neoprene gaskets approved for hub-and-spigot cast iron soil pipe. A ribbed neoprene gasket is applied to the accepting pipe, thus allowing the drain outlet to be pushed onto the pipe.

No-hub Outlet

The no-hub type utilizes a spigot (with no bead on the end) that is stubbed into a neoprene coupling with a stainless-steel bolting band (or other type of clamping device), which, in turn, accepts a downstream piece of pipe or headless fitting. See Figure 1-9.

IPS or Threaded Outlet

The threaded type is a tapered female thread in the drain outlet designed to accept the tapered male thread of a downstream piece of pipe or fitting. See Figure 1-10.

Noise Transmission

Avoiding direct metal-to-metal connections may reduce noise transmission along pipes. Using heavier materials generally reduces noise transmission through pipe walls. Isolating piping with resilient materials, such as rugs, belts, plastic, or insulation may reduce noise transmission to the building. See Table 1-9 for relative noise-insulation absorption values.

BUILDING SEWER INSTALLATION

The installation of building sewers is very critical to the operation of the sewer. Inadequate bedding in poor soils may allow the sewer to settle, causing dips and low points in the sewer. The settlement of sewers interrupts flow, diminishes minimum cleansing velocity, reduces capacity, and creates a point where solids can drop out of suspension and collect.

Following are some guidelines for installing building sewers.

- Where natural soil or compacted fill exists, the trench must be excavated in alignment with the proposed pitch and grade of the sewer. Depressions need to be cut out along the trench line to accept the additional diameter at the piping joint or bell hub. A layer of sand or pea gravel is placed as a bed in the excavated trench because it is easily compacted under the pipe, allowing more accurate alignment of the pipe pitch. The pipe settles into the bed and is firmly supported over its entire length.
- Where shallow amounts of fill exist, the trench can be over-excavated to accept a bed of sand, crushed stone, or similar material that is easily compacted. Bedding should be installed in lifts (layers), with each lift compacted to ensure optimum compaction of the bedding. The bed must be compacted in alignment with the proposed pitch and grade of the sewer. It is recommended that pipe joints or bell hub depressions be hand-prepared due to the coarse crushed stone. The soil-bearing weight determines trench widths and bedding thickness.
- Where deep amounts of fill exist, the engineer should consult a geotechnical engineer, who will perform soil borings to determine the depths at which soils with proper bearing capacities exist. Solutions include compacting existing fill by physical means or removing existing fill and replacing it with crushed stone structural fill.
- Backfilling of the trench is just as critical as the compaction of the trench bed and the strength of existing soils. Improper backfill placement can dislodge pipe and cause uneven sewer settlement, with physical depressions in the surface. The type of backfill material and compaction requirements must be reviewed to coordinate with the type of permanent surface. Landscaped areas are more forgiving of improper backfill placement than hard surface areas such as concrete or bituminous paving.

- Care must be taken when using mechanical means to compact soils above piping. Mechanical compaction of the first layer above the pipe by vibrating or tamping devices should be done with caution. Compacting the soil in 6-inch (150-millimeter) layers is recommended for a good backfill.

Proper sewer bedding and trench backfill will result in an installation that can be counted on for long, trouble-free service.

Table 1-9 Relative Properties of Selected Plumbing Materials for Drainage Systems

Materials	Noise Absorption	Corrosion Resistance ^a
ABS	Fair	Good
Cast iron	Excellent	Good
Clay	^b	Excellent
Concrete	^c	Fair ^d
Copper	Fair	Good
Glass borosilicate	^b	Excellent
Polypropylene	Fair	Excellent
PVC	Fair	Excellent
Silicon iron	^c	Excellent
Steel, galvanized	Good	Fair

^a This refers to domestic sewage. Consult manufacturer for resistance to particular chemicals.
^b Since these materials are used only aboveground for chemical waste systems, this is not applicable.
^c This material is usually allowed only belowground.
^d Susceptible to corrosion from hydrogen sulfide gas.

SANITATION

All drains should be cleaned periodically, particularly those in markets, hospitals, food-processing areas, animal shelters, morgues, and other locations where sanitation is important.

