7 Soil and waste systems

Learning objectives

Study of this chapter will enable the reader to:

1. define the parts of waste and drain systems;
2. understand the type of fluid flow in a waste pipe;
3. explain the ventilation requirements of drainage pipes;
4. list and explain the ways in which the water seal can be lost from traps;
5. know the permitted suction pressure in a waste system;
6. understand air pressure distribution in a stack;
7. know how to connect waste pipes into a stack;
8. know the diameters, slopes and maximum permitted lengths of waste and drain pipes for above-ground systems;
9. know how to design waste and drain pipes for ranges of sanitary appliances;
10. design domestic, high-rise and commercial building waste installations;
11. understand and use discharge units for pipe sizing;
12. explain the uses of different materials and jointing methods;
13. understand how drain systems are tested;
14. explain how drain systems are maintained.

Key terms and concepts

access 208; air pressure 206; air static pressure 207; blockage 217; connection to stacks 207; discharge stack 207; discharge units 214; drain 208; flow surge 206; grease and residues 217; induced syphonage 209; inspection 216; lime scale 217; maintenance 217; materials and jointing 215; ranges of appliances 213; rodding 217; self-syphonage 206; sewer 207; slope 207; smoke 216; solid deposition 211; testing 216; trap 207; trap seal loss 209; vented systems 214; waste pipe 206; water 206; water seal 207.

Introduction

The terminology of drainage systems is outlined and then the characteristic flow within the pipework is explained. Understanding how fluid flows through waste and drain pipework is fundamental to correct design.

The potential for water seal loss in traps beneath sanitary fittings and the deposition of solids in long sloping drains is examined.

Various standard pipework layouts for above-ground systems are shown. The fluid flow through drain pipes is subject to diversity in timing and duration, as are the hot- and cold-water supplies to the same appliances. However, the characteristic flows into and out of the appliance are not the same, and the use of discharge units for drains is explained.

The materials and jointing methods used for pipework are demonstrated, as are the testing and maintenance procedures.

Definitions

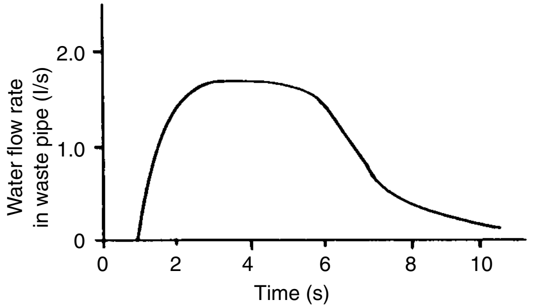
The following terms are used.

Bedding: material around a buried pipeline assisting in resisting imposed loads from ground and traffic.
Benching: curved smooth surfaces at the base of manholes, which assist the smooth flow of fluids.
Combined system: a drainage system in which foul and surface-water are conveyed in the same pipe.
Crown: the highest point on the internal surface of a pipe.
Discharge stack: vertical pipe conveying foul fluid/solid.
Foul drain: a pipe conveying water-borne waste from a building.
Foul sewer: the pipework system provided by the local drainage authority.
Invert: the lowest point on the internal surface of a pipe.
Manhole: an access chamber to a drain or sewer.
Separate system: a drainage system in which foul and surface-water are discharged into separate sewers or places of disposal.
Stack: vertical pipe.
Subsoil drains: a system of underground porous or un-jointed pipes to collect groundwater and convey it to its discharge point.
Surface-water drain: a pipe conveying rain water away from roofs or paved areas within a single cartilage.
Surface-water sewer: the local authority pipework system.
Waste pipe: pipe from a sanitary appliance to a stack.

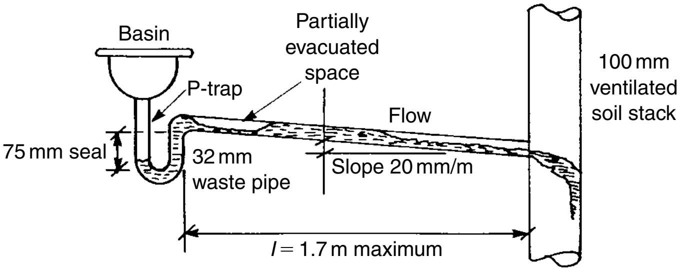
Fluid flow in waste pipes

The discharge of fluid from a sanitary appliance into a waste, soil or drain pipe is a random occurrence of short duration exhibiting a characteristic curve similar to that shown in Fig. 7.1.

