SP 35 (1987): Handbook on Water Supply and Drainage (with Special Emphasis on Plumbing) [CED 24: Public Health Engineering.]

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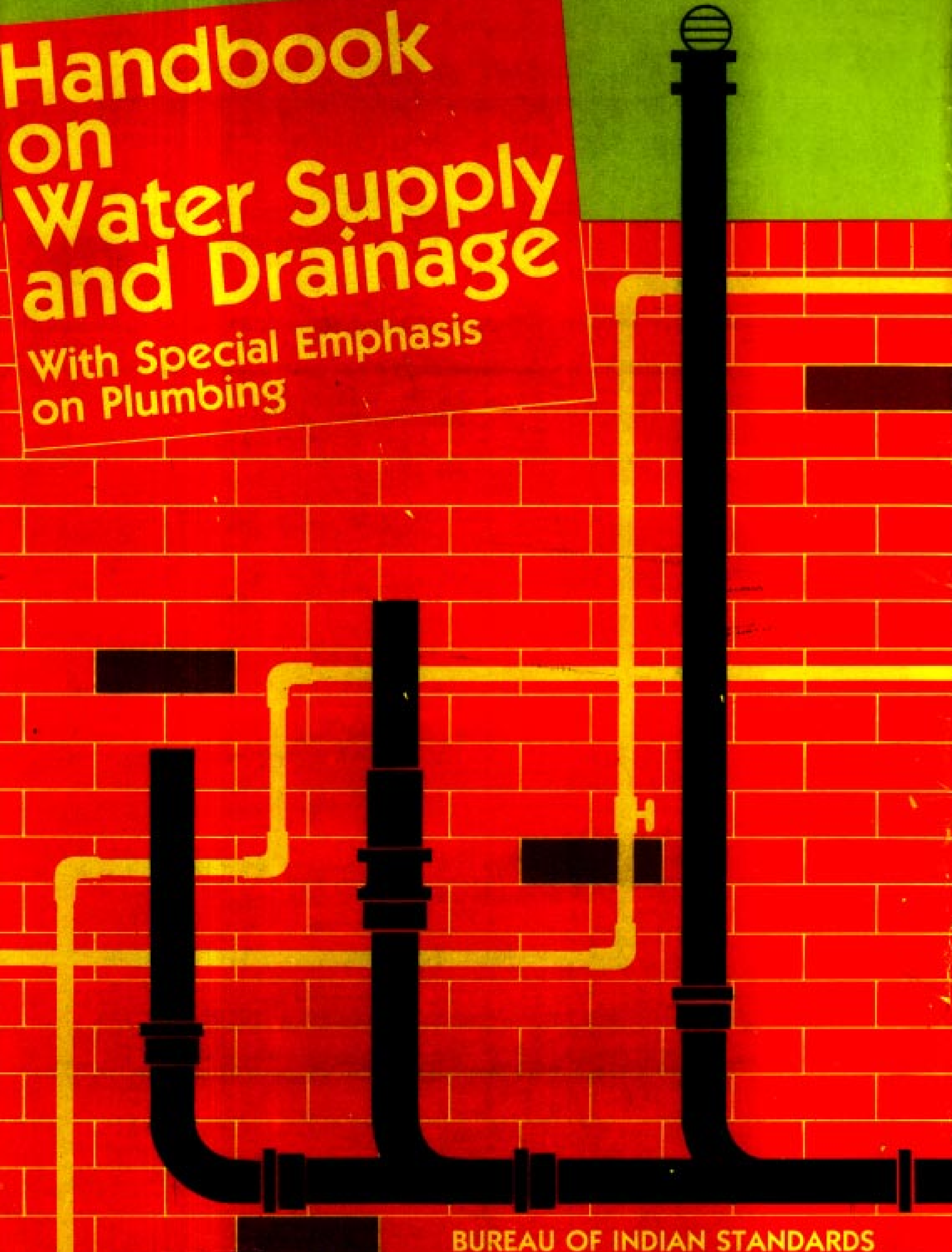
Handbook on Water Supply and Drainage

With Special Emphasis on Plumbing



BUREAU OF INDIAN STANDARDS

HANDBOOK
ON
WATER SUPPLY AND DRAINAGE
(WITH SPECIAL EMPHASIS ON PLUMBING)

HANDBOOK
ON
WATER SUPPLY AND DRAINAGE
(WITH SPECIAL EMPHASIS ON PLUMBING)

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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FOREWORD

Users of various civil engineering codes have been feeling the need for explanatory handbooks and other compilations based on Indian Standards. The need has been further emphasized in view of the publication of the National Building Code of India in 1970 and its implementation. The Expert Group set up in 1972 by the Department of Science and Technology, Government of India, carried out in-depth studies in various areas of civil engineering and construction practices. During the preparation of the Fifth Five-Year Plan in 1975, the Group was assigned the task of producing a Science and Technology plan for research, development and extension work in the sector of housing and construction technology. One of the items of this plan was the production of design handbooks, explanatory handbooks and design aids based on the National Building Code and various Indian Standards, and other activities in the promotion of the National Building Code. The Expert Group gave high priority to this item and on the recommendation of the Department of Science and Technology, the Planning Commission approved the following two projects which were assigned to the Bureau of Indian Standards.

a) Development programme on code implementation for building and civil engineering construction, and

b) Typification for industrial buildings.

A Special Committee for Implementation of Science and Technology Projects (SCIP), consisting of experts connected with different aspects, was set up in 1974 to advise the BIS Directorate General in identifying the handbooks and for guiding the development of the work. Under the first project, the Committee has so far identified subjects for several explanatory handbooks/compilations covering appropriate Indian Standards/Codes/Specifications which include the following:

Design Aids for Reinforced Concrete to IS : 456-1978 (SP : 16-1980)
Explanatory Handbook on Masonry Code (SP : 20-1981)
Explanatory Handbook on Codes of Earthquake Engineering (IS : 1893-1975 and IS : 4326-1976) (SP : 22-1982)
Handbook on Concrete Mixes (SP : 23-1982)
Explanatory Handbook on Indian Standard Code of Practice for Plain and Reinforced Concrete (IS : 456-1978) (SP : 24-1983)
Handbook on Causes and Prevention of Cracks in Buildings (SP : 25-1984)
Summaries of Indian Standards for Building Materials (SP : 21-1983)
Handbook on Functional Requirements of Industrial Buildings (SP : 32-1986)
Handbook on Timber Engineering (SP : 33-1986)
Handbook on Concrete Reinforcement and Detailing (SP : 34-1987)
Handbook on Water Supply and Drainage with Special Emphasis on Plumbing (SP : 35-1987)
Functional Requirements of Buildings (Other than Industrial Buildings)(SP : 41-1987)
Foundation of Buildings
Steel Code (IS : 800)
Building Construction Practices
Bulk Storage Structures in Steel
Formwork
Fire Safety
Construction Safety Practices
Tall Buildings
Inspection of Different Items of Building Work
Loading Code
Prefabrication

The Handbook on Water Supply and Drainage with Special Emphasis on Plumbing, which is one of the handbooks in the series, deals with the design, construction, maintenance, etc, of all water supply systems and waste water disposal systems with special reference to water supply systems within the premises and waste water collection, transportation and disposal from domestic sanitary appliances. It gives details for design of small individual disposal systems and broad outlines for the design of large scale transportation, treatment and disposal systems for sewage.

The Handbook is also intended to give detailed design for the water supply system within a premises and the treatment and disposal of domestic sewage in septic tanks and stabilization ponds in appendices, and charts for the design of all pressure pipes based on Hazen and William's formula as well as for the design of free flow conduits based on Manning's formula.

The Handbook, it is hoped, would provide useful guidance to public health engineers, plumbing engineers and others dealing with the material, design, construction, testing, inspection, etc, of water supply and drainage.

The Handbook is based on the draft prepared by Shri T. Durai Raj, former Deputy Adviser (PHE), Ministry of Works and Housing, Government of India. The draft was circulated for review to the Municipal Corportion of Greater Bombay; Engineer-in-Chief's Branch, Army Headquarters, New Delhi; Ministry of Works and Housing, New Delhi; Indian Institute of Technology, Bombay; Delhi Water Supply & Sewerage Disposal Undertaking, New Delhi; National Environmental Engineering Research Institute, Nagpur; All India Institute of Hygiene & Public Health, Calcutta; Public Health Departement (PWD), Government of Andhra Pradesh; Madras Metropolitan Water Supply and Sewerage Board; Central Public Health and Environmental Engineering Organization, New Delhi; Calcutta Metropolitan Development Authority, Calcutta; College of Military Engineering, Pune; Delhi Development Authority, New Delhi; Engineers India Ltd, New Delhi; Shri Balwant Singh; Shri Devendra Singh, Sanitary Consultant and Quantity Surveyor, Bombay; Shri S. G. Deolalikar, Consulting Sanitary Engineer, New Delhi; and their views have been taken into consideration while finalizing the Handbook.