For sanitation purposes, an acid-resisting enameled interior in floor drains is widely accepted. The rough surfaces of brass and iron castings collect and hold germs, fungus-laden scum, and fine debris that usually accompany drain waste, and there is no easy or satisfactory way to clean these rough surfaces. The most practical approach is to enamel them, and the improved sanitation compensates for the added expense. However, pipe threads cannot be cut into enameled metals because the enameling will chip off in the area of the machining. Also, pipe threads themselves cannot be enameled; therefore, caulked joints should be specified on enameled drains. Most adjustable floor drains utilize threaded adjustments, so these drains cannot be enameled. However, adjustable drains that use sliding lugs on a cast thread may be enameled.

A grate or the top ledge of a drain can be enameled, but the enamel will not tolerate traffic abrasion without showing scratches and, eventually, chipping. The solution to this problem is a stainless-steel or nickel-bronze rim and grate over the enameled drain body, a common practice on indirect waste receptors, sometimes referred to as “floor sinks.” Specifiers seem to favor the square, indirect waste receptor, but the round receptor is easier to clean and has better anti-splash characteristics. For cases where the choice of square or round is influenced by the floor pattern, round sinks with square tops are available.

In applications such as hospital morgues, cystoscopic rooms, autopsy laboratories, slaughterhouses, and animal dens, where blood or other objectionable materials might cling to the sidewalls of the drain, it is recommended to fit the enameled drain with a flushing rim.

Where the waste being drained can clog the trap, a heel inlet on the trap with a flushing connection is recommended in addition to the flushing rim, which merely keeps the drain sides clean. (This option may not be allowed by certain codes.) A 2-inch (50-millimeter) trap flushes more effectively than a 3-inch (80-millimeter) trap because it allows the flushing stream to drill through the debris rather than completely flush it out. A valve in the water line to the drain is the best way to operate the flushing-rim drain. Flush valves have been used and can save water; however, they are not as convenient or effective as a shutoff valve. In any flushing water-supply line to a drain, a vacuum breaker installed according to code must be provided.

KITCHEN AREAS

When selecting kitchen drains, the designer must know the quantity of liquid and solid waste the drains will be required to accept, as well as which equipment emits waste on a regular basis and which produces waste only by accidental spillage. Dishwashing machines, steamers, booster heaters, and other kitchen equipment may discharge waste of 180°F or higher into the sanitary drain, so cast iron piping or coolers may be required in these cases.

Floor-cleaning procedures should be ascertained to determine the amount of water used. If any amount of solid waste is to be drained, receptors must be specified with removable sediment buckets made of galvanized or stainless steel. Also, sufficient vertical clearance over these drains must be provided to conveniently remove the sediment buckets for cleaning.

Many kitchen planners mount kitchen equipment on a 5-inch (125-millimeter) curb. Placing the drain on top of the curb and under the equipment makes connection of indirect drain lines difficult and the receptor inaccessible for inspection and cleaning. Mounting the receptor in front of the curb takes up floor space, and the myriad of indirect drains that discharge into it create a potential hazard for employees who may trip over them. The solution requires close coordination between the engineer and the kitchen designer. Figure 1-11 shows an arrangement whereby any spillage in front of the curb can be drained by half of the receptor, while indirect drains are neatly tucked away.

Where equipment is on the floor level and an indirect waste receptor must be provided under the equipment, a shallow bucket that can be removed easily is recommended.

WATERPROOFING

Whenever a cast-iron drain is cemented into a slab, separation due to expansion and contraction occurs and creates several problems. One is the constant wet area in the crevice around the drain that promotes mildew odor and the breeding of bacteria. Seepage to the floor below is also a possibility. A seepage or flashing flange can correct this problem. Weep holes in the flashing flange direct moisture into the

