CHAPTER 09

Ventilation of Buildings for Controlling Indoor Air Pollution

INTRODUCTION

- Ventilation may be defined as the art of supplying air to a given space, and also includes the art to remove the old vitiated air from that space.
- In other words, ventilation includes both the exchange of air to the outside as well as circulation of air within the building.

9.1 Effects of Occupancy of a Space

When an enclosed space is inhabited by humans and/or animals, etc., the following effects are produced:

(i) Humidity of the space increases

(ii) Oxygen content of the space reduces

(iii) Carbon dioxide content of the space increases

(iv) Organic matter, and odours in the space increases

Reasons:

(a) Fresh air usually contains 21% of oxygen whereas; the exhaled air contains only about 17% oxygen. In order to avoid such oxygen deficits in a given building inhabited by people, it is necessary to ensure supply of sufficient quantity of fresh air through ventilation.

(b) Fresh air normally contains about 0.04% of carbon dioxide; whereas the exhaled air contains as high as 50% of carbon dioxide. To avoid such CO_2 excesses in a building, it is necessary to provide sufficient entry of fresh air, through proper ventilation.

(c) A person, on an average, produces about 300 B.Th.U. (≈ 69 kC) of heat per hour. A large part of this heat is lost by leakage through the rooms. Higher outside temperatures retard this dissipation, reduces leakage, and thereby causing discomfort to the occupants. Continuous supply of fresh air through proper ventilation is, therefore, very necessary to avoid heat effects.

(d) Moisture, in the form of water vapour, is released by inhabitants of a building at about 1.08 kg per day. This increases the humidity of the room/building, thereby decreasing evaporation and cooling of the bodies of the inhabitants, and thus causing them discomfort.

(e) Organic matter and odours are released by human beings from their skins, clothings and mouths. The increase of these in an enclosed space, occupied by several persons, may cause nausia, headache, and may even aggravate ones existing illness.

9.2 Purpose of Ventilation

The ventilation ensures the removal of bad effects of occupancy of an enclosed space :

(i) by removing and diluting CO_2 in the air.
(ii) by providing necessary oxygen to remove oxygen deficit caused by respiration.
(iii) by reducing humidity.
(iv) by reducing body odours.
(v) by lowering down the temperature by removing hot used up air and replacing it by colder fresh air.

9.3 Systems of Ventilation

A good ventilation system should generally fulfil the following requirements:

(i) It should admit sufficient quantity of fresh air, and remove the requisite used up or vitiated air.
(ii) Admitted air should be properly controlled with respect to its quantity as well as velocity of movement.
(iii) The system should be capable of changing the old air thoroughly, without leaving any stagnant pockets in the room.
(iv) Should avoid draughts, for which maximum permissible velocity of admitted air should not exceed 15 m/min i.e. 0.25 m/sec.
(v) The system should admit clean and humid air.
(vi) The system should also be capable of controlling the temperature of admitted air.

The ventilation systems can be broadly divided into two categories viz.

(i) Natural ventilation
(ii) Artificial mechanical ventilation

9.3.1 Natural Ventilation

- Natural ventilation is based upon providing suitable openings in a room, at lower levels for admitting free atmospheric air, and also at upper levels for removing the warmer and lighter used up air.
- Doors and windows near the floor level, thus, admit fresh air, and ventilators near the ceiling, take out the vitiated air from a room.
- Windows are generally provided at about 0.75 to 0.90 m above the floor levels, for admitting fresh outside air into the room.
- The size and the number of the windows provided, will depend upon the size of the room, number of occupants, the purpose and use of the room, etc. Besides admitting fresh air, the windows help in admitting natural day light.
- On minimum side, a window area of 0.052 m^2 per person should generally be provided, so as to ensure admission of atleast 28 cm of air per hour with a velocity not grater than 9 m/min.
- Another recommendation is to provide about $\frac{1}{10}$ to $\frac{1}{15}$ th of the floor area in the living rooms for windows.
- Every room should preferably be provided with atleast 2 windows. Kitchen must be provided with more window area.
- Provision of deflectors of 30 cm height at the bottom or top of a window, opening inward, permits the ventilation of the room, even when windows are closed.
- In a hot and humid climate like that of India, natural ventilation fails to provide the requisite comfort, and hence artificial ventilation methods are adopted.