Flows in waste pipes occur as surges, or plugs of fluid, which last for a short time. The pipe flows full at some time and a partially evacuated space appears towards the end of discharge, as shown in Fig. 7.2. Separation between the water attempting to remain in the P-trap and the plug falling into the soil stack causes an air pocket to form. The static pressure of this air will be subatmospheric. Air from the room and the ventilated soil stack bubbles through the water



7.1 Discharge of water from a sanitary appliance.



7.2 Design of a basin waste pipe to avoid self-syphonage.

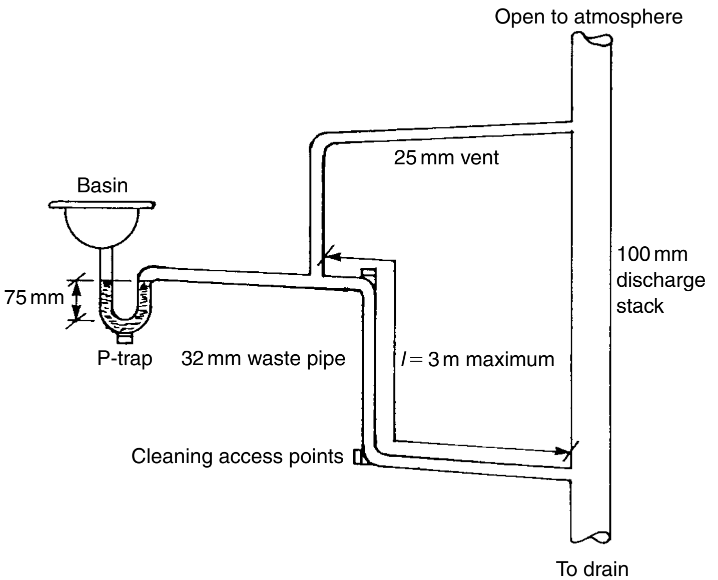
to equalize the pressures and a noisy appliance operation results. The inertia of the discharge may be sufficient to syphon most of the water away from the trap, leaving an inadequate or non-existent seal. The problem is avoided by using 32 mm basin waste pipes when the length is restricted to 1.7 m at a slope of 20 mm/m run, about 1°.

The sloping waste pipe can be up to 3 m long if its diameter is raised to 40 mm after the first 50 mm of run. This allows aeration from the stack along the top of the sloping section. Longer waste pipes with bends and steeper or even vertical parts have a 25 mm open vent pipe as shown in Fig. 7.3.

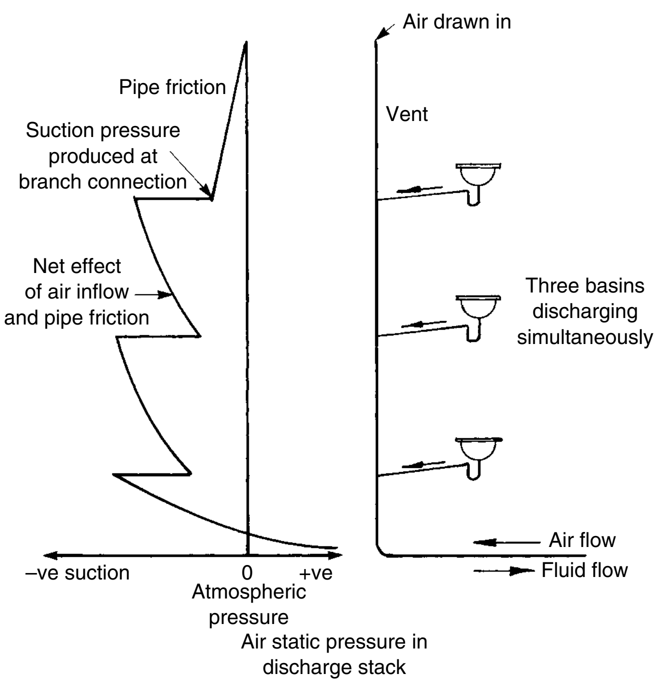
Vertical soil and vent stacks are open to the atmosphere 900 mm above the top of any window or roof-light within 3 m. Underground foul sewers are thus atmospherically ventilated. Water discharged into the stack from an appliance entrains air downwards and establishes air flow rates of up to a hundred times the water volume flow rate. Air flow rates of 10–150 l/s have been measured. The action of water sucking air into the pipe lowers the air static pressure, which is further reduced by friction losses.

Water enters the stack as a full-bore jet, shooting across to the opposite wall, falling and establishing a downward helical layer attached to the pipe surface. Restricted air passageways at such junctions further lower the air static pressure by their resistance to flow. Atmospheric pressure will be re-established at the base of the stack because of the flow of air into the low-pressure region. The falling fluid tends to fill the pipe near the base and positive air static pressures can be generated. Appliances connected to such a region may have their water seals intermittently forced out. Figure 7.4 shows the probable air static pressures during the simultaneous discharge of three appliances.

