In the past, tees often were used instead of pipe bends and the structures were called lampholes. Since cleaning equipment cannot be passed into the sewer through a tee, their use is no longer considered to be good design practice.

Regulations in most areas allow terminal cleanouts (if at all) only within 150 to 200 ft (45 to 60 m) of a manhole.

7.7. SERVICE LATERALS

Service laterals, also called house connections or service connections, are the branches between the street sewer and the property or curb lines, serving individual properties. They usually are required to be 4, 5, or 6 inches (100, 125, or 150 mm) in diameter, preferably with a slope of 1 in 48, or 2%. Sometimes 1% slopes are allowed and this seems to serve just as well. If a stoppage occurs in a service lateral, it may be due to root penetration, grease, or sometimes corrosion (in the case of iron pipes). Steeper slopes are of no benefit in coping with those problems.

Materials, joints, and workmanship for service laterals should be equal to those of the street sewer to minimize infiltration and root penetration. Particular attention should be paid to the construction of service laterals, especially compaction of bedding and backfill material, and jointing techniques, since these sewers frequently represent the major source of infiltration/inflow in a sanitary sewer system (see Chapter 3).

Often building sewers are constructed to the property or curb line at the time the street sewer is constructed. To meet the future needs of unsubdivided properties, wyes or tees sometimes are installed at what are presumed to be convenient intervals. Laterals or stubs not placed in use should be plugged tightly. Figure 7-7 shows typical connections. Typical connections to a deep sewer are shown in Fig. 7-8.

If wyes or tees are not installed when the sewer is constructed, the sewer must be tapped later, and deplorably poor connections often have resulted. This is especially true for those connections made by breaking into the sewer and grouting-in a stub. Either a length of pipe should be removed and replaced with a wye or tee fitting or, better, a clean opening should be cut with proper equipment and a tee-saddle or tee-insert attached. Any connection other than to existing fittings must be made by experienced workers under close supervision.

In some places, test tees are required on the service lateral, which permit the outlet to the street sewer to be plugged. This makes it possible to test the service lateral.

When a connection is to a concrete trunk sewer, a bell may be installed at the outside of the pipe. Three designs are shown in Fig. 7-9. Preferably the bell is provided by the manufacturer, but it can be installed in the field

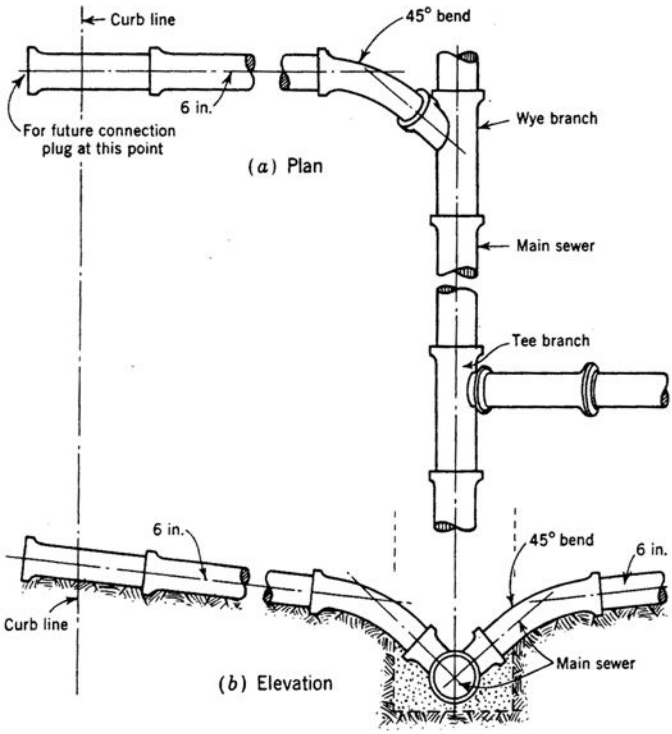


FIGURE 7-7. Service connection for shallow sewer (inch × 2.54 = cm).

if necessary. It must be high enough on the pipe so that the lateral will not be flooded by high flows in the sewer.

Large trunks are not ordinarily used as collecting sewers. When they are more than 3 or 4 ft (900 to 1,200 mm) in diameter, they frequently are paralleled by smaller collecting sewers that enter the trunks at manholes.

