12. Design of plumbing systems for single dwellings

12.1 General considerations

A single dwelling is a building designed for a single family or a group living as a family. It may be a house of one storey or more (whether detached or part of a terrace or block) or a self-contained apartment, and it has its own separate water and drainage connection. All pipes carrying either water or wastes should be watertight, durable and have a smooth and unobstructed interior. In order to avoid the risk of cross-contamination, the drinking-water supply from the water main and the drain connection to the public sewer should be separated. If for some reason water service and drainage pipes must be laid in the same trench, the water pipe should be laid on a firm shelf dug along one side of the common trench and should be at least 50 centimetres (20 inches) above the drain throughout its length, and both pipes should be laid with a minimum number of joints. Care should be extended to ensure that the water main is deep enough to prevent freezing in climates with low ambient temperatures.

Pipes need to be adequately protected against stresses caused by settlement or movement of ground where they pass into the building or under any interior wall. They should not be rigidly built into the structure, but should be separated by a layer of sand or flexible filler that can absorb stress due to unequal settlement.

The water service should be controlled by a corporation stop connected to the main by use of a special tool, which allows its installation without shutting off the public supply. The corporation stop is usually under the street or sidewalk and reaching the valve would require breaking the pavement. The incoming water service is further controlled by a curb cock typically situated near the point where the pipe crosses the boundary or property line. The curb stop is used to isolate the building from the main for repairs. It is normally placed in a box to allow easy access for opening and closing the valve. A long-handled wrench is the tool normally used to reach the valve. Where there is a serious risk of contamination of the public water mains by backsiphonage, this should be followed by a backflow prevention device. A stop shut-off valve should be located as close as possible to the meter and before any tappings or connections are made.

A drain cock should be positioned so that it allows emptying of all internal piping connected to the mains drinking-water supply. This system connection allows for drainage if the dwelling is left vacant for a period or if pipes need to be

modified or repaired. This is especially important in areas subject to frost. The drain cock should be easily accessible, and ideally it should be fitted with a hose connection to permit the drained water to be led outside the building. If fitted with a hose connection an approved backflow prevention device should be also installed.

12.2 Domestic storage tanks

There is considerable debate over the desirability in distributed water systems of domestic storage tanks or cisterns. An argument in favour of domestic storage is that it provides an air break that virtually excludes the possibility of back-siphonage and contamination of the public mains. Without this air break it is possible for contamination to occur whenever the mains pressure is reduced. In the event of temporary stoppage of mains supply (due to planned stoppages, breakdown or repairs), sufficient water is stored in the tank to provide domestic supply for a short period. The major disadvantage is that these tanks can become contaminated. Where distribution systems work without intermittency and the authority ensures a continuous positive pressure fixtures connected directly to the incoming water service pipe should be preferred, avoiding the need for a tank.

Tanks should always be covered by a close-fitting lid having an overlap to prevent its displacement, but not so airtight that air pressure can build up when the water level fluctuates within the tank (Taylor & Wood 1982). Those located below or at ground level are at special risk, as are those whose contents can be removed by dipping with a container. They should be inspected periodically and disinfected. Chlorine is frequently used but other approved disinfectants may also be effective.

In addition the pressure on plumbing fixtures remains constant despite fluctuations in the mains pressure. This is especially important where heaters or washing machines may be used.

An overflow pipe of at least 50 millimetres (2 inches) diameter must be fitted to every tank, and the tank and the overflow pipe should be fitted with insect screening. The internal diameter of the overflow pipe should be sized to accommodate the possible flow of water due to complete failure of the inlet valve. Possible restrictions caused by the insect screen should be taken into consideration. Enough space should be allowed to permit the water to rise to a height of at least twice the diameter above the top of the overflow without spilling. The ball valve inlet should be not less than 75 millimetres (3 inches) above the top of the overflow, thus providing an air break between the inlet pipe and the water in the tank.

The outlet(s) from the storage tank to the plumbing system should be taken from at least 50 millimetres (2 inches) above the floor of the tank, and should be controlled by a stop valve (or valves) at the first accessible point within the

dwelling. A separate drain should be set at the bottom of the tank and controlled by a valve to permit complete emptying of the tank. The diameter of the incoming service pipe should remain constant between the drain cock and the storage tank.

In a house with a pitched roof it is usual to locate the tank within the rafters, provided there is sufficient access to permit inspection, cleaning and repairs. For any roof mounting, the structure must be strong enough to carry the weight of the full tank. A full 500-litre (130 US gallons; 110 UK gallons) tank will weigh more than 500 kilograms (0.5 tonne). Sometimes it may be necessary to distribute the load by interconnecting two or more smaller tanks, but this should be avoided because of the potential that the water could stagnate (especially in the absence of residual disinfectant), thus causing excessive growth of heterotrophic bacteria (Bartram et al. 2003). If tanks are joined together, the inlets and outlets should permit a good throughflow of water to help delay or prevent stagnation. A single ball valve may serve to control the water level in both but each should have its own overflow pipe. In areas subject to extreme heat (> 20 °C) or cold (< 4 °C), tanks need to be insulated adequately. In a self-contained apartment it may be necessary to mount the tank near to the ceiling, such as inside an airing cupboard. A drip tray of adequate size below will collect condensation or leakage resulting from failure of the tank itself.