The pressure gradient shown in Fig. 7.4 can be drawn with the aid of data from experimental work (Wise, 1979). The maximum permitted pressure is −375 Pa as this is equivalent to the



7.3 Vented basin waste pipe.

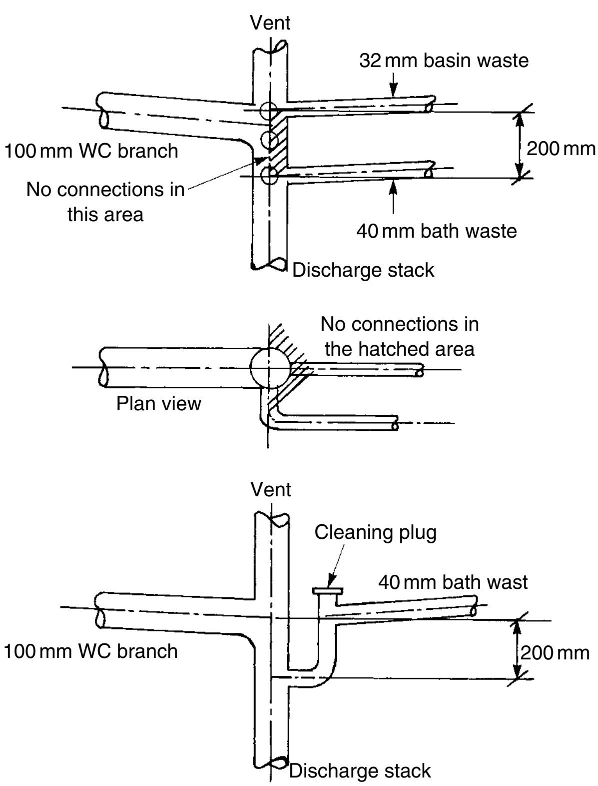


7.4 Air static pressure distribution in soil and vent pipes.

recommended trap depth of 75 mm water gauge for single-stack drain installations. When suction of this magnitude is applied to a 75 mm water seal, some of the water is sucked from the trap, leaving about 56 mm. This is sufficient to stop fumes entering the building.

Loss of water seal from a trap can occur through the following mechanisms.

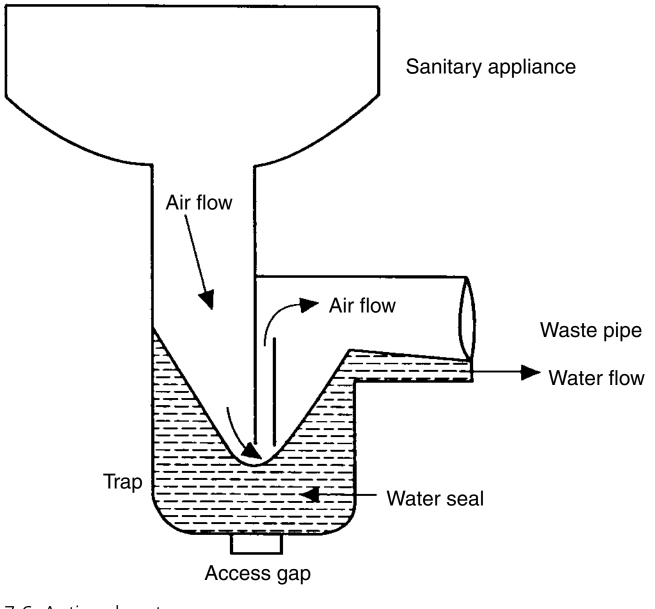
1. Self-syphonage: this can be avoided by placing restrictions on lengths and gradients and venting long or steep gradients.
2. Induced syphonage: water flow past a waste pipe junction in a stack or along a sloping horizontal range of appliances can suck out the water seal. This is overcome by suitable design of the pipe diameters, junction layouts and venting arrangements.
3. Blow-out: a positive pressure surge near the base of a stack could push out water seals of traps connected in that region. Waste pipes are not connected to the lower 450 mm of vertical stacks, measured from the bottom of the horizontal drain.
4. Cross-flow: flow across the vertical stack from one appliance to another. Waste pipes are not connected to soil and vent pipes where cross-flow, particularly from WC branches, could be caused, as shown in Fig. 7.5.
5. Evaporation: this amounts to about 2.5 mm of seal loss per week while appliances are unused.
6. Wind effects: wind-induced pressure fluctuations in the stack may cause the water seal to waver out. The vent terminal should be sited away from areas subject to troublesome effects. Wind-tunnel tests using smoke as a tracer are performed for large developments.



7.5 Permitted stack connections avoiding cross-flow.

7. Bends and offsets: sharp bends in a stack can cause partial or complete filling of the pipe, leading to large pressure fluctuations. Foaming of detergents through highly turbulent fluid flow will aggravate pressure fluctuations. Connections to the vent stack before and after an offset equalize air pressures. A bend of minimum radius 200 mm is used at the base of a soil stack to ensure constant ventilation.
8. Surcharging: an underground drain that is allowed to run full causes large pressure fluctuations. Additional stack ventilation is required.
9. Intercepting traps: where a single-stack system is connected into a drain with an interceptor trap nearby, fluid flow is restricted. Additional stack ventilation is used.
10. Admission of rainwater into soil stacks: when a combined foul and surface-water sewer is available, it is possible to admit rainwater into the discharge stack. Continuous small rainwater flows can cause excessive pressure fluctuations in buildings of about 30 storeys. Flooding of the stack during a blockage would cause severe damage.
11. Pumped or pneumatically ejected sewage lifting: the discharge stack is gravity-drained into a sump, from where it is pumped into a street sewer at a higher level. A separate vent is used for the sump chamber and pumped sewer pipe to avoid causing pressure surges.
12. Capillary: lint or hair remaining in a trap may either block the capillary or empty it. Additional maintenance is carried out in high-risk locations.
13. Leakage: leakage can occur through mechanical failure of the joints or the use of a material not suited to the water conditions.