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SECTION 1

INTRODUCTION

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SECTION 1
INTRODUCTION

1. INTRODUCTION

The Bureau of Indian Standards has been preparing several standards on items pertaining to public health engineering through the help of the several sectional committees and sub-committees constituted under the several Division Councils of the Bureau. The subjects are so varied as to come under the scope of the civil engineering, mechanical engineering, chemical engineering, structurals and metals, consumer products, etc.

The members constituting the committees are drawn from the Government, manufacturers, consumers, etc. The standards pertaining to public health engineering have been formulated at different times and are being revised as and when necessity arises due to changing times and the prevailing practice. However, there was a long felt need for a handbook on water supply and drainage with special emphasis on plumbing giving information on all related subjects in a comprehensive and coordinated manner giving references to the existing standards to facilitate quick and practical help. In this process, it has been necessitated to deviate from certain recommendations already made in certain standards, especially the computation of flow in small sized pipes and the unit fixture rate of flow. In the absence of research work in this field in the country, the work done in USA by Hunter has been used, charts prepared for application in this country with the units adopted here regarding possible peak rates of flow in plumbing systems. The Hazen and William's formula for pressure pipes and Manning's formula for free flow conduits have been recommended to be adopted in the design of plumbing systems.

A number of useful appendices to help the designer have been prepared and added to the Handbook. As this is only a coordinating Handbook, references have to be made to the relevant detailed standards already prepared for detailed design, construction, testing, maintenance, sampling and inspection, and marking. A list of all relevant Indian Standards pertaining to this Handbook has also been appended.

The recommendations made in the manuals on water supply and treatment as well as the manual on sewerage and sewage treatment prepared by the Special Committees constituted by the Ministry of Works and Housing, New Delhi, with which the BIS Directorate General was also associated, have been largely followed in the preparation of the Handbook.

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SECTION 2

TERMINOLOGY

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SECTION 2
TERMINOLOGY

2. TERMINOLOGY

2.0 The glossary of terms relating to water supply and sanitation, as given IS : 10446-1983 'Glossary of terms for water supply and sanitation', should be followed in addition to the following items.

2.1 Authority having Jurisdiction — The authority which has been created by a statute for administering the provisions and which may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.2 Available Head — The head of water available at the point of consideration due to mains' pressure or overhead tank or any other source of pressure.

2.3 Approved — Accepted or acceptable under an applicable specification stated or cited or accepted as suitable for the proposed use under procedures and powers of the Administrative Authority.

2.4 Backflow Connection — Any arrangement whereby backflow can occur.

2.5 Barrel — That portion of a pipe in which the diameter and wall thickness remain uniform throughout.

2.6 Branch, Interval — A length of soil or waste stack corresponding, in general, to a storey height but in no case less than 2.4 m within which the horizontal branches from one floor or storey of a building are connected to the stack.

2.7 Branch Vent — A vent connecting one or more individual vents with a vent stack or stack vent.

2.8 Building Combined Drain or Sewer — A building drain or sewer which conveys both sewage and storm water.

2.9 Building (House) Drain — That part of the lowest piping of a drainage system which receives the discharge from soil, waste and other drainage pipes inside the walls of the building and conveys it to the building (house) sewer beginning 0.9 m outside the building wall.

2.10 Building (House) Sewer — That part of the horizontal piping of a drainage system which extends from the end of the building drain which receives the discharge of the building drain and conveys it to a public sewer, private sewer, individual sewage disposal system or other point of disposal. Also called house connection.

2.11 Building (House) Trap — A device, fitting or assembly of fittings installed in the building drain to prevent circulation of air between the drainage system of the building and the building sewer.

2.12 Building Sanitary Drain — A building drain which conveys sewage but does not convey storm water.

2.13 Building (Sanitary) Sewer — A building sewer which conveys sewage but does not carry storm water.

2.14 Building (Storm) Drain — A building drain which conveys storm water but does not convey sewage.

2.15 Building (Storm) Sewer — A building sewer which conveys storm water but does not convey sewage.

2.16 Common Vent — A vent connecting at the junction of the two fixture drains and serving as a vent for both fixtures.

2.17 Communication Pipe — The part of the service pipe, extending from the water main up to and including the stop cock, which is under the control of the Authority.

2.18 Consumer — Any person who uses or is supplied water or on whose application such water is supplied by the Authority.

2.19 Consumer's Pipe — The portion of service pipe used for supply of water and which is not the property of the Authority.

2.20 Continuous Vent — A vertical vent that is a continuation of the drain to which it connects.

2.21 Deep Manhole — A manhole of such depth that an access shaft is required, in addition to the working chamber.

2.22 Degreasing — The process of removing greases and oils from sewage, waste sludge or garbage.

2.23 Depth of manhole — The vertical distance from the top of the manhole cover to the outgoing invert of the main drain channel.

2.24 Diameter — The nominal diameter of a pipe.

2.25 Direct Tap — A tap which is connected to a supply pipe and subject to water pressure from the water main.

2.26 Downtake Tap — A tap connected to a system of piping not subject to pressure from the water main.

2.27 Drainage — The removal of any liquid by a system constructed for the purpose.

2.28 Dry Vent — Any vent that does not carry water or water-borne waste.

2.29 Dwelling Unit — One or more rooms with provision for living, sanitary and sleeping facilities arranged for the use of one family.

2.30 Existing Buidling or Use — A building, structure or its use before the commencement of the Code and which does not conform to the Code.

2.31 Fixture Branch — In a water supply system, the water supply pipe between the fixture supply pipe and the water distributing pipe.

2.32 Fixture Drain — The drain from the trap of a fixture to the junction of that drain with any other drain pipe.

2.33 Fixture Supply — A water supply pipe connecting the fixture with the fixture branch.

2.34 Fixture Unit — A quantity in terms of which the load producing effects on the plumbing system of different kinds of plumbing fixtures is expressed on some arbitrarily chosen scale.

2.35 Fixture Unit Flow Rate — The total discharge flow in cubic feet per minute of a single fixture which provides the flow rate of that particular plumbing fixture as a unit of flow. Fixtures are rated as multiples of this unit of flow.

2.36 Flooded — A fixture is flooded when the liquid therein rises to the flood level rim or overflows on to the floor.

2.37 Fresh Air Inlet — A connection to the drainage system to permit the circulation of air through the system.

2.38 Geyser — An appliance for heating of water with a water control on the inlet side and free outlet.

2.39 Gulley Trap — A fitment with a trap and a screen through which the discharge from an open drain is taken to a sewer.

2.40 Horizontal Branch — A branch drain extending laterally from a soil or a waste stack, leader, house drain or house storm drain with or without vertical sections or branches, which receives the discharge from one or more fixture drains or plain water inlets and conducts it to the soil or waste stack or to the house drain or the house storm drain.

2.41 Horizontal Pipe — Any pipe which makes an angle of more than 45° with the vertical.

2.42 House Drain — That part of the lowest horizontal piping of a building drainage system, including the horizontal branch from the base of a stack connected to the main house drain which receives the discharge from soil, waste or other drainage pipes in the building and conveys it to the existing lateral, main sewer, cesspool or septic tank.

2.43 House Storm Drain — A drain used for conveying rain water, ground water, subsurface water, condensate, cooling water or similar discharge to the existing lateral or main sewer.

2.44 Individual Vent — A pipe installed to vent a fixture trap and which connects with the vent system above the fixture served or terminates in the open air.

2.45 Industrial Wastes — Liquid wastes resulting from the processes employed in industrial establishments and are free of faecal matter.

2.46 Junction Pipe — A pipe incorporating one or more branches.

2.47 Leader (Downspout) — The water conductor from the roof or gutter drain to the house storm drain or other piping serving as a storm drain including but not limited to a 'downspout' or a 'rain water conductor'.

2.48 Main Sewer — Any sewer owned or maintained by the public authority.

2.49 Minor Repairs — The repairing of an existing plumbing fixture, including the replacement of faucets or valves or parts thereof.

2.50 Plinth — The portion of a structure between the surface of the surrounding ground and surface of the floor immediately above the ground.

2.51 Plumbing Fixtures — Installed receptacles, devices or appliances which are supplied with water or which receive or discharge liquids or other liquid-borne wastes with or without discharge into the drainage system with which they may be directly or indirectly connected.

2.52 Residual Head — The head available at any particular point in the distribution system.

2.53 Return Offset — A double offset installed so as to return the pipe to its original alignment.

2.54 Rim — The unobstructed open edge of a fixture.

2.55 Riser — A water supply pipe which extends vertically one full storey or more to convey water to branches or fixtures.

2.56 Roof Drain — A drain installed to receive water collecting on the surface of a roof and to discharge it into the leader (downspout).