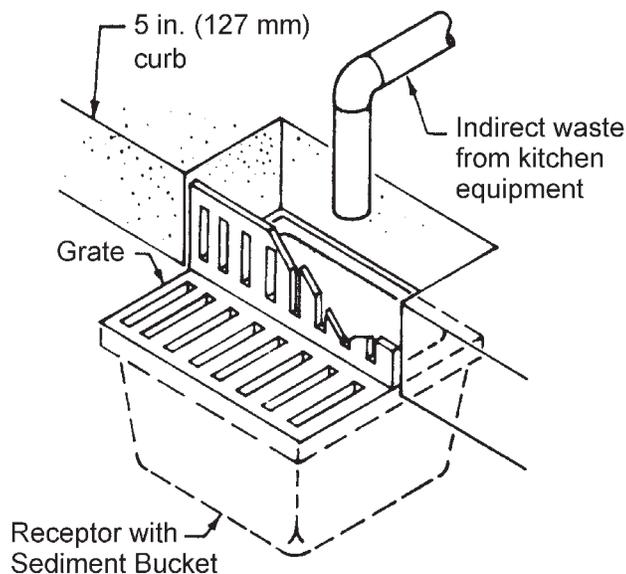


Figure 1-11 Combination Floor Drain and Indirect Waste Receptor

drain. Also, this flange accepts membrane material, and when used, the flashing ring should lock the membrane to the flange.

One prevalent misconception about the flashing flange is that it can have weep holes when used with cleanouts; however, there can be no weep holes into a cleanout to which moisture can run. Weep holes also should be eliminated from the flashing flanges of drains, such as reflection-pool drains, where an overflow standpipe to maintain a certain water level shuts off the drain entrance.

The term “non-puncturing,” used in reference to membrane-flashing, ring-securing methods, is now obsolete, as securing bolts have been moved inboard on flashing L flanges, and the membrane need not be punctured to get a seal. Of the various arrangements, this bolting method allows the greatest squeeze pressure on the membrane.

FLOOR LEVELING

A major problem in setting floor drains and cleanouts occurs when the concrete is poured level with the top of the unit, ignoring the fact that the addition of tile on the floor will cause the drain or cleanout to be lower than the surrounding surface. To solve the problem, cleanouts can be specified with tappings in the cover rim to jack the top part of the cleanout up to the finished floor level. Floor drains can be furnished with adjustable tops to attain an installation that is flush with the finished floor.

THERMAL EXPANSION

When excessive thermal expansion is anticipated, pipe movement should be controlled to avoid damaging changes in slope. Anchoring, using expansion joints, or using expansion loops or bends may accomplish this. When anchoring, avoid excessive stress on the structure and the pipe. Piping or mechanical engineering handbooks should be consulted if stress analysis

is to be performed due to excessive stresses or to the differing expansion characteristics of materials.

PROTECTION FROM DAMAGE

Following are some common hazards that may damage drains and drain piping and some methods of protection.

- Abrasion: Use plastic or rubber sleeves or insulate where copper pipe leaves the slab.
- Condensation: Insulate the piping.
- Corrosion: Use methods recommended in *Plumbing Engineering Design Handbook Volume 1*, Chapter 8: “Corrosion.”
- Heavy earth loads: Use stronger pipe or pipe sleeves.
- Expansion and contraction: Use flexible joints, loops, swing joints, or offsets.
- Fire: Use an appropriate building construction around the pipe. Some jurisdictions require metal piping within 2 feet (0.6 meter) of an entry into a firewall. All materials must conform to the appropriate fire ratings.
- Heat: Keep thermoplastic pipe away from sources of heat or use insulation.
- Nails: Use ferrous pipe, steel sleeves, or steel plates or do not locate pipe near possible nail penetration areas.
- Seismic activity: Brace pipe and provide flexible joints at connections between piping braced to walls or the structure and piping braced to the ceiling and between stories (where differential movements will occur).
- Settlement: Use sleeves or flexible joints. When embedded in concrete, cover piping with three layers of 15-pound (6.8-kilogram) felt.
- Sunlight: Protect thermoplastic pipe by insulation and a jacket or shade it to avoid warping.
- Vandals: Install pipe above reach or in areas protected by building construction. Piping must be supported to withstand 250 pounds (113.4 kilograms) hanging from the moving pipe.
- Wood shrinkage: Provide slip joints and clearance for pipe when wood shrinks. Approximately $\frac{5}{8}$ inch (16 millimeter) per floor is adequate for typical frame constructions, based on 4 percent shrinkage perpendicular to wood grain. Shrinkage along the grain usually does not exceed 0.2 percent.

ALTERNATE SANITARY SYSTEMS

The design and installation of alternative engineered plumbing systems are permitted in all codes, so long as they are designed by a licensed professional engineer who is responsible for the proper operation of the systems. If an alternative system is contemplated, submission to and approval by the authority having jurisdiction must be obtained. To expedite approval, the following steps are suggested.