9.3.2 Mechanical Ventilation

The artificial ventilation system can be broadly divided into:

1. The extraction or vacuum system
2. The propulsion or plenum system
3. The air conditioning system

1. The Extraction or Vacuum System

- It is one in which the used-up vitiated air is thrown out to the outside atmosphere, by means of suitable exhaust fans or blowers, installed near the top ventilators.
- This exhaustion of the warmer air from the room, causes lower pressure inside the room, thereby permitting inward leakage of new fresh atmospheric air through the doors, windows, and walls.
- Various types of fans are used for this purpose. They are usually of the rotary type, fixed in a convenient part of the ductwork, and driven usually by electric motors, though diesel and steam power may be used when electricity is not available.
- This system is simple and cheap, but contains a number of demerits such as:
  (i) There is no control on the quality of the incoming air. It can, hence, be installed only where outside area is not contaminated and over crowded.
  (ii) It is also apt to cause droughts.
- Inspite of these demerits, this system is largely used for kitchens, public halls, industrial plants, etc.
  (i) In kitchens, the system helps in exhausting smokes and odours
  (ii) In public halls, the system helps in exhausting out the ill effects of heavy occupancy
  (iii) In industrial plants, the system helps in exhausting out dusts and fumes, etc.

2. The Plenum System

- It involves forcing or pumping in fresh air, and causing the vitiated air to be exhausted out either by itself or through an exhaust fan placed at the outlet.
- The outlet exhaust fan is of smaller power than the inlet force fan.
- Due to larger rate of incoming air, a slight pressure is created, which allows an outward leakage of vitiated air through the outlets.
- Example of this system : Provision of a cooler at a window, with or without an exhaust fan at a ventilator, provides an example of such a plenum system of ventilation, largely adopted these days.
- In larger buildings, such a plenum system may consists of distributing the incoming forced air at different points in the building through a system of ducts and grills.

Advantages:

(i) Plenum system enables us to control the quality, humidity, and temperature of the incoming air and hence, this system is largely adopted these days for cinema houses, theatres, and even for individual homes.

(ii) This system obviates the risk of draughts, because of outward leakage, and by making outlets less powerful than the inlets.

- Moreover, such a system may either work normally upward with entry at floor level and exhaust at ventilator level, or may work downward, with exhaust at floor level and entry at upper level.

Disadvantages:

(i) The normal upward system when adopted, becomes costlier, as entry of air is provided at floor level under the seats, as is provided in some cinema halls, etc.

(ii) The downward system, when adopted by providing air inlet ducts at roof level, is opposed to natural laws, and necessitates vitiated air to be rebreathed, causing discomfort.

(iii) The air ducts require careful design in order to prevent draughts. This may involve using separate dampers for each room. The movement of air at the inlet as well as at the outlet needs to be properly controlled. This arrangement is quite costly.

- These objections can be overcome by

(i) employing the upward system

(ii) by air-conditioning the buildings

3. The Air conditioning System

- The atmosphere in the modern cities contains highly polluted smokes, fumes, dirts, germs, and bacteria, etc.
- In such environments, natural ventilation or even ordinary mechanical ventilation for bringing the outside polluted air into the building, will not serve us any useful purpose.
- In such conditions, it is necessary to completely control the temperature and quality of the outside air, before it is admitted into the room, and also to remove the heavy vitiated air at the optimum rates.
- The air-conditioning may be defined as the process of controlling the temperature, humidity and distribution of air in a building, with simultaneously removing the dirt, bacteria and toxic matter from the air. Air- conditioning, thus, provides a comfortable and whole-some ventilation to the buildings.
- The atmospheric conditions vary, the requirements of occupants also vary with respect to season.
- An air-conditioning system is required to work two ways.

(a) Summer air Conditioner

- In summer season, the external atmospheric temperature is high, and the hot air has to be cooled before it can be distributed in the building.
- During the process of cooling, however, the humidity of this air increases, because at lower temperatures with the same amount of moisture, the relative humidity increases.
- Hence, after cooling, it becomes necessary to reduce the humidity of this air, by drying it through a dehumidifier or the air is cooled and dried through the process of condensation.
- The clean, cooled and dried air is then finally forced out into the space to be conditioned.