Figure 7.6 shows the principle of operation of an anti-syphon trap. When excessive suction pressure occurs in the waste pipe, some of the water in the trap is syphoned out. When the central ventilation passage becomes uncovered, it connects the inlet and outlet static air pressures. This returns the waste pipe to atmospheric pressure and the syphonage ceases. Sufficient water remains in the trap to maintain a hygienic seal.



7.6 Anti-syphon trap.

Drainage installations should remove effluent quickly and quietly, be free from blockage, and be durable and economic. They are normally expected to last as long as the building and be replaced only because of changed requirements or new technology. Blockages occur when the system is overloaded with solids, becomes frozen, suffers restricted flow at poorly constructed bends or joints, or has building material left inside pipe runs. Each section of discharge pipework must be accessible for inspection and internal cleaning.

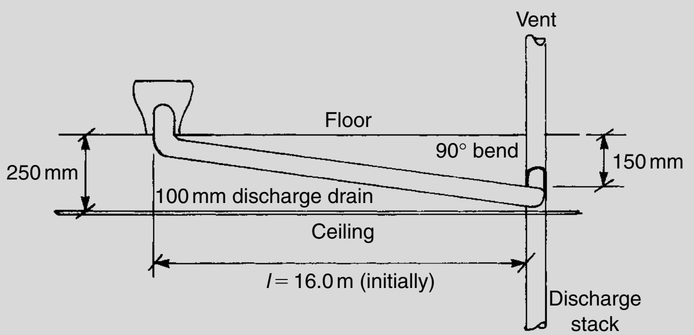
Transport of solids from WCs is the controlling problem in the design, installation and maintenance of sloping drains. Swaffield and Wakelin (1976) showed that, to maintain the flow from a WC and avoid deposition of solids in the drain, the ratio of the length L of sloping drain (metres) to the gradient G must be:

$$\frac{L}{G} = 35^2$$

Pipe bends produce rapid deceleration of solids downstream, followed by velocity regain as the remaining flush water catches up with and accelerates the solids with minimal loss of inertia. When minimum gradients are used, solid deposition could occur at a bend. To avoid this, the equivalent length of a bend can be taken as 5 m of straight pipe in design calculations. Solid deposition can also occur at a top entry into a sewer. Branch connections should be at 45° to the horizontal.

EXAMPLE 7.1

A WC is to be connected to a 100 mm soil stack, which runs in a 250 mm deep service duct formed from a false ceiling. It is intended that the WC be 16 m from the stack. There is a 90° bend just before the drain enters the stack. Determine whether the proposed layout will be satisfactory. Figure 7.7 shows the intended arrangement.



7.7 Sloping drain in a false ceiling for Example 7.1.

The allowed fall will be approximately 150 mm, subject to free available passage. The equivalent length of the sloping drain is $(L + 5)$ m. Then the gradient is:

$$G = \frac{0.15}{L\,m}$$

The intended conditions are:

$$G = \frac{0.15}{16} = 0.009375$$

and,

$$L = 16 + 5 = 21 \text{ m}$$

Using $L/G = 35^2$ for an equivalent length of 21 m the gradient cannot be less than:

$$G = \frac{L}{35^2} = \frac{21}{35^2} = 0.01714$$

The intended gradient is less than the minimum allowable gradient and so the design must be modified.

Assuming that the WC can be brought nearer to the stack, how far away can it be? There are two conditions to be met:

$$G = \frac{0.15}{L} \quad (7.1)$$

$$\frac{L+5}{G} = 35^2 \quad (7.2)$$

Substitute equation (7.1) into equation (7.2) to eliminate G:

$$(L+5) \times \frac{L}{0.15} = 35^2$$

This can be rearranged to:

$$L^2 + 5L = 183.75$$

$$L^2 + 5L - 183.75 = 0$$

This is a standard quadratic equation of the form,

$$ax^2 + bx + c = 0$$

where $x = L$, $a = 1$, $b = 5$ and $c = -183.75$. The solution of the quadratic is:

$$x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

Therefore

$$L = \frac{-5 \pm \sqrt{[5^2 - 4(-183.75)]}}{2}$$
$$= -5 \pm \sqrt{\frac{760}{2}}$$
$$= 11.284 \text{ m}$$