7.8. CHECK VALVES AND RELIEF OVERFLOWS

Where the floor of a building is at an elevation lower than the top of the next upstream manhole on the sewer system, a stoppage in the main sewer can lead to overflow of wastewater into the building. Devices that sometimes are used to guard against such occurrences include backflow preventers or check valves and relief overflows.

Backflow preventers or check valves may be installed where the house plumbing discharges to the house sewers. Usually a double check valve is specified. Even so, such devices frequently do not remain effective over long periods of time.

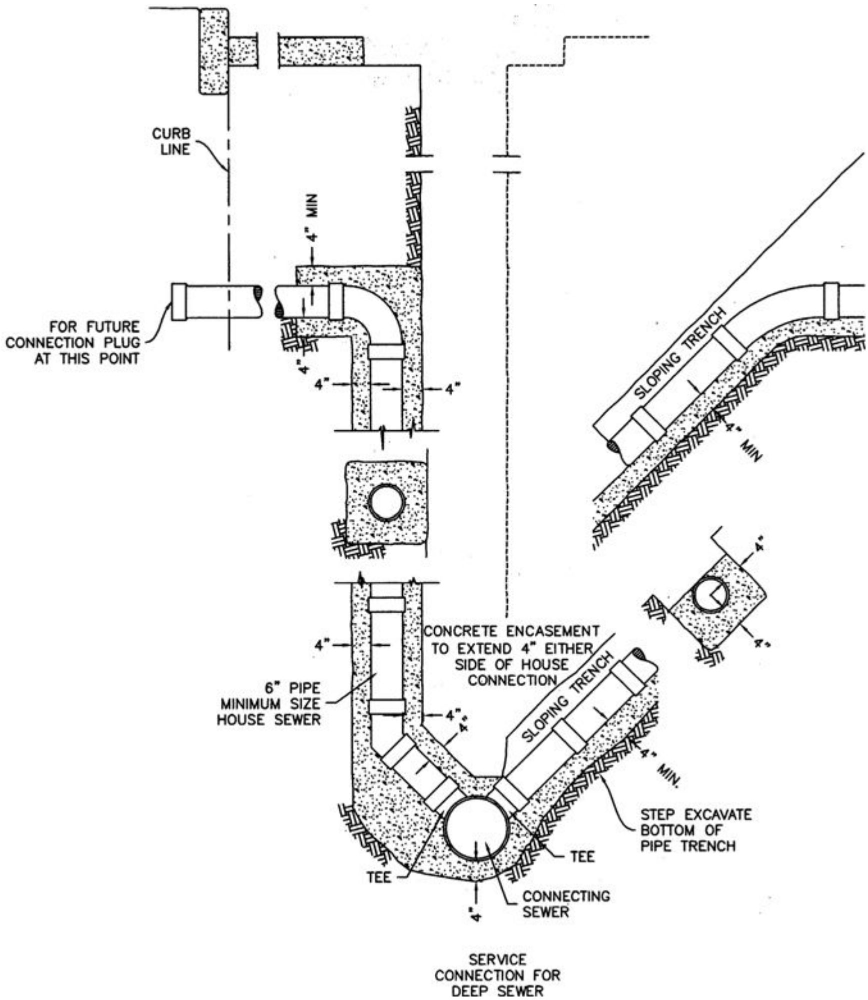
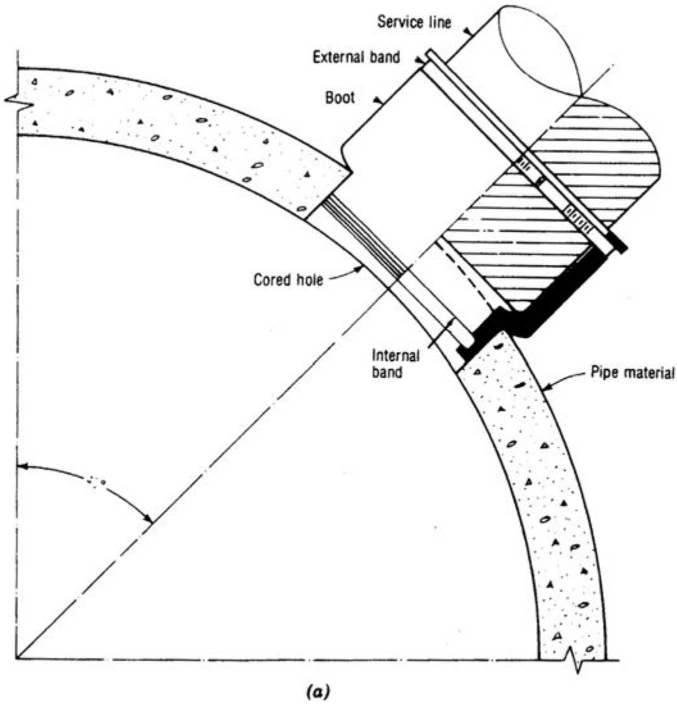