NOTE: A humidifier is in the form of a hygroscopic substance like ammonia, calcium chloride etc.

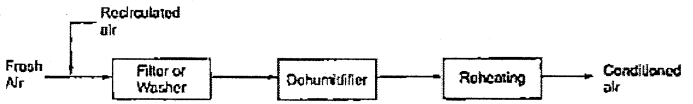


Fig. 9.1 Summer A.C. - Line Diagram

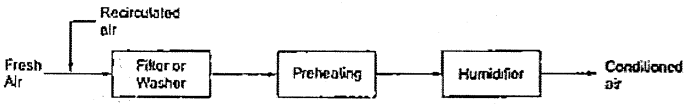


Fig. 9.2 Winter A.C. - Line Diagram

- The various steps involved in this conditioning are briefly given below:

(i) Filtration

- Fresh outside air as well as the vitiated reused air (recirculated air) is passed through a filter so as to remove the dust and other foot particles from it.
- Dry filters and viscous filters are the two types of filters, used for the purpose.
- Dry filters, made of close grained felt or cloth or jute are more commonly used.
- As a modern advancement on filter technique, electric precipitators are also used. Such precipitators work on the principle of producing high intensity ionizing field.

(II) Cooling and Drying (Dehumidification)

- This can be done by first lowering the temperature of the filtered air below the dew point, condensing out necessary amount of moisture, and then reheating the same with dry heat upto the desired temperature.
- Cooling of the air may be done in several ways; two of which are:
  - (a) cooling by mechanical refrigeration
  - (b) cooling by water spray method.

(a) Cooling by Mechanical Refrigeration

- It cools the air like a house hold refrigerator and is more suitable to tropical countries where temperature are to be lowered susbstantially.
- This method helps in cooling of air without wetting the same, with the help of a compressor and metal coils (tubes).
- A liquid refrigerant, such as freon, enters the metal coils under high pressure, as soon as the machine is switch ON.
- This liquid absorbs the heat from the coils and gets evaporates, thereby extracting heat from the metal coils and causing cooling of the coils
- This gas refrigerant is then converted into liquid by the condenser coils and the compressor.
- The liquid again evaporates by absorbing heat from the coils, causing further cooling of the coils.
- The process continues till the cooling is caused upto the desired level.

(b) Water Spray Method

- Water is first of all, cooled with the help of a refrigerant and this cooled water is then sprayed on the hot air coming out of the filters. The air, thus gets cooled by evaporation.
- This method increases the humidity of the air, and is generally not found suitable for humid climates.

Recirculation of Air

- During summer season, the temperature of room air is lower than the temperature of the outside air. And since an air conditioner has to cool down the hot air, it should be economical for it to cool the room air rather than the outside atmospheric air, if it becomes available to it. Moreover, in any case, the vitiated room air has to be removed by it.
- On these two considerations, air conditioners are designed to extract and avail the vitiated room air at optimum rates, and to take from the outside atmosphere, only that much quantity of air, as is necessary to prevent concentration of odours.
- This air, which is withdrawn by an air conditioner from the conditioned room, and is recirculated through the filters and other cooling units, is known as circulated air, and the process is called recirculation of air.

(b) **Winter Air Conditioner**

- In this season, the external atmospheric temperature is low, and this cold atmospheric air has to be heated up before it can be dispersed in the conditioned room.
- During this process of pre-heating, however, the humidity of the air reduces, at higher temperatures with the same amount of moisture, the relative humidity decreases.

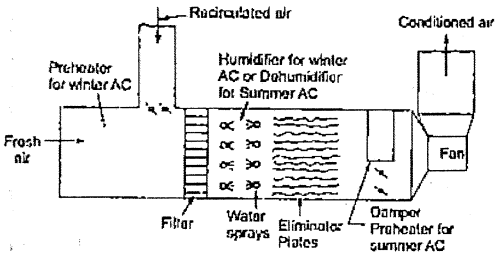


Fig. 9.3 Flow diagram of a complete two way air conditioner

- Hence, after heating, it becomes necessary to increase the humidity of this air, by carrying it through a humidifier, where air, may be mixed with the water vapour, by throwing water over the air with the help of spray.
- This humidified air is then passed through eliminator plates, so as to remove the water droplets, if any, in the humidified air.
- The clean, hot and optimally humid air is finally forced out into the space to be conditioned.