1. Indicate on the design documents that the plumbing system (or parts thereof) is an alternative design.
2. Submit enough technical data to support the proposed alternative design and prove that the system conforms

to the intent of the code. This shall include suitability for the intended purpose, strength, equivalent level of performance compared to traditional installations, safety, and quality of materials.

3. Include floor plans, riser diagrams, and an indication of the proposed flow.
4. Provide assurance that the manufacturer's installation instructions will be followed.
5. If approval is given, indicate on the permit and all construction applications that an alternative engineered design is part of the approved installation.
6. Alternative systems are characterized by, but not limited to, using a single stack for both sanitary and vent or no vent at all. One exception is a conventional drainage, reduced-vent system. All of the following systems have been used successfully in the United States and around the world for many years and have proven effective in actual use. All of the alternative systems discussed have combined sanitary and vent systems.

SOVENT AND PROVENT

The Sovent system was developed in 1959 in Switzerland. It is a patented, combination drainage and vent system that uses a single stack instead of a conventional two-pipe drainage and vent stack. The Sovent system uses cast iron and/or copper pipe and is suitable only for multistory buildings because it allows substantial economy in piping installation.

The Provent system is similar to the Sovent system, but it uses PVC. Although installed in many countries throughout the world, it remains an alternative, unconventional system with only limited usage in the United States.

It is not the intent of this chapter to provide specific design criteria for a Sovent or Provent system, but rather to discuss the individual component characteristics that will enable a plumbing engineer to obtain a working knowledge of how these systems work. A typical Sovent single-stack system is illustrated in Figure 1-12.

A Sovent or Provent system consists of three principal parts: piping for all branch wastes and stacks, an aerator fitting at each floor level where the branch waste lines connect to the stack, and a deaerator fitting at the base of the stack where it enters the house drain.

The starting point is the horizontal soil and waste branches. The fixture units and branch sizes are similar to those figures found in conventional systems. The maximum fixture units that may be connected to a branch or stack are also similar to that of conventional systems.

Branch sizes must be adjusted according to the following.

- A second vertical drop or a vertical drop of more than 3 feet (0.9 meter) requires an increase in the downstream side of the connection.
- When three 90-degree changes in direction occur in a horizontal branch, the horizontal branch shall be increased in size at the upstream side of the third change.
- When a branch serves two water closets and one or more additional fixtures, the soil line shall be

increased to 4 inches (100 millimeters) at the point where one water closet and one additional fixture are connected.

- The branch must be increased one size when a soil branch exceeds 12 feet (3.7 meters) in horizontal length.
- The branch must be increased one size when a waste line exceeds 15 feet (4.6 meters) in horizontal length.

Stacks must be carried full size through the roof. Two stacks can be connected at the top above the highest fixture or at the bottom prior to entering the building drain. The size is based on the total fixture units. Fixtures may be connected into a horizontal offset in a stack below the deaerator fitting.

An aerator fitting is required at each level where a soil branch, a waste line the same size as the stack, or a waste branch one size smaller than the stack is connected. The aerator consists of an upper stack inlet, a mixing chamber, and a baffle in the center of the fitting. This provides a chamber where the flow from the branches may gradually mix smoothly with the air and liquid already flowing in the stack. It also limits the turbulence and velocity of the incoming water. A 2-inch (50-millimeter) horizontal branch may enter the stack with no fitting. Two basic styles of aerator fitting meet the needs of most design conditions: the double-side entry fitting and the single-entry fitting. Face entry and top entry are used in special cases.

A deaerator fitting is required at the bottom of the stack and is designed to overcome the tendency of the falling waste to build up excessive back pressure at the bottom of the stack when the flow is decelerated by the bend into the horizontal drain. The deaerator consists of an air separation chamber, a nose piece, a pressure relief outlet at the top connected to the building drain, and a stack outlet at the bottom. The purpose of the deaerator is to separate the airflow from the stack to ensure the smooth flow of liquid into the building drain and to relieve the positive pressure generated at the stack's base. The configuration of the fitting causes part of the air falling with the liquid to flow through the pressure relief line, and the remainder of the air goes directly into the building drain.