Thus, if the WC is situated 11 m from the stack, the installed gradient of $0.15/11 = 0.014$ is steeper than that required by the design guide ($L/35^2$):

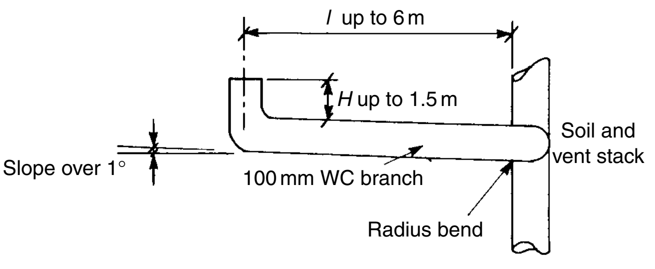
$$G = \frac{11 + 5}{35^2} = 0.013$$

and hence solid deposition should not occur.

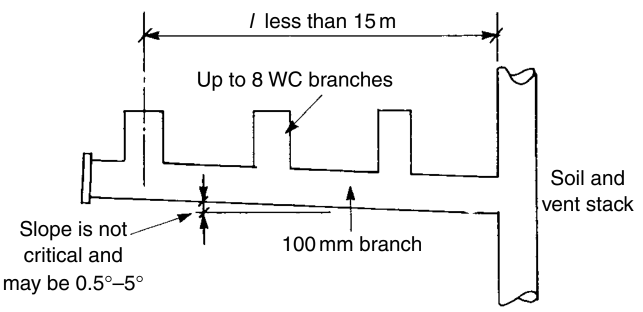
Pipework design

The arrangement of pipework (Building Research Establishment Digest 205, 1977) for various sanitary appliances is shown in Figs 7.8–7.12.

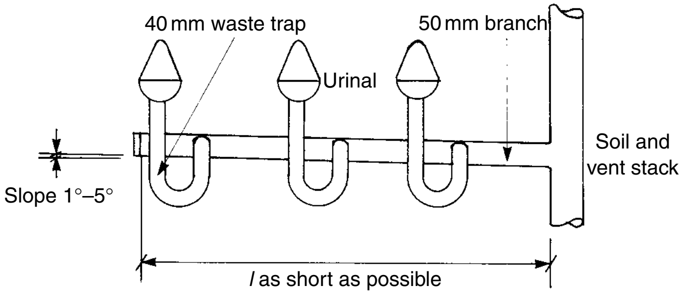
Groups of appliances for dwellings are depicted in Figs 7.13 and 7.14. A pumped WC discharge unit, as shown in Fig. 7.15, enables the use of a 22 mm diameter copper pipe to run long distances, and upwards, to connect into the soil and vent stack at a convenient location.



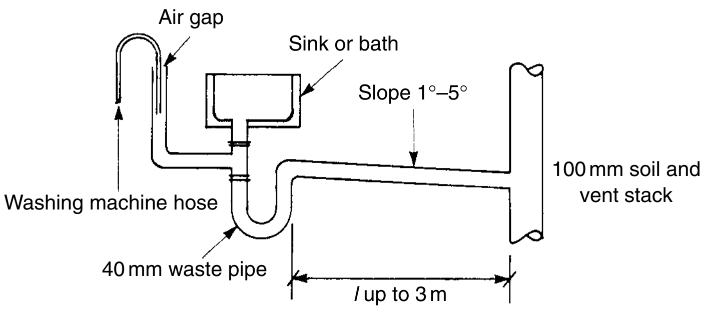
7.8 Branch pipe to a WC.



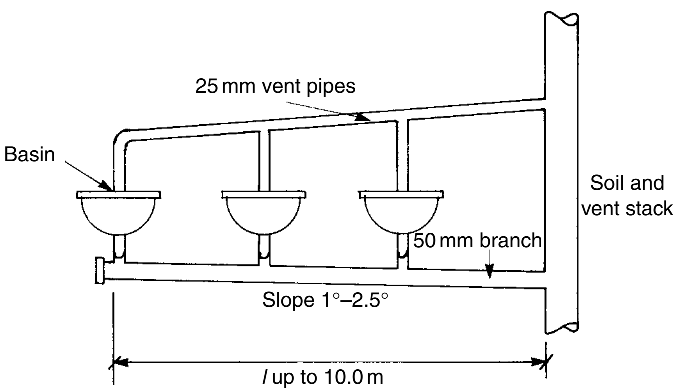
7.9 Branch for a range of WCs.