Figure 7-8. Service connection for deep sewer (inch × 2.54 = cm).

Any overflow of wastewater is undesirable but if a stoppage occurs in a street sewer, overflow may result. It will be from a manhole in the street, into a building, or on occasion at a designated overflow point. For the latter to be effective, it must be at an elevation lower than the floor level being protected. At this point, a relief device may be installed that encases a ball resting on a seat to close the end of a vertical riser and prevent flow into the sewer. The relief device must be constructed so that the ball will rise and allow overflowing wastewater to escape and thus provide relief. This practice is not encouraged except in the most extreme conditions and



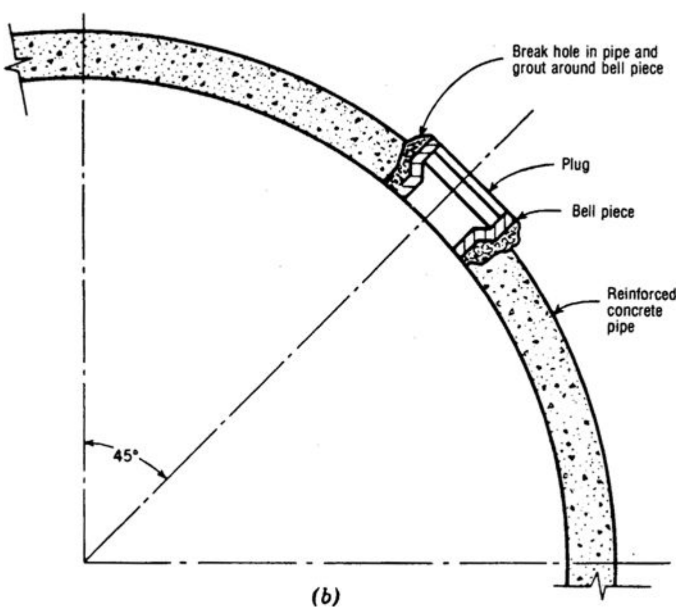
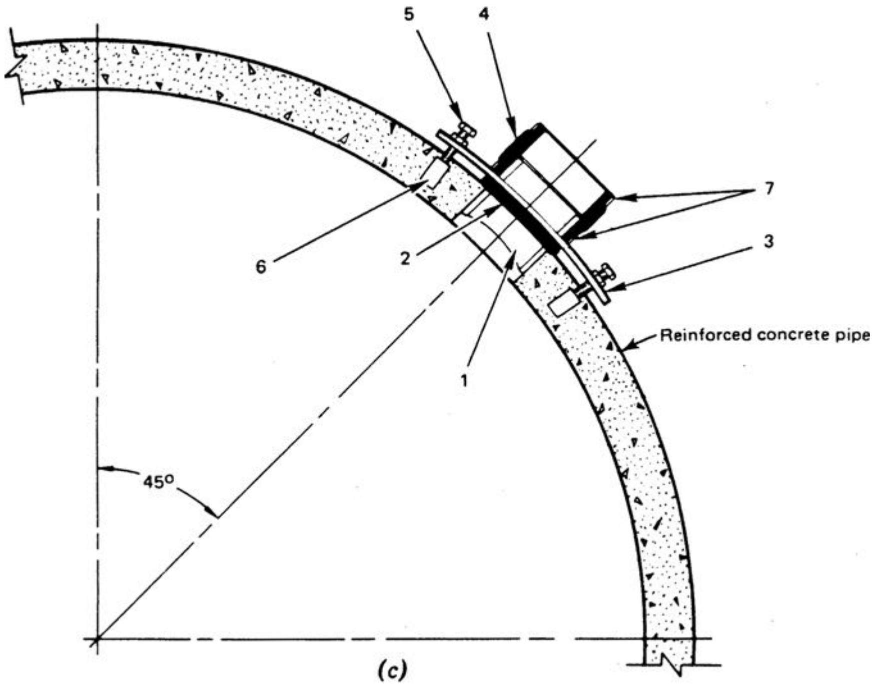


FIGURE 7-9. A–C Various connections to large sewers. A and C courtesy NPC, Inc., Milford, N. H.