2.57 Roughing-in — The installation of all parts of the plumbing system which can be completed prior to the installation of the fixtures. This includes drainage, water supply and vent piping, and the necessary fixture supports.

2.58 Sanitary Sewer — A sewer which carries sewage and to which storm, surface and ground waters are not intentionally admitted.

2.59 Sewer, Branch — A sewer which receives sewage from a relatively small area and discharges into a main sewer.

2.60 Sewer, Building — *See* Building (House) Sewer.

2.61 Sewer, Building Storm — *See* Building Storm Sewer.

2.62 Sewer, Combined — A sewer receiving both surface run-off and sewage.

2.63 Sewer, Common — A sewer in which all owners of abutting properties have equal rights.

2.64 Sewer, Main — *See* Main Sewer.

2.65 Sewer, Private — A sewer privately owned and used by one or more properties.

2.66 Sewer, Sanitary — *See* Sanitary Sewer.

2.67 Sewer, Storm — A sewer which carries storm water and surface water, street wash and other wash waters or drainage but excludes sewage and industrial wastes.

2.68 Soil Waste — The discharge from water closets, urinals, slop sinks, stable or cowshed gullies and similar appliances.

2.69 Stack — The vertical main of a system of soil, waste or vent piping.

2.70 Stop Tap — A device which includes stop cock, stop valve or any other device for stopping the flow of water in a line or system of pipes at will.

2.71 Storm Drain — *See* Building Storm Drain.

2.72 Storm Sewer — *See* Sewer Storm.

2.73 Sump — A tank or pit which receives sewage or liquid waste, located below the normal grade of the gravity system and which must be emptied by mechanical means.

2.74 Supports Supports, hangers and anchors are devices for supporting and securing pipe and fixture to walls, ceilings, floors or structural members.

2.75 Systems of Drainage

a) *Combined System* — A system in which foul water (sewage) and surface water are conveyed by the same sewers and drains.

b) *Separate System* — A system in which the foul water (sewage) and surface water are conveyed by separate sewers and drains.

c) *Partially Separate System* — A modification of the separate system in which part of the surface water is conveyed by the foul (sanitary) sewers and drains.

2.76 Systems of Plumbing

a) *One-Pipe System* — The system of plumbing in which the waste connections from sink, baths and wash basins, and the soil pipe branches are all collected into one main pipe which is connected directly to the drainage system. Gulley traps and waste pipes are completely dispersed with but all the traps of water closets, basins, etc, are completely ventilated to preserve the water seal.

b) *One-Pipe System—Partially Ventilated* — Also called single stack, partially ventilated. A system in which there is one soil pipe into which all water closets, baths, sinks and basins discharge. In addition, there is a relief vent which ventilates only the traps of water closets.

c) *Two-Pipe System* — The system of plumbing in which soil and waste pipes are distinct and separate, the soil pipes being connected to the drain direct and waste pipes through a trapped gulley. All traps of all appliances are completely ventilated in this system.

d) *Single Stack System* — The one-pipe system in which there is no trap ventilation.

e) *Single Stack, Partialy Ventilated* — *See* one-pipe system, partially ventilated. A via media between the one-pipe system and the single stack system.

2.77 Terminal Pressure — The residual head at the end of distribution system.

2.78 Waste Water (Sullage) — Spent water from baths, wash basins, sinks and similar appliances, which does not contain human or animal excreta.

2.79 Water Level — The designed top water level of the cistern.

2.80 Water Main (Street Main) — A water supply pipe for public or community use which vests in the Authority. It refers to the pipe for the general conveyance of water as distinct from communication pipe for the conveyance of water for individual premises.

2.81 Water Outlet — A water outlet, as used in connection with the water distributing system is the discharge opening for the water to:

a) a fixture;

b) atmospheric pressure (except into an open tank which is part of the water supply system);

c) a boiler or heating system; and

d) to any water operated device or equipment requiring water to operate, but not a part of the plumbing system.

2.82 Water Works — Water works for public water supply include a lake, river, spring, well, pump with or without motor and accessories, reservoir, cistern, tank, duct whether covered or open, sluice water main, pipe, culvert, engine or machinery, land or building or a thing for supply or used for storing, treating and supplying water.

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SECTION 3
PLUMBING

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SECTION 3
PLUMBING

3.1 Plumbing Defined — Plumbing, in general, refers to the system as well as the material fixtures and the apparatus used inside a building for supplying water, removing the used water with other liquid and water-borne wastes as also the connected ventilating system. In practice, it also includes the system of storm water or roof drainage and exterior system components connecting to a source, such as a public or a private water system or a point of disposal of waste or used water, a public sewer system or an individual disposal system, namely, a domestic septic tank with arrangement for disposal of its effluent through a leaching cesspool or a collecting well with arrangements for removal of its contents by means of a vacuum car.

3.2 Plumbing Systems — The plumbing systems include:

a) water supply and distributing pipes from a public water system or a private water system or a private water supply system from a bore well or other source,

b) plumbing fixtures for the use in water supply as well as the collection and disposal of used waters,

c) sanitary drainage system to carry the wastes from the plumbing fixtures to the public or private disposal system,

d) Anti-siphonage system which carry only the air for the purpose of ventilation and preventing the failure of the water seals in traps thereby preventing the entry of foul air from the public or private drainage system into the building, and

e) Storm water drainage system to collect and carry rain water or water not used by occupants of the building to a public storm water drain or to a local garden or a pond.

3.3 Planning for Plumbing

3.3.1 Buildings whether they are for residential purposes or business purposes or industrial purposes or public recreation places, should be built with an eye for general sanitation and, an effective and intelligently planned plumbing. The layout of the building should be such as to allow for good and economical plumbing to be carried out. The location of plumbing equipment including the washing and sanitary appliances; hot water heaters, storage cisterns, etc, in a building may have marked effects on the efficiency and cost of plumbing. Many buildings, public and private, have been designed without sufficient regard to this factor and the plumbing has suffered accordingly. While it is not suggested that the plumbing of a building should be held to be of such relative importance as to control and restrict planning unreasonably, a fair compromise should be effected bearing in mind the serious inconveniences to building users which may arise from an unsatisfactory plumbing system and the undue costs of installation and upkeep which may be incurred thereby. Early consideration to the layout of the plumbing installation should remove many of the disadvantages which have formerly arisen. It is needless to emphasize that close grouping of plumbing equipment is desirable.

3.3.2 As the building is a place where protected water supply terminates so far as the building is concerned for the user and where the used or waste water starts collecting for passing outside, the possibility of contamination of the protected water supply through cross connections between the piping systems and at plumbing fixtures has to be borne in mind in the design of plumbing system and effective steps taken to avoid such a contingency.

3.3.3 Another important factor to be considered is the noise in plumbing. The serious annoyance and even ill effects on health of residents due to noise caused by the operation of plumbing systems, particularly in the case of flats, is to be noted.

3.3.4 The modern design lays emphasis on the concealment of plumbing like other services. While realizing the advantages from the point of view of internal and external appearance of buildings of concealing plumbing work within walls or ducts, sufficient precaution and safeguards are to be taken in the event of leakages, protection against frost where pipes are burried in outside walls and the possible harbouring of vermin behind casings. These considerations will point out that, in certain types of buildings, accessibility of piping is essential even if it means that pipes will be seen.

Any pipe or fittings which is proposed to be concealed either in the wall or below the flooring has necessarily to be wrapped with hessian cloth dipped in bitumen. Before the actual concealment work is done, it is also necessary to test these fittings for adequate water tightness.

3.3.5 There is a change in the adoption of 'single pipe system' and 'single stack system' from the orthodox type of 'two-pipe system' with a view to economize on the cost of plumbing and improvement of appearance. For low cost housing this may be considered. But for ultimate economy and efficiency, the orthodox system is to be favoured.

3.3.6 Above all, it is important to stress on the adoption of national standards, be it for selection of materials or equipment or construction or testing of the installations to achieve the best results by way of good materials at reasonably low cost, reliable and approved workmanship, and uniformity and interchangeability of the several similar components of the system.

3.4 Principles of Plumbing

3.4.1 The principles usually enunciated are the basic goals in environmental sanitation worthy of accomplishment through properly designed, acceptably installed and adequately maintained plumbing systems. Constant reference to sound principles is the surest way of maintaining good standards, guiding developments along the right lines and discouraging unwise departures from traditional practice.

3.4.2 The essentials of good plumbing necessitates the observance of the principles detailed below. These relate to the plumbing fixtures, the plumbing pipes and the plumbing systems as a whole.

3.4.2.1 The plumbing fixtures are to be:

a) made of smooth and non-absorbent material;

b) located in well ventilated enclosures;

c) free from concealed fouling spaces;

d) easily accessible for the intended use;

e) able to withstand adequate pressure;

f) connected to a drainage system with water seal traps;

g) tested for leaks, defects, etc, and rectified promptly, where necessary; and

h) heating and storage water cisterns are to be proofed against contamination and explosions through overheating.