7.10 Branch for a range of urinals.



7.11 Branch from a sink or bath.

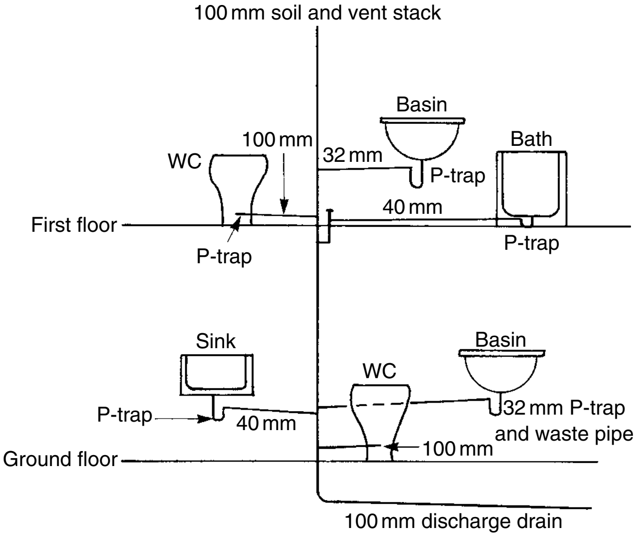


7.12 Branch discharge pipe for a range of up to 10 basins.

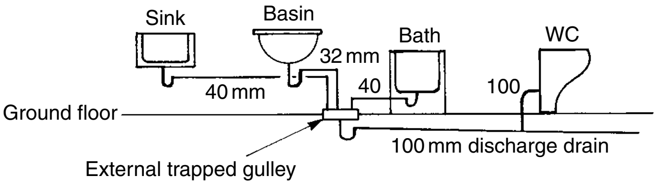
Discharge unit pipe sizing

The intermittency of discharge from appliances necessitates the use of discharge units that relate to the flow volume, flow time and interval between flows from sanitary fittings in a similar way to the demand units for water supplies to such fittings. Typical discharge units are as follows (domestic use): WC, 14; basin, 3; bath, 7; urinal, 0.3; washing machine, 4; sink, 6. A group consisting of WC, bath, sink and two basins has a value of 14 discharge units.

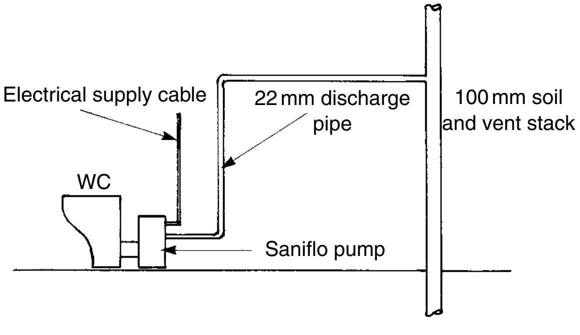
A 100 mm diameter stack can carry 750 discharge units, a 125 mm diameter stack can carry 2500 discharge units and a 150 mm diameter stack can carry 5500 discharge units.



7.13 Soil and vent stack in housing.



7.14 Drainage pipework for a bungalow.



7.15 Pumped WC discharge system.

Materials used for waste and discharge systems

The materials available for waste pipes and soil and vent stacks are listed in Table 7.1.

A clearance of 30 mm should be left between external pipes and the structure to allow free access and for painting. Secure bracketing to the structure is essential and allowance for thermal expansion should be made. Pipes passing through walls or floors should be sleeved with a layer of inert material to prevent the ingress of moisture into the building and provide the elasticity required for thermal movement. This is particularly important with plastics.

Table 7.1 Materials for waste and discharge pipework.

Material	*Application*	*Jointing*
Cast iron	50 mm and above vent and discharge stacks	Lead caulking with molten or fibrous lead; cold compound caulking
Galvanized steel	Waste pipes	BSPT screwed
Copper	Waste pipes and traps	Compression, capillary, silver solder, bronze weld or push-fit ring seal
Lead	Waste pipes and discharge stacks	Soldered or lead welded
ABS	Up to 50 mm waste and vent pipes	Solvent cement and push-fit ring seal
High-density polyethylene	Up to 50 mm waste and ventilating pipes and traps	Push-fit ring seal and compression fittings
Polypropylene	Up to 50 mm waste and ventilating pipes and traps	Push-fit ring seal and compression couplings
Modified PVC	Up to 50 mm waste and vent pipes	Solvent cement and push-fit ring seal
Unplasticized PVC	Over 50 mm soil and vent stacks; vent pipes under 50 mm	Solvent cement and push-fit ring seal
Pitch fibre	Over 50 mm discharge and vent stacks	Driven taper or polypropylene fitting with a push-fit ring seal

Note: ABS, acrylonitrile butadiene styrene; PVC, polyvinyl chloride.

Testing

Inspection and commissioning tests on drainage installations are carried out as follows.

Inspection

During installation, regular inspections are made to check compliance with specifications and codes. Particular attention is given to quality of jointing, security of brackets and removal of swarf, cement or rubble from inside pipe runs.

Air pressure

Prefabricated waste pipe systems will be factory tested before delivery to the site. The complete system will be tested on completion by filling the water seals and inserting air bags, expandable bungs, into the ends of stack pipes. A rubber hose is inserted into the vent stack through a WC water trap. The air pressure in the stack is hand-pumped up to 38 mm water gauge, measured on a U-tube manometer. This pressure must remain constant for 3 min without further pumping. Soap solution wiped onto joints will reveal leak locations.