1—Acrylonitrile-butadiene-styrene (ABS), PVC, or cast iron (CI) nipple;
2—Large neoprene "donut";
3—Cast ductile flange;
4—Neoprene coupling;
5—Stainless steel nuts, bolts, and washers;
6—Lead lag anchors;
7—Stainless steel clamps.

FIGURE 7-9. (Continued).

usually with regulatory approvals. Building owners who have valuable property in basements that might be flooded usually protect themselves, insofar as possible, by check valves.

7.9. SIPHONS

"Siphon" in sewerage practice almost always refers to an inverted siphon or depressed sewer which would stand full even with no flow. Its purpose is to carry the flow under an obstruction, such as a stream or depressed highway, and to regain as much elevation as possible after the obstruction has been passed.

7.9.1. Single- and Multiple-Barrel Siphons

Siphons are often constructed with multiple barrels. The objective is to provide adequate self-cleansing velocities and maintenance flexibility under widely varying flow conditions. The primary barrel is designed so that a velocity of 2 to 3 fps (0.6 to 1.0 mps) will be reached at least once each day, even during the early years of operation. Additional pipes, regulated by lateral overflow weirs, assist progressively in carrying flows of greater magnitude (i.e., maximum dry-weather flow to maximum storm flow). The overflow weirs may be considered as submerged obstacles, causing loss in head as flow passes over them. The weir losses may be assumed equal to the head necessary to produce critical velocity across the crest. Weir crest elevations are dependent on the depths of flow in the upstream sewer for the design quantity increments. Sample crest length calculations are presented in textbooks (Fair and Geyer 1954).

Many engineers maintain that for sanitary sewers there is usually no need for multiple barrels. They reason that solids which settle out at low flows will flush out when higher flows are obtained, except for those heavy solids that would accumulate even at high flows. Single-barrel siphons generate less sulfide and cause less loss of hydraulic head than do multiple barrels. Single-barrel siphons have been built with diameters ranging from 6 to 90 inches (150 to 2,300 mm) or more. Engineers holding to this concept generally favor a small barrel if initial flows are to be much lower than in later years, with a larger barrel constructed at a later date or constructed at the outset and blocked off so that it can always operate as a single-barrel siphon. In some situations a spare barrel may be desirable purely for emergency or maintenance use.

7.9.2. Profile

Two considerations that govern the profile of a siphon are provision for hydraulic losses and ease of cleaning. The friction loss through the barrel will be determined by the design velocity. For calculating this head loss, it is advisable to use a conservative Hazen-Williams friction coefficient of 100 (Manning *n* from 0.014 for small sizes to 0.015 for the largest). In the case of multiple-barrel siphons, additional losses due to side-overflow weirs must be considered.

Siphons may need cleaning more often than gravity sewers. For easy cleaning by modern methods, the siphon should not have any sharp bends, either vertical or horizontal. Only smooth curves of adequate radius should be used. The rising leg should not be so steep as to make it difficult to remove heavy solids by cleaning tools that operate hydraulically. Some agencies limit the rising slope to 15%, but slopes as great as 50% (30 degrees) are used in some places. There should be no change of pipe diameter within the length of a barrel since this would hamper cleaning operations.

The engineer should also incorporate the use of gates and/or stop logs at the opening of each siphon pipe. This facilitates easy isolation of one of more of the pipes for future cleaning operations.

7.9.3. Air Jumpers

Positive pressure develops in the sewer atmosphere upstream from a siphon because of the downstream movement of air induced by the sewage flow. In extreme cases, this pressure may equal several inches (centimeters) of water. Air therefore tends to exhaust from the manhole at the siphon inlet, escaping in large amounts even from a pick hole. Under all except maximum flow conditions, there is a drop in water surface elevation into a siphon, with consequent turbulence and release of odors. The exiting air can thus be the cause of serious odor problems. Conversely, air is drawn in at the siphon outlet.