3.4.2.2 The plumbing pipes are to be:

a) made of durable material, connected by suitable and satisfactory joints of good workmanship to give satisfactory service during its reasonable life expectancy;

b) located in places avoiding dead spaces which are not easily cleared;

c) easily accessible for inspection, working and repairs;

d) made rodent proof; and

e) tested for leaks, defects, etc, and promptly rectified, where necessary.

3.4.2.3 The plumbing systems are:

a) required for minimum amount of water for proper performance and cleaning;

b) to avoid cross-connections between the protected water supply system and the waste water system;

c) to be well ventilated with no danger of siphonage, aspiration or forcing of trap seal under conditions of ordinary use; and

d) to be well designed, executed, operated and maintained according to national standards and statutory provisions of the local administrative authority concerned.

3.5 Local Administrative Authorities — The buildings built with modern sanitary facilities are mostly in cities and towns which are administered by municipal corporations and municipalities created under a statute by the State or Central Government.

3.5.1 It is incumbent on the municipal corporation to make adequate provisions by any means or measures which it may lawfully use or take for several matters which include the following:

a) the construction and maintenance of works and means for providing supply of water for public and private purposes;

b) the construction and maintenance and cleaning of drains, drainage works, public latrines, urinals and similar conveniences; and

c) the scavenging, removal and disposal of filth, rubbish and other obnoxious or polluted matters.

3.5.2 Municipal corporations are also empowered to make the owner of buildings or the persons primarily liable for the payment of the property taxes in respect of the same to:

a) take a connection from the municipal water works adequate for the requirements of the persons occupying or employed in the premises; and

b) provide supply pipes and water fittings, etc, and take all measures as may, in the opinion of the Authority, be necessary for the above purposes.

3.5.3 New premises constructed or reconstructed are also to be occupied only after proper arrangement is made for water supply.

3.5.4 The corporation has also statutory provisions to enforce effective draining of the premises into the municipal drains or cesspool.

3.5.5 It also enforces that necessary appliances and fittings are provided for gathering and receiving filth and other polluted and obnoxious matter from and convey the same off the said premises and of effective flushing the drain of the said premises and every fixture connected therewith.

3.5.6 In the case of town municipalities, village panchayats and military contonments, where the standards as prescribed for municipal corporations are not feasible, certain relaxations are provided to suit their financial capacity. But there is no compromise on the essentials of providing a supply of protected water (though it may be on a lesser scale) and proper disposal of waste or used water.

3.5.7 The several acts created by the Administrative Authorities mentioned earlier also provide for matters relating to the supply of protected water to private premises and for the collection and disposal of the waste water. In addition each local authority is empowered to make its own bye-laws under the Act for carrying out the provisions of the Act, in great details to suit local needs and financial capacity. These may vary from place to place depending upon the stipulations by the Local Authorities. A copy of the procedure adopted by the Madras Metropolitan Water Supply and Sewerage Board is given in Appendices A and B.

3.5.8 *Licensing of Plumbers* — As already mentioned the house plumbing is the beginning of the drainage system and the termination of the water distributing system. It is here that a cross-connection between the protected water suply system and the waste water disposal system is possible due to bad plumbing. Such a contingency, when it happens, may endanger health of the entire (city) community (or town). It is therefore necessary that all works relating to plumbing within and outside the premises are properly executed under the supervision of the authorities at all stages. In this view it is essential that all works are carried out by plumbers licensed by the corporation or the local authority and who are punishable by the local authority for any lapses on their part in complying with the provisions of the rules or the bye-laws framed thereunder.

Though this system of licensing plumbers is insisted in all municipal corporations, it is yet to be enforced in all municipalities and townships, etc. Where licensing of plumbers is insisted, necessary provision is made for the examination and certification of all such plumbers to ensure a certain and uniform standard for the efficient performance of their duties. Rules regarding the grant of licence and service conditions of plumbers framed by the Madras Corporation and followed at present by the Madras Metropolitan Water Supply and Sewerage Board are given in Appendix C.

3.6 Plumbing Codes and Manuals — The several principles of plumbing mentioned earlier are enunciated and amplified in greater detail to suit local needs in the various plumbing codes and manuals issued by the several State Boards of Health in the USA. National Building Code of India 1983 has dealt with the plumbing services in Part IX of the Code. BIS has also published a number of standards for works relating to water supply and drainage system, etc, relating to buildings. These are to be taken for guidance in the preparation of the building bye-laws relating to water supply and drainage by local authorities with suitable adaptation to meet local needs and to suit their financial capacity. The aim of this Handbook is to coordinate the several recommendations in various Indian Standards and codes, and to amplify the provisions in these standards.

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SECTION 4

HYDRAULICS AND PNEUMATICS

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SECTION 4
HYDRAULICS AND PNEUMATICS

4.1 Problems Involved — Among the hydraulic and pneumatic problems involved in plumbing may be included water pressure; gas, air and steam pressures; the flow of fluids under pressure, as in water supply pipes; the flow of liquids at or near atmospheric pressure under conditions of open channel flow, as in drainage pipes; the measurement of rates of flow of fluids; and the characteristics of pressures resulting from the movement of air, water and solids in drainage pipes and the flow of air in vent pipes.

The selection of the proper sizes of pipes for plumbing installations is an important problem, the correct solution of which involves the principles of hydraulics and pneumatics of the flow of fluids in closed conduits, that is, under a pressure and at atmospheric pressure. In practice 'rules of thumb', authoritative publications and national code or local bye-laws requirements are commonly used. Such practical aids to the selection of pipe sizes are usually based on experience rather than on theory. However, a theoretical background helps appreciation of the practical usages and creates greater confidence in plumbing work. The peculiar conditions of flow in the plumbing drainage pipes have to be understood for a proper design of the installation.

4.2 Hydrostatic Water Pressure — Water is a liquid that at any point exerts equal intensity of pressure in all directions. The intensity of pressure on a submerged surface is expressed in kgf/cm² or in metres of water above the atmospheric pressure at the point where the pressure is being read.

$$h = 10\,p \text{ or } p = \frac{h}{10}$$

where

h = depth of submergence in metres, and

p = intensity of pressure in kgf/cm².

The value of p is also the gauge pressure since it is the pressure that would be shown on a pressure gauge. Absolute pressure is equal to the sum of atmospheric pressure and gauge pressure.

4.3 The total head at any point in a conduit flowing full

= pressure energy + kinetic energy

+ potential energy

$$= \frac{P}{wg} + \frac{V^2}{2g} + z$$

where

P = pressure of the moving liquid (kgf/m²),

w = density of the liquid (kg/m³),

g = acceleration due to gravity (m/s²),

V = velocity of flow (m/s), and

z = height of the point above the datum line (m).

Bernoullis Theorem — This states that in the streamlined flow of an incompressible fluid, the total head remains constant from section to section along the stream tube.

$$\frac{P}{wg} + \frac{V^2}{2g} + z = \text{constant}$$

If loss of head between two points A and B is h_f then,

$$\frac{P_A}{wg} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{wg} + \frac{V_B^2}{2g} + z_B + h_f$$

4.4 Pressure of Atmosphere — The pressure of the atmosphere at the earth's surface is due to the weight of column of air above. As the air is compressible and as a consequence the density varies, the atmospheric pressure is measured by the column of liquid it will support. This again varies with the amount of moisture in air and temperature. The average value is taken as 10 332 kgf/m² or 1·033 2 kgf/cm² or 10·332 metres head of water.

4.5 Gauge Pressure — The pressure of water in a pipeline or a vessel is measured by some type of gauge. The gauge registers the pressure above or below atmospheric pressure. To get the absolute pressure, the gauge pressure must be added or subtracted from the atmospheric pressure as the case may be. For pressures below the atmospheric pressure, the gauge pressures are observed on a *vacuum gauge*. If the pressures are above the atmospheric pressure, the gauge pressures are measured on a *pressure gauge*.

4.6 Siphonage — Siphonage, aspiration, suction, negative pressure, partial vacuum or vacuum and other terms are used synonymously to indicate a pressure below atmospheric or below gauge pressure. The flow through a siphon is due to the difference in elevation of the free surfaces above and below the siphon (h).

The greatest height over which water could be apparently lifted by suction is equal to the atmospheric pressure which is 10·36 metres at sea level. This height is further reduced due to vapour pressure of water which varies with temperature and is equal to atmospheric pressure at boiling point of water (100°C). The atmospheric pressure also gets reduced with the increase in elevation above sea level. Table 1 gives the atmospheric pressure y in metres of water for different elevations x above sea level in metres.

The values can also be obtained from the equation $y = 10.366 - 0.001\,108\,57x$.