Smoke

Existing stacks can be tested by the injection of smoke from an oil-burning generator or a smoke cartridge, provided that it will not cause damage to the drain materials. This is less severe than the air test, as smoke pressure remains low and damage from the test itself is less likely. Suitable warnings must be given to the occupants of the building.

Syphonage

The simultaneous discharge of several appliances should reveal a minimum remaining water seal of 25 mm in all traps. Discharge should take place quietly and smoothly.

Maintenance

Periodic inspection, testing, trap clearance, removal of rust and repainting should be a feature of an overall service maintenance schedule. Washers on access covers require occasional replacement. The use of chemical descaling agents, hand or machine-operated rodding and high-pressure blockage removal must be carefully related to the drainage materials and the skill of the operator.

Lime scale removal

Lime scale is found in hard-water areas. A dilute corrosion-inhibited acid-based descaling fluid is applied directly to scale visible on sanitary appliances and is then thoroughly flushed with clean water. The fluid is a mixture of 15% inhibited hydrochloric acid and 20% orthophosphoric acid.

Removal of grease and soap residues

A strong solution of 1 kg of soda crystals and 9 l of hot water is flushed through the system. The soda crystals are mixed with the hot water in a basin. When the soda is fully dissolved, the plug is released. This may be necessary frequently in commercially used appliances.

Blockage

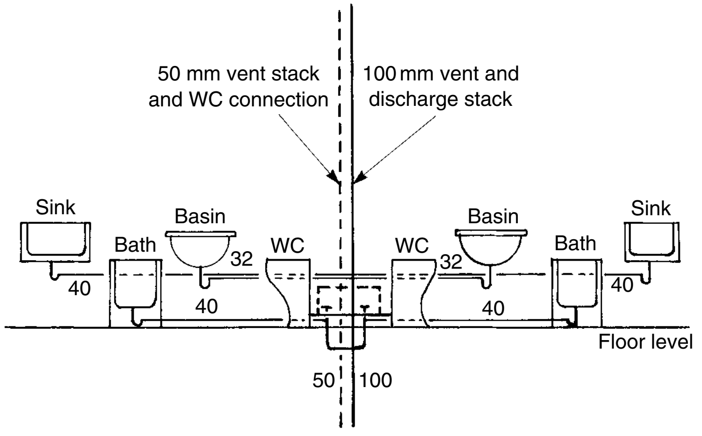
A hand plunger may be sufficient but repeated blockage should be investigated. Hand rodding from the nearest access point can be performed using various tools as appropriate. A kinetic ram gun can be used for blockage in branch pipes. The impact of compressed air from the gun creates a shock wave in the water, which dislodges the solids. However, a blow-back from a stubborn blockage may injure the operator and damage the pipework and therefore the ram gun must be limited to the removal of soft materials. Coring and scraping mechanical tools can be used to remove hard lime scale in 100 mm pipes, provided that the materials will withstand the maintenance operation. A steel cutter is revolved by a flexible drive fed through the drain pipework.

EXAMPLE 7.2

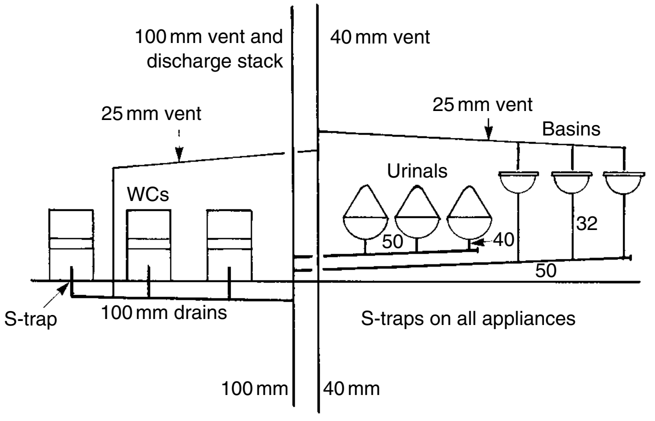
Draw a suitable arrangement of a sanitary pipe system for a 22-storey block of flats with two groups of appliances on each floor. Each group consists of a WC, a bath, a sink and a basin, all sited close to the stack.

$$\text{Discharge units carried by the stack} = (22 \times 2) \text{ flats} \times 14\ DU$$
$$= 616\ DU$$

Therefore a 100 mm soil and vent stack can be used as 750 *DU* is the capacity limit. A typical floor layout is shown in Fig. 7.16.



7.16 Typical floor layout for two flats in Example 7.2.



7.17 Typical floor layout for Example 7.3.

EXAMPLE 7.3

A 14-storey office block is to have ranges of three WCs, three basins and three urinals on each floor. The WCs and urinals are situated on each side of the stack, but the common waste pipe from the basins is to be 5 m long and have four bends. The following discharge units can be assumed: urinal, 0.3; WC, 14; basin, 3. Draw a suitable discharge pipework arrangement and state the pipe sizes to be used.

$$\text{Discharge units carried by the stack} = 14 \times (3 \times 0.3 + 3 \times 14 + 3 \times 3)$$
$$= 727\ DU$$

A 100 mm discharge and vent stack can be used in the arrangement shown in Fig. 7.17. An additional ventilating stack of diameter 40 mm is recommended in BS 5572: 1978, as shown.