The plumbing engineer must explain the special requirements of the Sovent or Provent system to the installing contractor. The engineer also should make regular inspections of the project to ensure that the design conditions are met. A complete set of contract documents shall be provided to the owner to allow proper alteration or expansion of the project in the future.

SINGLE-STACK SYSTEM

The single-stack system is a combination drainage and vent system consisting of a single stack instead of conventional separate drainage and vent stacks. In this drainage system, the drainage stack serves as both a single-stack drainage and vent system when properly sized. To relieve internal air pressures, the one-pipe system must be larger than that required for drainage purposes alone. The drainage stack and branch piping shall be considered vents for the drainage

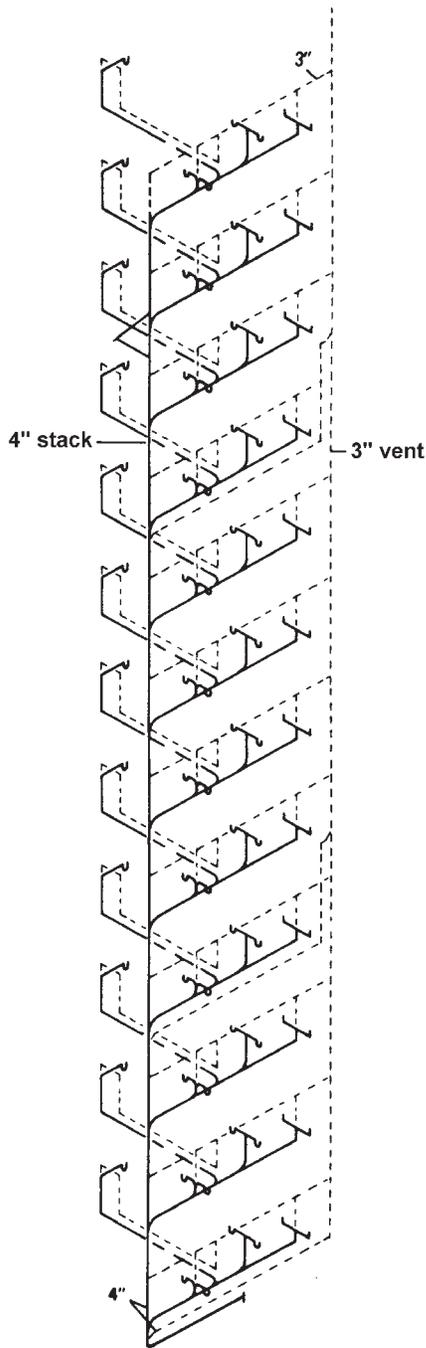


Figure 1-12 Typical Sovent Single-stack System

system as a whole. Although the pipe sizing is larger in a single-stack system than in a conventional one, installation savings are achieved by reducing the amount of vent piping required.

The major components of the one-pipe system are oversized, unvented S traps instead of the conventionally sized and vented P traps and fixtures that allow water to run off after the trap is closed to fill the traps with water to maintain the trap seal. The trap arm length is limited to reduce any suction buildup, and the stack is oversized to limit internal air pressure and vacuum buildup.

Often referred to as the Philadelphia stack, this unconventional system has operated successfully for more than 100

years with no problems. Consideration has been made by code bodies to include this system as an engineered design, which allows it to be used providing the engineer has designed it in accordance with code.

REDUCED-SIZE VENTING

In 1974, the National Bureau of Standards (NBS) conducted a laboratory study of one-story and split-level experimental drainage systems where the vents varied from one to six pipe sizes smaller than those for conventional systems. They showed satisfactory hydraulic and pneumatic performance under various loading conditions. At the same time, the 10-story wet vent system at the Stevens Institute Building Technology Laboratory had been modified by reducing the vents one to three pipe sizes in accordance with the plans and specifications of the NBS. The results also indicated that the vents in a two-story housing unit can safely be made smaller than previously allowed without jeopardizing the trap seals.

This system may allow economies of pipe size in the venting design of low-rise residential buildings, although this particular system has not been accepted by authorities. It is limited to special conditions and requires the vent pipes to be of a material such as copper or plastic that will resist the buildup of corrosion products.