Vapour pressure is the pressure exerted by the tendency of a liquid to vapourize. This tendency varies with the temperature of the liquid as shown in Table 2.

4.7 Air and Gas Locks — A bend or hump extending upward above the regular line of the run of a pipe as shown in Fig. 1 or extending above the hydraulic grade line as in a siphon, may permit the accumulation of air or gas in the bend. It is also called air binding. The effect may be either to reduce or to cut-off flow in the pipe or to require pressure to force the trapped air through the pipe. The trapped air will diminish or stop flow through the pipe by reducing the cross-sectional area available for flow. It will act as a stoppage that no amount of rodding will remove and that is not to be found when the pipe is opened for examination.

Air locks are likely to give trouble in pipes under low pressure and in siphons because of inadequate force to push the air along the pipe. The formation of an air lock can be prevented by avoiding the creation of upward humps in a pipeline or by the installation of an air release valve at the highest point where air or gas is likely to accumulate.

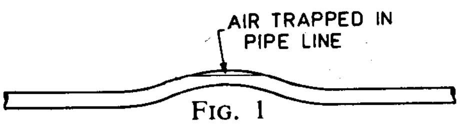


FIG. 1

4.8 Cavitation — Water vapourizes or boils at 100°C at atmospheric pressure. Water will boil or vapourize at a lower temperature if the pressure is reduced. This phenomenon may occur in plumbing pipes, equipment and pumps. It is called cavitation. It may be defined as a rupture of the continuity of a liquid as it turns to vapour owing to a sudden reduction of pressure. Low pressures are produced in conduits by a sudden increase of velocity. They are produced in equipment as, for example, in pumps when a moving object such as an impeller passes rapidly through the water. In other words, the pressure reduces as the velocity head increases in order that their sum may remain constant.

The rapidity with which a high vacuum is made and broken, and water changes from a liquid to a vapour and back to liquid again may be so great as to create sounds varying from a rattle to a loud roar. A corrosive effect may appear on the surfaces of metal exposed to cavitation. The phenomenon is avoided by maintaining low velocities between liquids and surfaces in contact, and by avoiding sudden accelerations in velocities of flow in closed conduits.

4.9 Water Hammer

4.9.1 If the velocity of water flowing in a pipe is suddenly diminished, the energy given up by the water will be divided between compressing the water itself, stretching the pipe walls and frictional resistance to wave propagation. This pressure rise or water hammer is manifest as a series of shocks sounding like hammer blows

TABLE 1 ATMOSPHERIC PRESSURE FOR DIFFERENT ELEVATIONS

(*Clause* 4.6)

x (m)	0	500	1 000	1 500	2 000	2 500	3 000	3 500	4 000
y (m)	10.37	9.82	9.28	8.74	8.19	7.65	7.11	6.57	6.02

TABLE 2 VAPOUR PRESSURE FOR DIFFERENT TEMPERATURES OF LIQUID

(*Clause* 4.6)

Temperature °C	0	5	10	15	20	25	30	35	40	45	50
Vapour pressure in mm of mercury	4.579	6.543	9.209	12.788	17.535	23.756	31.824	42.175	55.324	71.88	92.51

Temperature °C	55	60	65	70	75	80	85	90	95	100
Vapour pressure in mm of mercury	118.04	149.38	187.54	233.7	289.1	355.1	433.6	525.76	633.90	760.00

which may have sufficient magnitude to rupture the pipe or damage connected equipments.

It may be caused by the nearly instantaneous or too rapid closing of a valve in the line or by an equivalent stoppage of flow such as would take place with the sudden failure of electricity supply to a motor driven pump. The shock pressure is not concentrated at the valve and, if rupture occurs, it may take place near the valve simply because it acts there first. The pressure wave due to water hammer travels back upstream to the inlet end of the pipe, where it reverses and surges back and forth through the pipe getting weak on each successive reversal. The excess pressure due to water hammer is additive to the normal pressure in the pipe. Complete stoppage of flow is not necessary to produce water hammer as any sudden change in velocity will create it to a greater or lesser degree. The intensity of water hammer pressure varies directly with the velocity of flow in the pipe. If the velocity is kept below, the effect of water hammer could also be reduced.

Water hammer is held within bounds in small pipelines by operating them at moderate velocities because the pressure rise in kgf/cm^2 cannot exceed about 11.5 times the velocity expressed in metres per second. In larger lines the pressure is held down by changing velocities at a sufficiently slow rate so that the relief wave returns to the point of control before excessive pressures are reached. If this is not practicable, pressure-relief or surge valves are used.

4.9.2 *Prevention of Water Hammer* — The common causes in plumbing are the sudden closing of valves or taps particularly of the automatic self-closing type and the quick-closing types. Water hammer may be caused also by displacing air from a closed tank or pipe from the top by the condensation of steam in water in a closed pipe, by reciprocating pumping machinery by the sudden stoppage of a pump and by other means. Water hammer can be prevented when a closed tank or pipe is being filled by filling it from the bottom, allowing the air to escape from the top. Steam and water should not be allowed to come into contact in a closed pipe. To this end, downward dips in steam pipes should be avoided or suitable provision for drainage should be provided in case dips are unavoidable. The installation of an air chamber may control water hammer.

Other methods of avoiding water hammer include the use of slow closing valves and taps such as the screw down types and of pressure reducing valves. Other types are air chambers installed near the valve that is causing water hammer and is possible in a vertical position over the top of a riser pipe. The air chamber should have a capacity of atleast 1 percent of the total capacity of the pipeline in which the water hammer is occurring. The purpose of placing the air chamber on the top of the riser pipe is two fold:

a) air in the riser pipe will be compressed making way for excess water under pressure (trapped in the chamber aiding in keeping air in the chamber); and

b) it will receive the full thrust of the pressure from the vertical pipeline and will be more effective in its operation. Provision should be made for renewing the air in the chamber. This can be done by the use of a stop-and-waste valve and a pet cock.

If the water hammer is created in the water main in the street, the house plumbing may be protected by locating an air chamber on the service pipe as it enters the building.

The installation of a pressure reducing valve on the supply line to the source of the water hammer will result in a reduction of the velocity of flow in the pipe.

4.10 Flow of Water Under Pressure (Water Pipes) — The formula popularly used for the flow of water in conduits under pressure is the Hazen and William's formula given below:

$$V = 0.849\ CR^{0.63} \times S^{0.54} \qquad ...(1)$$

where

V = velocity in metres per second,

R = hydraulic radius in metres,

S = slope of hydraulic gradient (metre per metre), and

C = Hazen and William's coefficient.

For circular pipes, where $R = \frac{D}{4}$, the above formula becomes

$$V = 4.567 \times 10^{-3} \times C \times D^{0.63} \times S^{0.54} \qquad ...(2)$$

where D is the diameter of the pipe in mm.

The formula for Q, the discharge in kilolitres per day (kld) becomes

$$Q = 3.1 \times 10^{-4} \times C \times D^{0.63} \times S^{0.54} \qquad ...(3)$$

The value of C decreases with increasing surface roughness and the age of the pipe. The recommended values for new pipes and the values to be adopted for design purposes are given in Table 3.

Charts for the value of 100 for C have been prepared and given in Fig. 2 and 3. The chart in Fig. 2 is for all diameters and the chart in Fig. 3 is mainly for small diameter pipes. These charts can be used for other values of C also. For any other value of C, say C_1, the values of V and Q, as found from the chart for a given D and S, are to be multiplied by a factor $K_1 = \frac{C_1}{100}$ and for a given