Questions

1. List the ways in which an above-ground drainage installation satisfies its functional requirements.
2. Describe, with the aid of sketches, the ways in which the water seal can be lost from a trap and the precautions taken to avoid this happening.
3. Describe the types of fluid flow encountered in drainage pipework.
4. Outline the development of current drainage practice from the early Roman occupation of Britain.
5. State the meaning of the following terms: bedding; combined system; drain; sewer; manhole; separate system; stack; discharge pipe; vent.
6. Sketch the pipework layout for a typical group of sanitary appliances in a dwelling, where they are all connected into a stack. Show suitable pipe sizes, slopes and details of the connections at the stack.
7. A range of WCs is to be connected into a common branch pipe of outside diameter 125 mm fitted within a false ceiling 300 mm deep. It is intended that the furthest WC should be 18 m from the stack. The branch has a 90° bend between the last WC and the stack. Determine whether the proposed arrangement would be satisfactory. If it is not, calculate the maximum distance that could be allowed between the furthest WC and the stack.
8. State the meaning of the term 'discharge unit'. How many WCs can be connected into a discharge stack of diameter 100 mm?
9. Sketch sections through four types of joint used in drainage pipework to show their constructional features, method of providing a seal, and thermal expansion facility.
10. Sketch the installation of a vertical discharge stack within a plasterboard service duct in a house, clearly showing suitable dimensions and support.
11. Sketch and describe the methods of testing above-ground drainage installations.
12. Describe the maintenance work needed to support the efficient operation of drainage installations in residences, laundries, canteens and hotels.
13. Draw a suitable sanitary pipework installation for a 10-storey block of flats with two groups of appliances on each floor connected to one stack. Show pipe sizes and routes.
14. A 20-storey office block is to have ranges of 5 basins, 5 urinals and 5 WCs on alternate floors. Draw a suitable pipework installation, stating pipe sizes and slopes.
15. What is the principle design requirement for waste pipes from water appliances?

    1. Pipes not leaking.
    2. Must empty basin, sink or shower tray within 30 s.
    3. Avoidance of long horizontal pipes.
    4. Never reduce pipe diameter below waste outlet size.
    5. Maintain water seal at trap of each appliance.

16. What type of water flow occurs in the waste pipe from a basin?

    1. Turbulent.
    2. Laminar.
    3. Steady continuous stream along lower half of sloping pipes.
    4. Water swirls clockwise down vertical and along sloping pipes, adhering to the walls of the pipe due to the Coanda effect.
    5. Full-bore surge followed by dribbling.

17. Which of these is a problem that can occur in waste pipe systems?

    1. There are no problems in a correctly designed system.
    2. Pipes installed at too steep an angle create noise and suction problems.

3. Long horizontal waste pipes connecting to vertical stacks do not drain water away fast enough and cause flooding in baths and shower trays.
4. Self-syphonage from the trap due to inertia of water flow.
5. Self-syphonage due to leaks.

18. Which is a cause of induced syphonage in a waste pipe?

    1. Positive back-pressure from downstream pipes.
    2. Low atmospheric air pressure.
    3. Waste pipes running full.
    4. High atmospheric air pressure.
    5. Insufficient ventilation of vertical stack.

19. How are waste pipe system syphonage risks reduced?

    1. Adequate ventilation to open air.
    2. Installing larger diameter waste pipes than normally recommended.
    3. Connecting every waste trap individually to the vertical stack.
    4. Maintaining air-tightness of the drainage system.
    5. Regular internal cleaning of all waste and drain systems.

20. How are ground floor waste pipes connected into the sewer system?

    1. Unvented direct connection.
    2. Trapped pipe connects directly to a trapped outdoor gulley on sewer system.
    3. Untrapped direct pipe connection to the foul sewer.
    4. Trapped pipes at a steep gradient connect to the foul sewer.
    5. Trapped pipes connect vertically to the foul sewer.
    6. Trapped pipes at a shallow gradient connect to the foul sewer.

21. How are above-ground drain systems tested to ensure adequate water seals remain in traps during normal use?

    1. Each sanitary fitting filled, drained and remaining trap seal depth measured.
    2. All sanitary fittings in a group filled then drained simultaneously.
    3. Each section of waste pipe system sealed and pumped to an air pressure of 150 mm water gauge for 10 min, then air and water released.
    4. Water pumped up stack to test effectiveness of water seals in traps.
    5. Air pressure in stack and waste pipes hand-pumped to 38 mm water gauge. This pressure maintained for 3 min without further pumping.