VACUUM DRAINAGE SYSTEM

Vacuum drainage operates on the principle that the majority of the system is under a continuous vacuum. The system is proprietary and is made by various manufacturers, all of which have different names for devices performing similar operations, so generic identification is used here. Various designs are capable of sanitary and waste disposal, either separate or in combination, and are used for various projects such as prisons, supermarkets, and ships. There is no direct connection from the sanitary waste to the vacuum system. The one big advantage is that piping is installed overhead and no pipe is required to be placed underground.

The system consists of three basic components: a vacuum network of piping and other devices that collects and transports waste from its origin, vacuum generation pumps, and a vacuum interface device at the point of origin that isolates the vacuum piping from atmospheric pressure. When the system serves water closets, the water closets must be purpose made, designed to rinse and refill with 0.5 gallon (2.2 liters) of water.

The piping network for a vacuum waste system is held under a constant vacuum between 12 and 18 inches of mercury (in Hg) (40–65 kilopascals) and generally is fabricated from PVC, copper, or other nonporous, smooth-bore material. Horizontal piping shall slope at a rate of $\frac{1}{8}$ inch per foot (1.18 millimeter per meter) toward the vacuum center. This piping slope is the same as in conventional systems. If this slope cannot be maintained, the traps created in the piping runs when routed around obstacles would be cleared because of the differential pressure that exists between the vacuum center and the point of origin. The discharge of the piping system is into the waste storage tanks.

The vacuum generation system includes vacuum pumps, which create a vacuum in the piping and storage tanks that collect and discharge the waste into the sewer system. The vacuum pumps run only on demand, and redundancy is provided. They also have sewage pumps that pump the drainage from the storage tanks into the sewer.

The vacuum interface is different for sanitary drainage than for clear waste. Vacuum toilets operate instantly upon flushing, and when a vacuum toilet is cycled, a discharge control panel assembly is activated, sending the discharge to the tank. A valve acts as an interface between the vacuum and the atmosphere. The tank will discharge into the sewer when a predetermined level of discharge is reached.

When clear water is discharged, the water goes into an accumulator. When a controller senses that sufficient waste is present, it opens the normally closed extraction valve, which separates the atmospheric pressure from the vacuum and removes the waste from the accumulator.

Because vacuum toilets use 0.5 gallon per flush, the holding tanks can be smaller than those for conventional toilets. A flush control panel is designed to provide all of the control functions associated with the vacuum toilet. The control panel consists of a flush valve, flush controller, water valve, and vacuum breaker. All controls are pneumatically operated. The flush controller controls the opening of the flush valve and the rinse valve as well as the duration of the time the flush valve is open.

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CE Questions — "Sanitary Drainage Systems" (CEU 187)

Circle the correct answers below.

- A _____ is the main vertical pipe that carries clear water waste from non-sanitary fixtures.**
 - soil stack
 - building drain
 - waste stack
 - vent stack
- What is the recommended drainage fixture unit value for a kitchen sink?**
 - 2
 - 3
 - 4
 - 5
- How many drainage fixture units maximum may be connected to one 3-inch sanitary stack with two branch intervals?**
 - 20
 - 42
 - 48
 - 72
- An offset is sized and sloped like a _____.**
 - building sewer
 - building drain
 - horizontal branch
 - vertical stack
- The equation $Q = AV$ calculates what?**
 - flow velocity
 - flow quantity
 - friction loss
 - area of flow
- The minimum slope of a 2-inch horizontal drain is _____.**
 - 1/8 inch per foot
 - 1/4 inch per foot
 - 1/2 inch per foot
 - 1 inch per foot
- A typical ejector pump installation contains which of the following?**
 - float
 - discharge pipe
 - gate valve
 - all of the above
- Cleanouts should be installed no more than _____ apart for 3-inch piping.**
 - 50 feet
 - 75 feet
 - 100 feet
 - 150 feet
- A _____ prevents water from passing around a drain to the area below.**
 - grate
 - gasket
 - flashing ring
 - cleanout
- The recommended material for aboveground soil waste piping within a building is _____.**
 - PVC
 - cast iron
 - galvanized steel
 - all of the above
- In a Sovent system, the branch must be increased one size when a waste line exceeds _____ in horizontal length.**
 - 12 feet
 - 15 feet
 - 18 feet
 - 20 feet
- The horizontal piping in a vacuum waste system shall slope _____ inch per foot toward the vacuum center.**
 - 1/16
 - 1/8
 - 1/4
 - 1/2