Recirculation of air

- Recirculation of air is done in the winter A.C. similar to what is done in the summer A.C (as room air is to be heated up to lesser extent than the outside air, which causes economy).

NOTE: Preheating in a winter air conditioner may be done by admitting the air through a heater, or by passing it over the coils heated by hot circulation water.

Example 9.1 A cooling room air-conditioner, modifies the moisture content of the air, before letting it out by

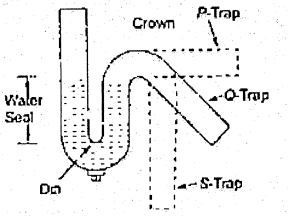
(a) reducing humidity
(b) increasing humidity
(c) optimally reducing as well as increasing humidity
(d) none of these, as it does not modify humidity

Ans. (a)

MISCELLANEOUS

9.4 Functions and Types of Traps being Used in Sanitary Plumbing System

- Traps may be defined as fittings, placed at the ends of the soil pipes or the sullage pipes (waste pipes) to prevent the passage of foul gases from the pipes to the outside.
- This is possible because traps do enclose or maintain water seal between the pipe and the outside. This water depth does not allow gases to escape to the outside of the pipe.
- The efficiency and effectiveness of a trap will depend upon the depth of the water seal. Greater is this depth, more effective the trap will be.
- This water seal generally varies from 25 mm to 75 mm ; 50 mm being quiet common in most of the traps.



P, Q and S Traps shown together

Fig. 9.4

Types: Depending upon their shapes, the traps may be of three types, i.e.

(i) P-trap (ii) Q-trap (iii) S-trap

- A trap essentially consists of a U-tube, which retains water, acting as a seal, between the foul gases (inside the pipe) and the outside atmosphere.
- They are largely used for baths, sinks and labatories. In all such needs, they are made with enlarged mouth, so that the waste pipe may be thoroughly flushed out.

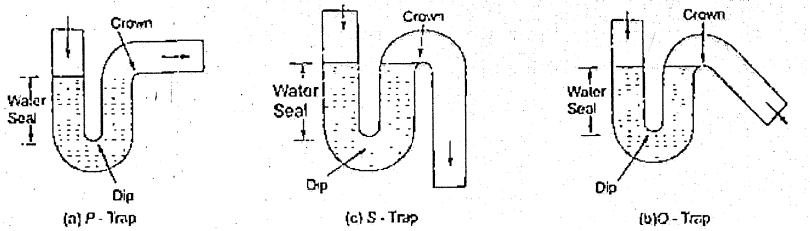


Fig. 9.5 Types of traps

- Depending upon their use, the traps may again be of three types i.e.

(i) Floor trap (ii) Gully trap (iii) Intercepting trap

1. **Floor Trap**

- These traps are generally used to admit waste water (sullage) from the floors of rooms, kitchens, baths, etc. into the room drain (sullage pipe).
- These are invariably provided with cast iron or galvanised or stainless steel gratings (Jallis) at the top, so as to prevent the entry of solid and larger sticky matter into the drain pipe, to avoid frequent blockade.
- A commonly used patented name of such a trap is Nahni trap.

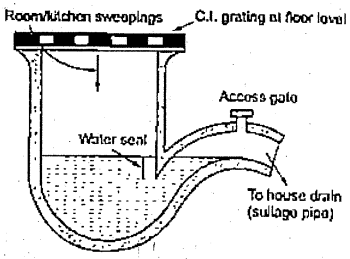


Fig. 9.6 Floor Trap

2. **Gully Trap**

- A gully trap or a gully is often provided at the junction of a room or a roof drain and the other drain coming from bath, kitchen, etc.
- The foul sullage from baths, will enter through the side inlet (called back inlet), and the unfoul room washings or rain water from roof or courtyard will enter from the top.
- The rain water pipes or sullage pipes discharging into drains, are often connected to them through such traps.
- Gully traps may either have a S-trap or a P-trap.
- The water seal is usually 50 mm to 75 mm deep. The top of the trap is covered by a C.I. grating to exclude the entry of coarser materials to avoid blockade.