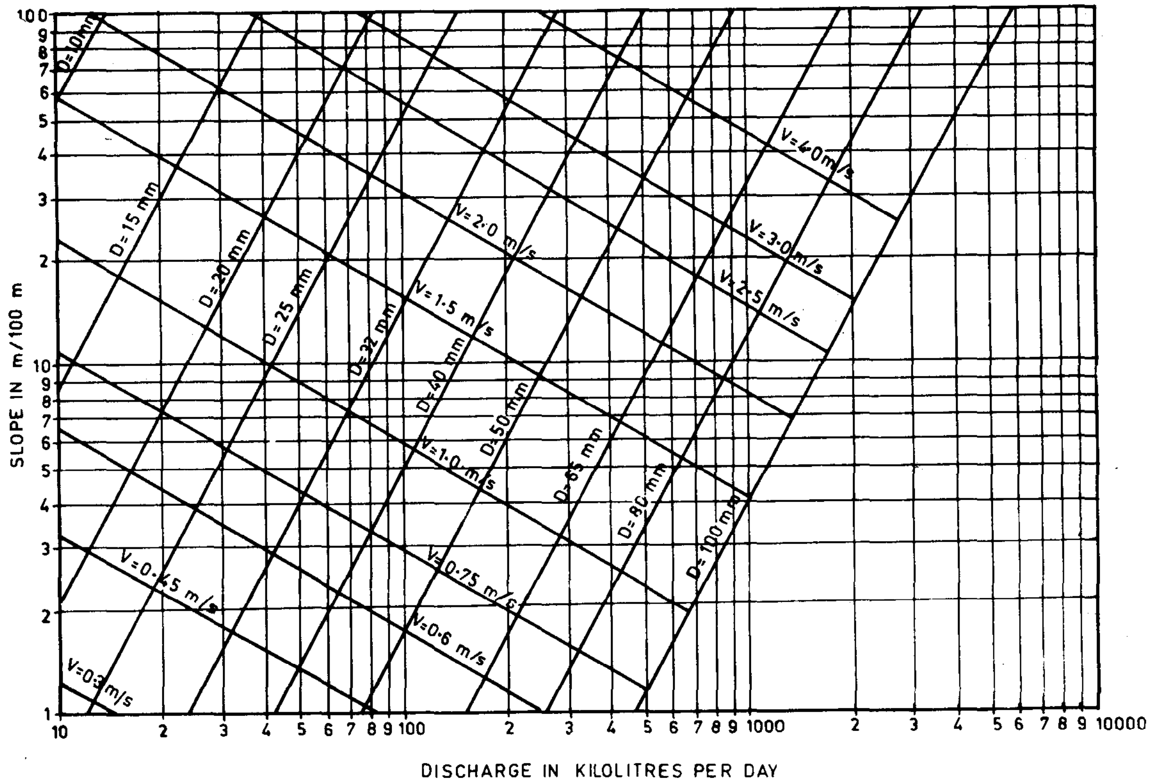


FIG. 3

D and Q or V the value of S as found from the chart has to be multiplied by a factor

$$K_2 = \left[\frac{100}{C_1}\right]^{1.85}$$

TABLE 3 RECOMMENDED VALUE OF HAZEN AND WILLIAM'S COEFFICIENT C

(*Clause* 4.10)

CONDUIT MATERIAL	RECOMMENDED VALUE OF C	
	For New Pipe	For Design Purposes
Cast iron	130	100
Galvanized iron > 50 mm	120	100
Galvanized iron 50 mm and below (used for house connections)	120	55
Steel, riveted joints	110	95
Steel, welded joints, lined with cement or bituminous enamel	140	110
Steel, welded joints	140	100
Concrete	140	110
Asbestos cement	150	120
Plastic pipes	150	120

Values of K_1 and K_2 for various values of C are given in Table 4.

Hazen and William's formula is applicable to flow of water under pressure and at velocities normally used for plumbing pipes. It may be mentioned here that the Tamil Nadu Water Supply and Drainage Board has prepared a set of tables for the use of Hazen and William's formula instead of charts, which may also be referred to, if needed and found convenient.

4.11 Flow of Water Under Gravity (Drainage Pipes) — For free flow of water in conduits under gravity, the Manning's formula given below is recommended:

$$V = \frac{1}{n} \times R^{2/3} \times S^{1/2} \qquad ...(4)$$

where

V = velocity in metres per second,

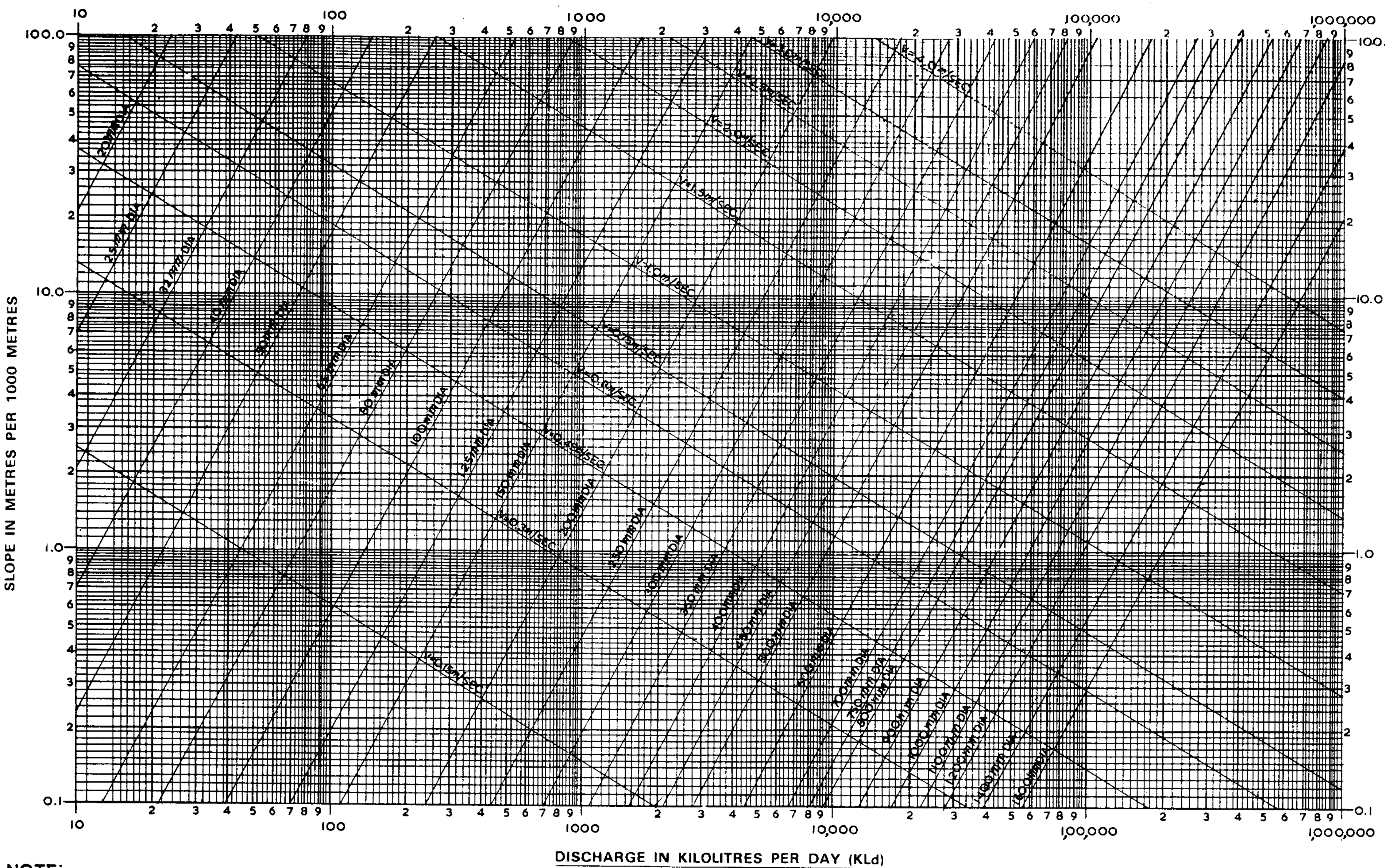
R = hydraulic radius in metres,

S = slope of hydraulic gradient (metre per metre), and

n = Manning's coefficient.

For circular pipes where $R = \frac{D}{4}$, the formula for V becomes

$$V = \frac{3.968}{n} \times 10^{-3} \times D^{2/3} \times S^{1/2} \qquad ...(5)$$



NOTE:— FOR ANY OTHER VALUE OF 'C' SAY 'C_1', THE VALUES OF v AND Q AS FOUND FOR A GIVEN d AND s FROM THE CHART ARE TO BE MULTIPLIED BY A FACTOR $K_1 = \left(\frac{C_1}{100}\right)$; AND FOR A GIVEN d AND Q OR v, THE VALUE OF SLOPE AS FOUND FROM THE CHART HAS TO BE MULTIPLIED BY A FACTOR $K_2 \left(\frac{100}{C_1}\right)^{1.85}$

VALUE OF C	70	80	90	100	110	120	130	140
K_1	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
K_2	1 94	1.51	1.22	1.0	0.84	0.71	0.62	0.54

CHART FOR DISCHARGE, ETC. ACCORDING TO HAZEN & WILLIAMS FORMULA

1) $v = 4.567 \times 10^{-3} \times C \times d^{0.63} \times s^{0.54}$
2) $Q = 3.1 \times 10 \times C \times d^{2.63} \times s^{0.54}$
3) $V = 0.849\, C\, r^{0.63}\, s^{0.54}$

WHERE

- v VELOCITY IN METRES PER SECOND
- Q = DISCHARGE IN KILOLITRES PER DAY (KLd)
- d = DIA OF CIRCULAR PIPE IN *mm*
- s = SLOPE
- C = HAZEN AND WILLIAMS COEFFICIENT OF 100 ADOPTED
- r = HYDRAULIC RADIUS IN METRES