Some authorities may specify a standard tank size based upon the number of occupants and fittings, and the expected consumption per person (see Table 11.1). Thus, in an area where the daily water consumption is assumed to be 80 litres (20 US gallons; 18 UK gallons) per adult and 40 litres (10 US gallons; 9 UK gallons) per child, a dwelling capable of housing five adults would need a tank with a capacity of 400 litres (100 US gallons; 90 UK gallons). An apartment designed for two adults and one child would require a storage capacity of only 200 litres (50 US gallons; 45 UK gallons).

While tanks should be sufficiently accessible to permit maintenance, cleaning and adjustment of the ball valve when necessary, they should never be so placed that water can be withdrawn manually by the householder through dipping or ladling, because this would make it much more vulnerable to microbial contamination.

The sink tap connected directly to the main is doubly vulnerable to the possibility of water used for drinking or food preparation becoming contaminated within the building plumbing system. When this connection is permitted, it should be protected by an approved air gap or backflow protection device or an air gap between the outlet of the tap and the overflow level of the fixture or sink.

12.3 Domestic water closets

Table 11.2 lists diameters for connections from the water line or storage tank outlet to the various plumbing fixtures. Water closets should each be provided with a flushing cistern with an internal or external overflow controlled by a ball

valve or a similar device. Properly designed flushing cisterns deliver a fixed quantity of water in a short period, and refill at a steady rate through an inlet valve. The air break in the cistern provides an additional health safeguard.

Some authorities permit the use of flushometer valves instead of flushing cisterns for domestic water closets. However, these contribute to excessive water use. Pipes of a greater diameter are required to give a complete flush, and this may add to the cost. Flushometer or flush valves are also pressure and flow dependent and have maximum and minimum operating parameters. Overflows, normally at least twice the diameter of the inflow inlet pipe, should be taken through the wall to discharge outside. They should not discharge into the closet bowl because leakage often goes undetected. Overflow pipes should be located so as to provide a visible warning that the ball valve is not operating properly to cut off the incoming supply.

The inlet valve itself should be set higher than the top of the overflow pipe, the vertical separation being at least one and a half times the diameter of the overflow.

12.4 Wastewater traps

The outlet from every plumbing fixture should be trapped separately by a water seal device with a liquid seal of not less than 50 millimetres (2 inches) and not more than 100 millimetres (4 inches) in depth. Self-sealing waste valves may also be appropriate for this purpose. The pipe leading from the trap needs to have a diameter at least equal to that of the trap itself. The requirement that each plumbing fixture should be equipped with its own separate trap may be relaxed under certain circumstances, notably when combination fixtures are used, such as prefabricated units incorporating shower, washbasin, sink or other fixtures. It is sometimes allowable to install separate fixtures of this nature and combine the untrapped outlets into a single trap serving all. Under no circumstances should a water closet be part of such an arrangement; it is better to insist upon individual trapping. The amount of money saved by combining outlets is small, and the drains above the trap are more subject to clogging and the emission of foul odours due to the deposition of grease or soap on the wall of the pipe.

Sinks, washbasins and similar fixtures should incorporate overflows that discharge into the waste pipe below the stopper and above the outlet trap. Washbasins and similar fixtures may incorporate integral or attached overflows to discharge into the fixture waste pipe above the water seal of the trap and below the drain plug or stopper to the fixture. Sinks used in food preparation areas should not be fitted with overflows as they can become an entrapment area for food particles and a breeding ground for microorganisms and vermin. The outlet from a water closet should be not less than 75 millimetres (3 inches) in diameter.

Other domestic fixtures should have outlets of at least the following dimensions:

- washbasin, bidet or dishwasher: 32 millimetres (1.25 inches);
- sink or shower: 40 millimetres (1.5 inches).

Note: Some codes of practice require that a shower drain may not be less than 50 millimetres (2 inches) in diameter.

Each fixture should have a grille or strainer to prevent solids, such as hair and pieces of soap, from entering and choking the trap. The grille or strainer should be easily removed in case a child's finger becomes trapped.

12.5 Drains and ventilation pipes

The vertical ventilation or stack pipe is an essential feature of all plumbing systems. It prevents foul odours from the drain entering the building and also provides outlet to the open air. It also ensures that neither vacuum nor pressure can build up in the drainage system that might suck or blow the liquid seal from the fixture traps. There is no significant health difference between systems with exterior stacks and those with interior or concealed stacks. When plumbing is to be installed in existing buildings not already equipped with plumbing systems, installation may be simpler and less expensive if external stacks are allowed.

In some locations the most common method of installing the stack pipe in single dwellings is by mounting it outside against the exterior wall of the building. The weight of the pipe is supported at the lower end by a radius bend, set into a block of concrete adjacent to the building foundation. Its upper end is taken through or around the eaves (of a sloping roof) and extended upward at least 0.3 metre (1 foot). The water closet is located inside and adjacent to the exterior wall and its outlet carried through the wall to join the stack pipe at a junction fitting. Provision should be made to permit thermal movement between different plumbing materials, fixtures, pipes and fittings and the infrastructure of buildings into which such materials are installed. Of particular importance is pipework between fixed points that need to incorporate stress relief points and flexible joints to prevent failures to the plumbing system itself or the host structure.