Attempts to close the inlet structure tightly will usually force the air out of plumbing vents or manholes farther upstream. Insofar as the attempt to close the sewer tightly is successful, oxygen depletion in the sewer atmosphere occurs, aggravating sulfide generation where this is a problem.

To overcome this difficulty, a number of siphons built in recent years have used air jumpers (i.e., pipes that take the air off the top of the inlet structure and return it at the end of the siphon). Usually, the jumper pipe is one-third to one-half the diameter of the siphon. Sometimes the pipe can be suspended above the hydraulic grade line of the sewer, but in other cases it must run more or less parallel to the siphon. In these cases, provision must be made for dewatering the jumper; otherwise it will fill with condensate. In some cases a drain has been installed to a percolation pit. One large air jumper in use consists of 48-inch- (1,200-mm)-diameter pipe paralleling a 90-inch- (2,300-mm) siphon, 2,000 ft (610 m) long, utilizing a sump pump for dewatering.

7.9.4. Sulfide Generation

Sulfide may be produced in a long siphon. There is nearly always a hydraulic jump or turbulence at a siphon inlet, which causes absorption of oxygen and delays the onset of sulfide buildup in comparison with pressure mains that lack this initial aeration. Thus, sulfide buildup may be delayed for as much as an hour if the wastewater is of low temperature or low biochemical oxygen demand (BOD). When higher temperatures prevail, and especially if oxygen absorption at the inlet is minimal, sulfide buildup may be underway in 20 minutes. For any given flow and wastewater characteristics, the sulfide concentration produced in a filled pipe is roughly proportional to the pipe diameter. (For further details, see Chapter 4.)

7.10. FLAP GATES OR DUCKBILL VALVES

Flap gates or duckbill valves are installed at or near sewer outlets to prevent back-flooding of the sewer system by high tides or high stages in the receiving stream. These are common only in combined or storm sewers.

Duckbill valves are made of elastomers which are not susceptible to corrosion. They are commercially available in sizes up to 96-inch (2,438-mm) diameter. The valves have been found to be self-cleansing.

Flap gates may be made of wood, cast iron, or steel. They are commercially available in sizes up to 8 ft (2.4 m) in diameter. Larger gates can be fabricated from plates and structural shapes. They should be hinged by a link-type arrangement which allows the gate shutter to seat more securely. Hinge pins, linkages, and seats should be corrosion-resistant.

The maintenance of flap gates requires regular inspection and removal of debris from the pipe and outlet chamber, lubrication of hinge pins, and cleaning of seating surfaces.

7.11. SEWERS ABOVE GROUND

Occasionally, in rolling or hilly terrain, it is desirable and economical to build sewers above the surface of the ground or across gullies and stream valleys. Such sewers often are constructed in carefully compacted fill. Sometimes it is better to suspend a sewer over a waterway or a highway than to go under it by means of an inverted siphon. Sewer crossings in such cases have been constructed by installing or hanging the pipes on bridges, by fastening them to structural supports which rest on piers, by supporting them with suspension spans and cables, and by means of sewer pipe beams.

Structural design of suspended sewers is similar to that of comparable structures with supporting members of timber, steel, or reinforced concrete. Foundation piers or abutments should be designed to prevent overturning and settlement. The impact of flood waters and debris should be considered.

If the sewer is exposed, as on a trestle, steel pipe may be used with coating and lining for corrosion protection. Sometimes sewers of other materials are carried inside steel pipes. The steel pipe may be supported by simple piers at suitable intervals.

In recent years, prestressed concrete pipe beams have been used to span waterways and other obstacles. Generally, they have been of three types:

1. A rectangular section with a circular void extending the full length of member, either pretensioned or post-tensioned, and similar to a hollow box highway girder. This section is normally used for smaller sewers.