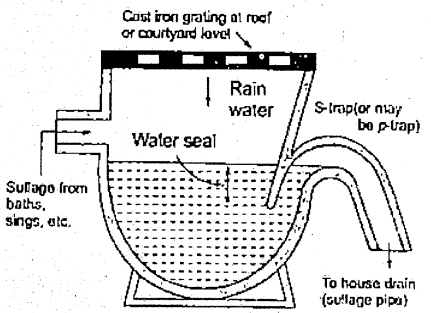


Fig. 9.7 Gully Trap

3. **Intercepting Trap**

- It is often provided at the junction of a house sewer and a municipal sewer, so as to prevent the entry of the foul gases of the municipal sewer, into the house drainage system.
- This trap at such a junction is often provided in a small man-hole constructed just near the house, either outside in the street or in a corner inside the house boundary.

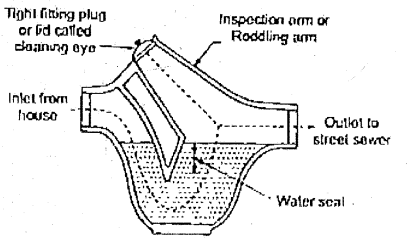


Fig. 9.8 Intercepting Trap

- This trap is provided near its top with an access gate or a plug, called cleaning eye, for removing silted matter from inside the trap in case of blockade.
- It has a high depth of water seal, say about 100 mm.

Merits of Interceptors:

(i) Foul gases of public sewer cannot pass through the interceptor and hence prevented from entering the house drainage system.

(ii) Harmful pathogenic bacteria contained in the public sewers are thus prevented from entering the house drains, due to the presence of the interceptor.

(iii) Properly designed and constructed interceptors can quickly remove the foul matter of the house drains into the public sewer.

Demerits of Interceptors:

(i) If the discharge from house drains is small, the solid heavy matter may be retained in the trap and may start decomposing, producing foul gases.

(ii) If the lid or the plug is not fitted properly, or is broken, foul gases from public sewer will do enter the house drain.

(iii) Cleaning through the inspection arm of the trap is not easy.

(iv) Interceptor itself forms an obstruction to the normal flow of sewage.

(v) Omission of interceptors from house drainage is found not to present too serious a difficulty or a problem.

9.5 System of Plumbing

Following are the four principle systems adopted in plumbing of drainage work in a building:

(1) Two pipe system

(2) One pipe system

(3) Single stack system

(4) Partially ventilated single stack system.

There systems are discussed below:

9.5.1 Two Pipe System

- This is the best and the most improved type of system of plumbing.
- In this system, two sets of vertical pipes are laid, i.e., one for draining night soil, and the other for draining sullage.
- The pipes of the first set carrying night soil are called soil pipes and the pipes of the second set carrying sullage from baths etc., are called sullage pipes or waste pipes.
- The soil fixtures, such as latrines and urinals, are, thus, all connected through branch pipes (laterals) to the vertical soil pipe; whereas, the sludge fixtures such as baths, sinks, wash basins, etc. are all connected through branch pipes to the vertical waste pipe.
- This system requires large number of pipes, and is thus quite costly