FIG. 2. CHART FOR DISCHARGE, ETC. ACCORDING TO HAZEN AND WILLIAMS FORMULA

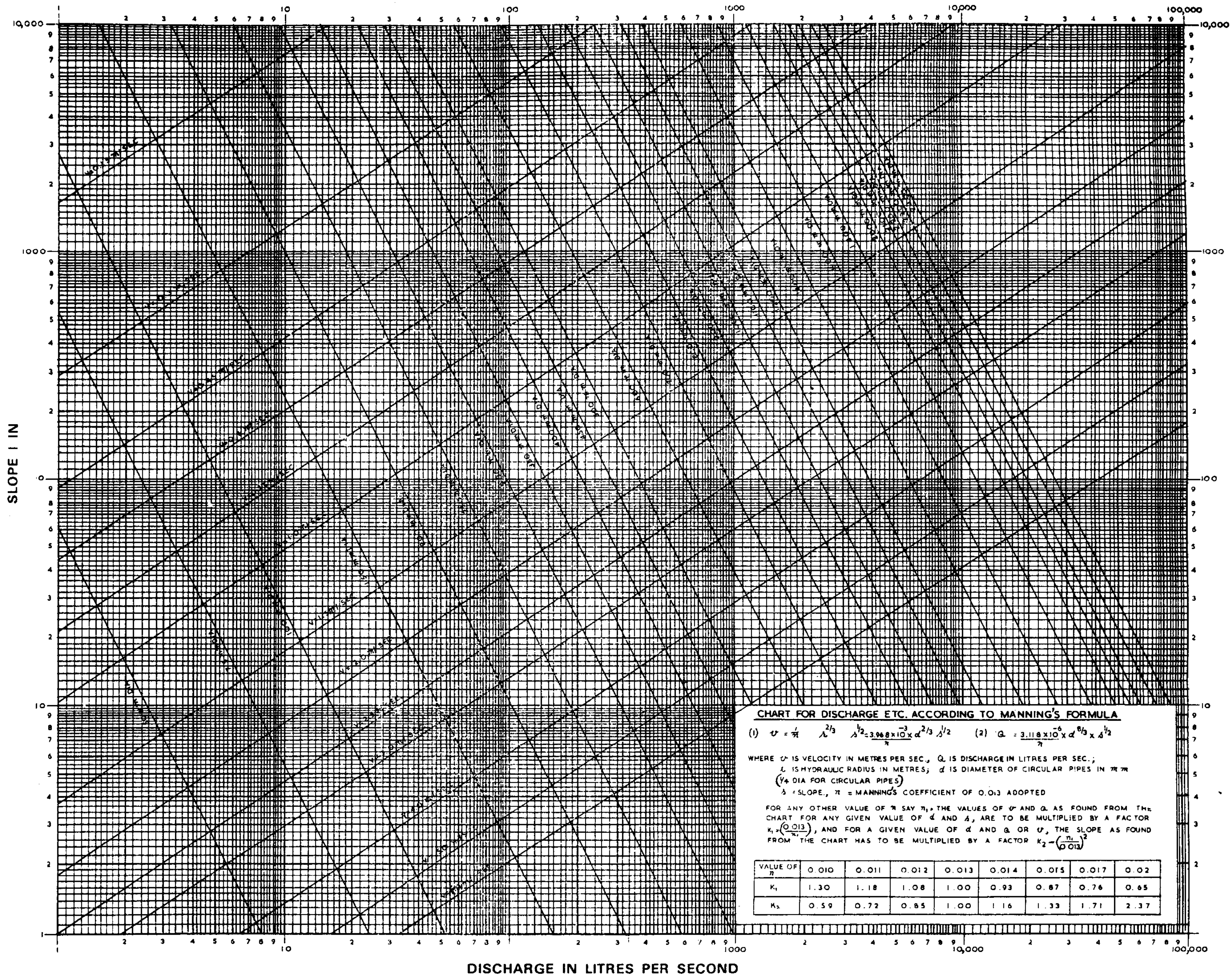


FIG. 4. CHART FOR DISCHARGE ETC. ACCORDING TO MANNING'S FORMULA

where D is the diameter of the pipe in mm.

The formula for Q, the discharge in litres per second, becomes:

$$Q = \frac{3.118}{n} \times 10^{-6} \times D^{8/3} \times S^{1/2} \quad ...(6)$$

The values of n varies directly with the roughness of surface. The coefficients of roughness for different surface linings in clean straight channels, as given in Table 5, are generally used for design purposes unless local experimental results or other considerations warrant the adoption of any other lower value for the coefficient.

For design of sewers and other free flow conduits in plumbing work, a value of $n = 0.013$ may be adopted for plastic pipes and 0.015 for all other pipes. The chart given in Fig. 4 is prepared for a value of 0.013 for n. For any other value of n, say n_1, the values of V and Q as found from the chart for any given value of D and S, are to be multiplied by a factor $K_1 = \frac{0.013}{n_1}$; and for a given value of D and Q or V, the slope as found from the chart has to be multiplied by a factor $K_2 = \left[\frac{n_1}{0.013}\right]^2$. Values of K_1 and K_2 for different values of n are given in Table 6.

It may be mentioned here that the Tamil Nadu Water Supply and Drainage Board has prepared a set of tables for the use of Manning's formula instead of charts which may also be referred to, if needed and found convenient.

4.12 Head Loss Due to Specials and Appurtenances as Given in 2 of IS : 2951 (Part 2)-1965.

4.12.1 Pipeline specials and appurtenances add to the head losses which are expressed at velocity heads as $\frac{V^2}{2g} K$

where

V = average velocity in a pipe of corresponding diameter in metre per second,

g = acceleration due to gravity in m/s^2, and

K = a specific resistance coeficient for the special or appurtenance.

Values of the resistance coefficients K for various specials and appurtenances carrying turbulent flow are given in Table 7. Flanged specials and appurtenances have lower resistance coefficients than screwed specials and appurtenances. The lower limits in Table 7 should be used with flanged specials and appurtenances particularly with sizes above 10 cm nominal diameter.

4.12.2 A simple way to account for the resistance offered to flow by specials and appurtenances is to add to the length of the pipeline a length which will give a pressure drop equal to that which occurs in the specials and appurtenances in the line. This is specially useful in the design of the pipe sizes in plumbing work. The equivalent length in metres, Le, is given by the following equation:

$$Le = CKD$$

where

Le = equivalent length in metres,

C = special coefficient according to the type of the special or appurtenance as given in Table 8,

K = resistance coefficient as given in Table 7, and

D = diameter of fitting in mm.

4.13 Head Loss in Meters

4.13.1 *Domestic Meters* — The head loss in domestic meters varies from 3 to 10 metres according to the discharge through the meter. The minimum discharges with the head loss exceeding 3 m and maximum discharge with the head loss exceeding 10 m are given in Table 9 and 10 (*see* Fig. 5).

4.13.2 *Bulk Meters* — The bulk meters may be of the vane wheel type or the helical type. The head loss in the vane wheel type meters varies from 3 to 10 metres according to the discharge through the meter. The head loss in the helical type meters varies from 1 to 3 metres according to the discharge through the meter. The range of discharges for these two types of meters are given in Table 11.

4.14 Equivalent Pipes — Pipes are said to be equivalent when they will carry the same rate of flow with the same loss of head.

TABLE 4 VALUES OF K_1 AND K_2 FOR DIFFERENT VALUES OF C

(*Clause* 4.10)

Value of C	70	80	90	100	110	120	130	140
K_1	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
K_2	1.94	1.51	1.22	1.0	0.84	0.71	0.62	0.54

TABLE 5 COEFFICIENTS OF ROUGHNESS FOR DIFFERENT SURFACE LININGS

(*Clause* 4.11)

Type of Lining	Condition	n
Glazed coating or enamel	In perfect order	0.01
Timber	a) Planed boards carefully laid	0.014
	b) Planed boards, inferior workmanship or aged	0.016
	c) Unplaned boards, carefully laid	0.016
	d) Unplaned boards, inferior workmanship or aged	0.018
Masonry	a) Neat cement plaster	0.018
	b) Sand and cement plaster	0.015
	c) Concrete, steel trowelled	0.014
	d) Concrete, wood trowelled	0.015
	e) Brick in good condition	0.015
	f) Brick in rough condition	0.017
	g) Masonry in bad condition	0.020
Stone work	a) Smooth, dressed ashlar	0.015
	b) Rubble set in cement	0.017
	c) Fine, well-packed gravel	0.020
Earth	a) Regular surface in good condition	0.020
	b) In ordinary condition	0.025
	c) With stones and weeds	0.030
	d) In poor condition	0.035
	e) Partially obstructed with debris or weeds	0.050
Steel	a) Welded	0.013
	b) Riveted	0.017
	c) Slightly tuberculated	0.020
Cast iron	In good condition	0.013
Asbestos cement	In good condition	0.012
Plastic (smooth)	In good condition	0.011

TABLE 6 VALUES OF K_1 AND K_2 FOR DIFFERENT VALUES OF n

(*Clause* 4.11)

Value of n	0.010	0.011	0.012	0.013	0.014	0.015	0.016	0.017	0.018	0.02
K_1	1.30	1.18	1.08	1.00	0.93	0.87	0.81	0.76	0.72	0.65
K_2	0.59	0.72	0.85	1.00	1.16	1.33	1.51	1.71	1.92	2.37

4.15 Flow of Water in Systems of Pipes (Equivalent Length and Head Loss)

4.15.1 Pipes of different sizes and length may be connected in series or in parallel or in combination of this. When the pipes are in series, the loss of head in the system for any flow is easily determined with the help of the chart. If on the other hand it is to calculate the flow in the system for any given total loss of head, this cannot be done directly but has to be worked out after determining an equivalent pipe for the system. Likewise for pipes in parallel the flow in the pipe can be determined if the loss of head is given. If on the other hand it is desired to calculate the loss of head in the system for any total flow, it will have to be determined after finding an equivalent pipe for the system.