2. A pretensioned circular pipe section which may be produced in most any diameter. This type is economical for long crossings.
3. Reinforced concrete pipe sections assembled and post-tensioned to form the required sewer pipe beam. These beams may be fabricated economically using standard pipe forms and prestressing equipment. The pipes are cast with longitudinal cable ducts in the walls. After curing, the pipes are aligned and post-tensioning cables are inserted and jacked to the design tension, and anchored. Pressure grouting of the ducts completes the manufacture and the sewer beam is then shipped to the job site for installation.

Protection against freezing and prevention of leakage are important design and construction considerations for aboveground sewers. It has been found necessary in some designs to employ expansion jointing between aboveground and belowground sewers. Special couplings are available for such purposes. Anchorage provision also must be made to prevent permanent creep. Expansion joints in sewers supported on bridges or buildings should match the expansion joints in the structures to which the sewer is attached.

7.12. UNDERWATER SEWERS AND OUTFALLS

7.12.1. Ocean Outfalls

Communities adjacent to a seacoast may discharge their treated wastewater into the ocean. Disinfected secondary effluents generally are discharged relatively close to shore but usually beyond the distance designated for body contact. Primary effluents are carried far enough to sea to avoid any undesirable effects. In the United States, with very few exceptions, all ocean discharges must have secondary treatment, but this is not the usual policy in other countries where the discharge of primary effluent is considered satisfactory if suitable depths and distances are reached.

For proper design, it is essential to obtain detailed data on the following:

- Bathymetric profiles of possible outfall routes.
- Nature of the ocean bottom.
- Water density stratification or thermoclines, by seasons.
- Patterns of water movement at point of discharge and travel time to shore.

Since seawater is 2.5% denser than sanitary wastewater, the discharged wastewater rises rapidly, normally producing a boil at the surface. The rising plume mixes with a quantity of seawater, which is generally from

10 to 100 or more times the wastewater flow. Dilution increases rapidly as the wastewater field moves away from the boil. The required length and depth of the outfall is related to the degree of treatment of the wastewater. The length must be calculated so that time and dilution will adequately protect the beneficial uses of the adjacent waters.

Much research has been done regarding the dilution of the wastewater and the die-away of the bacteria (Rawn and Palmer 1930; Brooks 1960; Abraham 1963; Pomeroy 1960; Pearson 1956; Gunnerson 1961). A full treatment of that subject is beyond the scope of this Manual.

Where the outfall is deep and there is good density stratification (thermocline), the rising plume may pick up enough cold bottom water so that the mixture is heavier than the surface water. The rising plume therefore stops beneath the surface or reaches the surface and then resubmerges.

Diffusers may be used to gain maximum benefit of density stratification. If, however, they merely divide the flow into many small streams in a small area (a gas burner type of diffuser), they do little good. The flow must be dispersed widely so that huge flows of dilution water can be utilized at low velocity.

The diffuser must be approximately level if it is to accomplish reasonably uniform distribution. For design of the diffuser, the rule of thumb may be used that the total cross-sectional area of the ports should not be more than half the cross-sectional area of the pipe. In large diffusers, often exceeding 0.6 miles (1 km) in length, the diffuser diameter may be stepped down in size toward the end (Rawn et al. 1960). Computerized calculations are used in the design of these large diffusers.

These principles are well-illustrated by the Los Angeles City outfall in Santa Monica Bay, California. The effluent is carried by a 12-ft- (3.7-m)-diameter pipe to a point 5 miles (8 km) from shore at a depth of 190 ft (58 m), then dispersed through a Y-shaped diffuser with the two arms totaling 8,000 ft (2,400 m) in length. Except for certain periods in winter when the thermocline is practically nonexistent, no wastewater can be seen rising to the surface. The flow of effluent, which has been upgraded to full secondary standards, exceeds 340 mgd (14 m^3/sec), yet the bathing waters of the highly popular beaches on the Bay show no bacterial evidence of the wastewater discharge.

Ocean outfalls require specialized design expertise; however, a general overview is provided here. Outfalls into the open ocean generally are buried to a point where the water is deep enough to protect them from wave action, hydrodynamic forces, and shifting bottom sands—usually about 30 ft (10 m). Trenches in rock are formed by blasting. Beyond the buried portion, the outfall rests on the bottom, with a flanking of rock to prevent currents from undercutting it where the bottom is soft.

Ocean outfalls in the smaller sizes are now usually made of steel pipe, mortar-lined and coated. Steel pipes are welded and usually can be