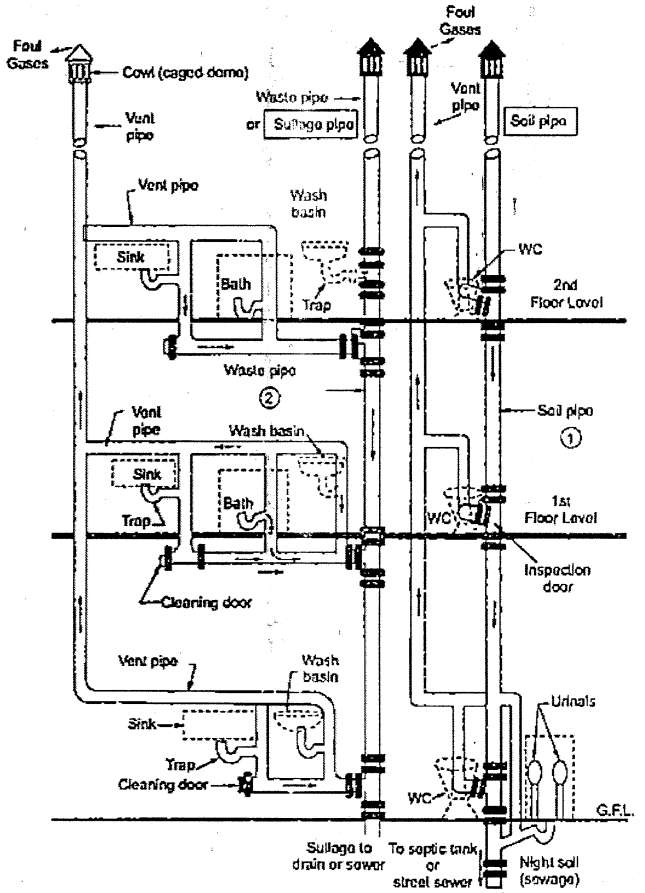


Fig. 9.9 Two Pipe System

9.5.2 One Pipe System

- In this system, instead of using two separate pipes (for carrying sullage and night soil), only one main vertical pipe is provided, which collects the night soil as well as the sullage water from their respective fixtures through branch pipes.
- This main pipe is ventilated in itself by providing cowl at its top, and in addition to this, a separate vent pipe, however, is also provided.
- This system, thus, has two pipes, instead of four pipes of the two pipe system.

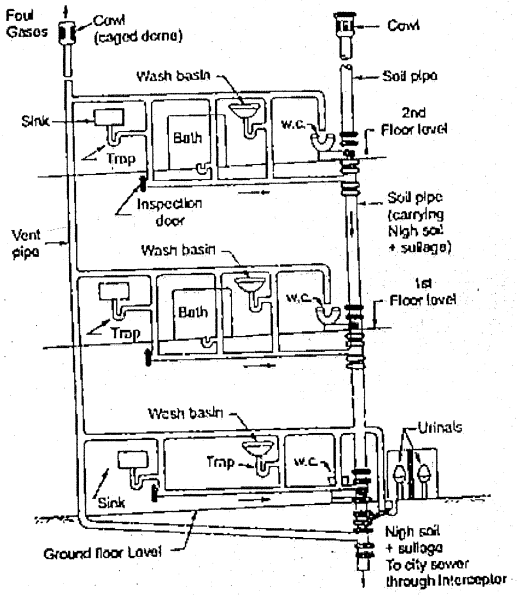


Fig.9.10 One pipe system of plumbing

9.5.3 Single Stack System

- This system is a single pipe system without providing any separate ventilation pipe. Hence, it uses only one pipe, which carries the sewage as well as the sullage, and is not provided with any separate vent pipe, except that it itself is extended upto about 2 m higher than the roof level and provided with a cowl, for removal of foul gases.

9.5.4 Partially Ventilated Single Stack or Single Pipe System

- This is an improved form of single stack system in the sense that in this system, the traps of the water closets are separately ventilated by a separate vent pipe called relief vent pipe.
- This system, thus, uses two pipes as in a single pipe system, but the cost of branches is considerably reduced compared to single pipe system, because the sullage fixtures are not connected to the vent pipe.