The use of exterior stack pipes of this nature is not universal. In cold climates the danger of blockage or fracture from freezing prevents their use, and it may be necessary to keep all drainage within the building using a one-pipe system, as described later in this document. However, air admittance valves may also be used in primary or secondary ventilated systems, provided they are used within their application limits (see section 6.2.4). Exterior stacks may also be considered an eyesore, and the authority may require that the stack be installed within a wall where it cannot be seen except for the section that projects through the roof. An interior stack should be tested for not less than 15 minutes and visually examined to ensure that all joints are watertight prior to the application of the wall finishing material that will conceal the piping. This may be done by closing all outlets except the highest and completely filling the stack with water. If leaks are

detected, the water should be drained from the stack, the leak repaired and the system retested until no leaks are evident. If leaks do occur in concealed pipes, a foul odour may be the only indication that a pipe is not watertight or gasproof. Exterior pipes reduce the risk of leakage going undetected and are far more accessible if repairs are necessary.

As indicated earlier, the upper end of any type of stack should be at least 0.3 metre (1 foot) above roof level. If the roof is flat and accessible this height should be increased to at least 2 metres (6 feet). The stack pipe should be well clear of windows or fresh-air inlets, and should be protected by a wire cage to stop birds nesting in it. Where it is impossible to carry any internal stack above roof level it may be taken through the outside wall of the building and carried upwards to terminate at least 3 metres (10 feet) horizontally from or 0.75 metre (2.5 feet) above any window or other opening of the building or of any adjacent building. No vent pipe, either above the roof or through the wall, should be used for any other purpose, such as supporting an antenna, stay wire or other structural fixture.

Water closets should be connected to the horizontal drain leaving the building by the shortest possible route. For dwellings more than one storey high, the drain from a water closet on the upper floor should descend vertically, the upper part of this vertical pipe being carried upward to terminate in the open air above roof level. In single-storey buildings a vertical ventilation pipe should be carried upward from the top of the drain as close as possible to the outlet from the water closet. The connection of the water closet outlet to the stack pipe should be by means of a junction fitting. Where the water closet bowl is set on a rigid floor such as concrete, the pipe connecting it to the stack may be of rigid material with cement mortar or other solid jointing. Where the floor is of wood or other resilient material, either the pipe must be of plastic or of similar non-rigid composition or the joint between the bowl and the outlet pipe must be flexible, otherwise there is a danger of the bowl snapping.

Where in a single-storey building the stack is carried upward from the top of the water closet outlet pipe, the weight of the vertical stack must be either supported independently or a concrete base block must be provided to prevent deformation or crushing of the horizontal outlet pipe. At the bottom of the stack pipe a radius bend (to prevent clogging) leads the water closet outlet to the head of the horizontal drain connecting with the public sewer.

Outside the building at least one watertight inspection point or access chamber should be constructed; this should have a rigid cover capable of bearing any loads that it is exposed to. This access chamber serves several purposes:

- It gives an access point from which the drains can be inspected and rodded (both towards and away from the building).
- It provides a point from which tests can be applied to the drainage element of the plumbing system.

- It forms a junction into which the drainage from other plumbing fixtures may be brought to discharge into the horizontal drain. If more than one water closet is installed in the building the junction between them must also be made in the access chamber.

An additional access chamber should be constructed wherever there is a change of direction or gradient of the horizontal drain, a junction of two drains or a length of drain of more than 30 metres (100 feet).

When the two-pipe system with exterior stack pipes is used, the outlets from fixtures other than water closets should be carried outside the building and discharged into the horizontal drain at an inspection joint or access chamber. Relaxation of this condition is sometimes permitted where, for example, a single washbasin or similar fixture is to be connected directly to a stack or horizontal section of the drainage system within the building. In such cases a properly made fitting with no interior obstruction that might cause clogging should be used, and any connection to a horizontal section should be made at the top of the pipe. Clean-outs should be provided to enable all parts of the connection to be rodded.

Formerly it was considered necessary for an interceptor chamber, boundary trap or access chamber with a trapped outlet to be constructed at the last point on the property before the horizontal drain crossed the boundary. Some authorities still make this mandatory. Occasionally a fresh-air inlet is also required, but modern practice omits the need for this trap in the drain provided the plumbing system is ventilated as described above.

12.6 Connections to the public sewer

The wastewater drain should terminate at the public sewer where it is connected by a branch fitting or by a saddle jointed to the upper part of the pipe. The sewerage authority will often have its own regulations for jointing to the sewer. The actual jointing operation is frequently carried out by staff employed by the authority (the cost being charged to the owner of the building). In some cases the authority will construct the entire drain system from the property boundary to the sewer. Much will depend on whether the authority takes over ownership and responsibility for maintenance of this part of the drain. The plumbing code of practice should specify the respective responsibilities of authority and owner in this matter.