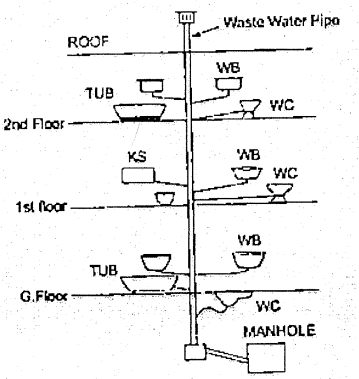


Fig.9.11 Single stack system of plumbing

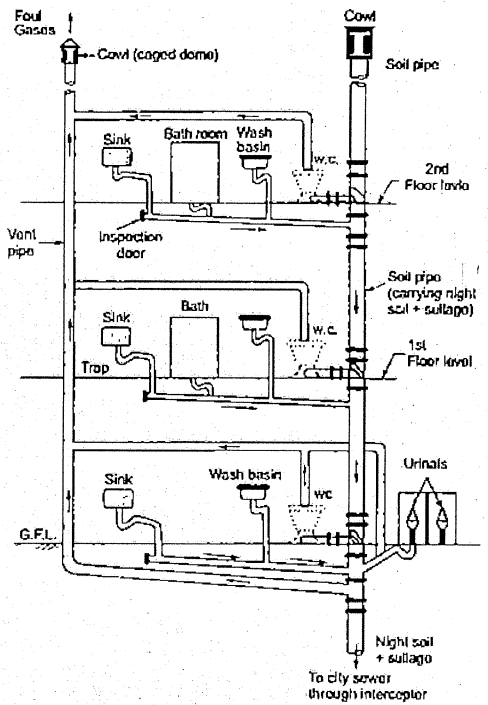


Fig. 9.12 Partially ventilated single pipe system

Example 9.2 The most wholesome ventilation of buildings is provided by

(a) natural ventilation (b) plenum system of ventilation

(c) A.C. system of ventilation (d) vacuum system of ventilation

Ans. (c)

Example 9.3 Soil pipe in plumbing services means a pipe

(a) made of clay (b) carrying soiled materials

(c) carrying waste from water closets (d) carrying industrial waste water

Ans. (c)

NOTE

The commonly adopted sizes for house drains for average conditions, are as follows

Soil pipe = 100 mm ϕ Sullage pipe (vertical) = 75 mm ϕ

Sullage pipe (horizontal) = 32 mm to 50 mm ϕ Vent pipe = 50 mm ϕ

9.6 Sanitary Fitting and Other Accessories

The sanitary fittings are the appliances used in a house plumbing system, to receive the human excreta and sullage waste of the house. Such fittings include:

(a) Soil Fittings

(i) Water Closets (W.C.) (ii) Urinals

(b) Ablution Fittings

(i) Flushing cisterns of water closets (ii) Wash basins

(iii) Baths (iv) Kitchen sinks

9.6.1 Water Closets (W.C).

- A water-closet is a water-flushed plumbing fixture, designed to receive the human excreta directly and is connected to the soil pipe by means of a trap.
- Two types of waste-closets are in common use:
  1. The Squatting or the Indian type
  2. The Pedestal or the European type

(i) The Squatting or the Indian type:

- The Indian type W.C. has a squatting pan 45 cm to 63 cm in overall length and 45 to 50 cm in height.
- The pan is fitted either with a P-trap or S-trap, which is then connected to the soil pipe.
- It is made of vitreous china or porcelain
- The trap has an opening for fixing an anti-siphonage pipe or a vent pipe.
- The pan has a flushing rim to spread the flush water.
- This W.C. requires at least 10 litres of water for proper flushing.

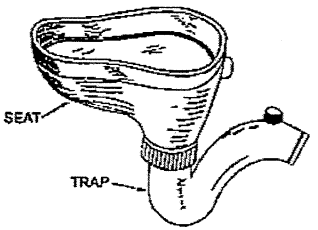
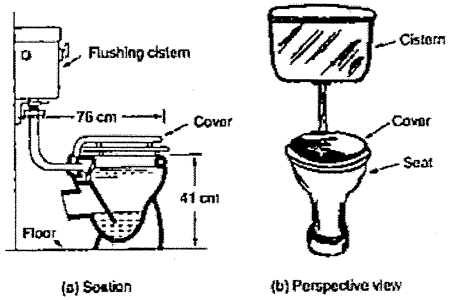


Fig. 9.13 Indian Type W.C. Pan and Trap

(ii) The Pedestal or the European types:

- The European type, sometimes called wash-down type of W.C.
- It is provided with a wide flushing rim and a 50 mm trap.
- The W.C. may be provided with a P-trap or a S-trap, depending upon the outlet existing in the wall or the floor, respectively.
- These types of water-closets require less space than the Indian type and can be located along with the bath in the same room
- They are normally flushed with a low level cistern.



(a) Section (b) Perspective view

Fig. 9.14 Pedestal or Europeon type W.C.

9.6.2 Urinals

- Urinals can be of different forms and shapes. The common varieties are :
  (i) the bowl type or the basin type (ii) the stall type or the slab type
- The bowl type is generally used for private houses or buildings and the stall type is generally used for public buildings and municipal toilets.

9.6.3 A Flushing Cistern

- A flushing cistern is a device which releases a fixed quantity of water under pressure, so as to flush and clean the pan and trap of a water-closet or a urinal.
- High level cisterns are those which operate with a minimum height of 1.25 m and the Low level cisterns are those which operate with a maximum height of 30 cm.

9.7 Ventilation of House Drains

- The entire sewage system of a house is ventilated by providing vent pipes and antisiphoniage pipes and sometimes by fresh air inlet.
- Such a ventilation system is required to the serve the following purposes.
  (i) to relieve the pressure of foul gases developed in house drains, which may otherwise break the water seals of the shallow seat traps.
  (ii) to prevent breakage of traps seals by siphonic action.
  (iii) to dilute the foul gases in the drains and to reduce their obnoxious effects, in case such gases happen to escape out into the house due to some reason or the other.

9.8 Antisiphonage Pipes

- Water seals of traps in multistoried buildings or houses may sometimes get broken due to siphonic action as explained below.
- When waste water is suddenly discharged from a sanitary fixture on the upper floor, it moves down rapidly through the soil (or the waste) pipe, and in its movement, it may suck some air from the lateral pipe connecting the soil pipe with the fixture at the lower floor.
- This sucked air causes siphonic action, resulting in the flow of water from the trap of the fixture to the soil pipe and thus, breaking its water seal.
- To overcome this difficulty a separate pipe of smaller diameter is attached to the traps, which connects the trap with the vent pipe. The pipe is known as anti siphonage pipe and it supplies air to the short branch pipe of the lower fixture at the time of section, otherwise also, it acts as a vent pipe connection of the lower fixture.
- This pipe, thus normally serve as a vent pipe and as an antisiphonge pipe in case suction takes place as explained.

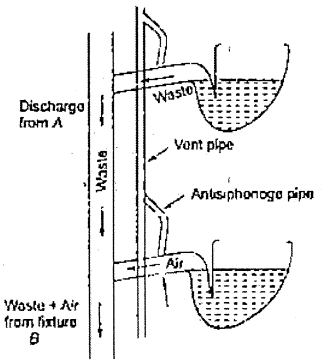


Fig. 9.15 Induced Siphonage and Anti-siphonic pipe

Example 9.4 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I	List-II
A. Anti-siphonage	1. Protects trap seal from backflow
B. Benching	2. Has sloped floor in inspection chamber
C. Invert	3. Preserves the water seal in trap
D. Vent pipe	4. The lowest point

	A	B	C	D
(a)	3	2	4	1
(c)	3	4	2	1

	A	B	C	D
(b)	1	4	2	3
(d)	1	2	4	3

Ans. (a)

Summary

- The purpose of ventilation is to providing necessary oxygen and removing and diluting CO_2, reduce humidly.
- A Gully trap is often provided at the junction or a roof drain and the other drain coming from bath, kitchen etc.
- Soil pipes are the pipes which carry the night soil, and sullage pipes are the one pipes which carry the sullage from bathroom and kitchens.

Objective Brain Teasers

Q.1 The ventilation of public halls, by means of air coolers and exhaust fans, is known as
(a) the plenum system
(b) the vacuum system
(c) the A.C. system
(d) None of these

Q.2 Point out the incorrect statement
(a) a summer A.C. uses a de-humiditifier
(b) a winter A.C. uses a humidifier
(c) recirculation of room air takes place in a summer A.C. as well as in a winter A.C
(d) all the above are correct

Q.3 In single stack drainage system in houses, we provide
(a) one soil pipe only
(b) one soil pipe and one vent pipe
(c) one sullage pipe only
(d) one soil pipe and one sullage pipe

Q.4 The industrial process that generates inoustrial waste water containing chromium is
(a) food processing (b) tannery
(c) polleries (d) soap manufacturing

Q.5 The odour of drying paint or varnish is derived from which of the following chemical compounds?
(a) Organic gases
(b) Volatile organic compounds
(c) Ethylene
(d) Acetylene

Q.6 Environmental impact assessment includes
(a) Environmental statement
(b) Environmental management plan
(c) Risk and hazard assessment and mitigation
(d) All of the above

Answers

1 (a) 2. (d) 3. (a) 4. (b) 5. (b) 6. (d)