4.16 Flow Down Vertical Pipes (Drainage Pipes) — The flow down vertical drainage pipes such as soil pipes, waste pipes and stacks is different from that encountered in water supply pipes as the drainage pipes do not normally run full. It has often been thought that discharges pass down the vertical pipes as solid plugs of water but this is not usually the case. Most of the water flows down as an annular sheet round the inside wall, the remainder of the pipe being occupied by

TABLE 7 RESISTANCE COEFFICIENTS FOR SPECIALS AND APPURTENANCES

(Clause 4.12.1)

SL No.	DESCRIPTION OF SPECIALS AND APPURTENANCES	RESISTANCE COEFFICIENT (*K)
(1)	(2)	(3)
i)	Inlets or Reducers	
	a) Bell mouth	0.04 to 0.05
	b) Square edged	0.47 to 0.56
ii)	Elbows	
	a) Regular screwed 45° elbow	0.30 to 0.42
	b) Regular screwed 90° elbow	0.55 to 0.90
	c) Regular flanged 90° elbow	0.21 to 0.30
	d) Long radius flanged 45° elbow	0.18 to 0.20
	e) Long radius flanged 90° elbow	0.14 to 0.23
	f) Long radius screwed 90° elbow	0.22 to 0.60
iii)	Bends	
	a) Screwed return bend, close-pattern	0.75 to 2.2
	b) Flanged return bend composed of two 90° flanged elbows	
	1) Regular	0.38
	2) Long radius	0.25
iv)	Inward Projecting Pipe	0.62 to 1.0
v)	Valves	
	a) Globe valves	
	1) Composition disc globe valve	0.23 to 5.2
	2) Bevel seat globe valve	6.2 to 7.2
	3) Plug disc globe valve	7.2 to 10.3
	b) Gate valves	
	1) Wedge disc gate valve	0.05 to 0.19
	2) Double disc gate valve	0.08 to 0.13
	c) Check valves	
	1) Swing check valve	0.6 to 2.3
	2) Horizontal (left) check valve	8 to 12
	3) Ball check valve	65 to 70
	d) Angle valve	2.1 to 3.1
	e) Y or blow off valve	2.9
	f) Foot valve	15
vi)	Standard Screwed Tee	
	a) Branch blanked off	0.4
	b) Line blanked off	
	1) Flow from line to branch	0.85 to 1.3
	2) Flow from branch to line	0.92 to 2.15
vii)	Long Radius Screwed Tee	
	a) Line blanked off	
	1) Flow from line to branch	0.37 to 0.80
	2) Flow from branch to line	0.50 to 0.52
viii)	Couplings and Unions	0.02 to 0.07
ix)	Reducing Bushing and Coupling Used as Reducer	0.05 to 2.0

NOTE — Used as increaser, loss is up to 40 percent more than that caused by a sudden enlargement.

*K = Decreases with increasing wall thickness of pipe and rounding of edges.

TABLE 8 SPECIAL COEFFICIENTS

(*Clause* 4.12.2)

Special or Appurtenance	Value of *C*
Gate valve	0.08
Globe valve	0.05
Angle valve	0.03
Ordinary entrance	0.035
Couplings or unions	0.06
Elbows	
a) Square	0.066
b) Standard	0.044
c) Medium sweep	0.07
d) Long sweep	0.082
Tees	0.066

TABLE 9 DISCHARGES WITH HEAD LOSS NOT EXCEEDING 10 m

(*Clause* 4.13.1)

Nominal Size of Meter in mm	Discharge Per Hour in Litres	
	Semi-positive Type	Inferential Type
15	2 000	2 500
20	3 400	3 500
25	5 500	5 500
40	10 000	16 000
50	15 000	23 000

TABLE 10 MINIMUM DISCHARGES

(*Clause* 4.13.1)

Nominal Size of Meter in mm	Discharge Per Hour in Litres	
	Semi-positive Type	Inferential Type
15	1 000	1 500
20	2 000	2 500
25	3 000	3 500
40	6 000	8 000
50	9 000	14 000

a core of air drawn down by the discharge, the air entering the pipe through the open top or the ventilating pipes. Solids with some water fall down the centre of the pipe occupied by the air. The entrained air mixes with the falling water, the mixture occupying a greater space than that occupied by the water alone.

The falling water and air occupy the full cross-section of the vertical pipe and in falling down together act as a long elastic piston expelling air ahead of it and drawing air in behind it. The air mixed with water allows part of the piston to expand and contract as the water at lower end is accelerated or retarded. Siphonage and back pressure are thus created to be transmitted throughout the piping system relieved by venting. Siphonage may be expected to develop when first of the falling water has acquired a velocity greater than that of the water following it. If the curvature of the foot piece at the base is gentle and the house drain or sewer is unobstructed by a main trap, entrained air can be discharged freely into the sewer. In this case the water falls to the outside of the bend and then flows along the invert of the drain with the air moving along above the water. The air and water discharge together into the main drain or sewer and the air escapes through the vertical pipes adjacent to the one discharging.

The back pressure formed at the head of the falling column of water will be small and about 3 mm. Similarly the siphonage at the top of the stack will also be small if there is adequate venting. If there is inadequate venting, the back pressure and siphonages may even be in many metres of water. Rapid alternations of back pressure and siphonage may churn the water in the traps without expelling the same. For pipes relatively long with respect to their diameter, the sudden transmission of such pressures may rupture the seal of a trap. Only a small change in the volume of air confined in a pipe is required to force the seal of a trap. To force a 7.5 cm trap, a

TABLE 11 RANGE OF DISCHARGES FOR SPECIFIED HEAD LOSS

(*Clause* 4.13.2)

Nominal Size of Meter in mm	Discharge in Litres Per Hour				Head Loss	
	Vane Wheel Type		Helical Type		Vane Wheel Type	Helical Type
	From	To	From	To		
50	17 000	30 000	20 000	50 000	Three metres to Ten metres according to flow	One metre to three metres according to flow
80	27 000	50 000	62 000	125 000		
100	40 000	70 000	100 000	200 000		
150	80 000	150 000	250 000	500 000		
200	150 000	250 000	400 000	800 000		
250	220 000	400 000	550 000	1 100 000		
300	300 000	500 000	750 000	1 500 000		
350	—	—	1 000 000	2 000 000		
400	—	—	1 500 000	3 000 000		
500	—	—	2 500 000	5 000 000		

charge of about $\frac{1}{130}$ of the absolute air pressure is sufficient in the vertical pipe. The effect on the intensities of back pressures ar.d siphonages by solids discharged with water as in the case of water-closets may be appreciable when the rate of flow is low but is negligible when the rate approaches the discharge capacity of the drainage pipe. For practical purposes the effect of solids on discharges can be disregarded. However, it is important to consider slopes, angles of turns, types of connections, smoothness of passages, cleavents, etc, to avoid clogging of the pipes by solids.

4.17 Flow Through Branch Pipes — The flow in branch pipes differ from that in the vertical pipe since only a mixture of solids and water without slugs of air is involved in the former. Horizontal pipes should be designed to flow less than full with vents provided to permit entry and exist of air since the pipes are alternately partly filled with and emptied of water which causes air movements. Pressures may be created in horizontal pipes when two or more fixtures are discharged simultaneously at a rate sufficient to fill the pipe between them without allowing for adequate venting.

Pressures created in vertical pipes may be transmitted undiminished to and through connected horizontal pipes. This is important in considering the distance between traps, vertical pipes and vent pipes.

4.18 Plumbing Traps — The principal points of a plumbing trap are the crown weir, the dip and the seal. The crown weir is the lowest point in the trap over which the liquid must flow to leave the trap. the dip of a trap is the lowest point in the trap to which the liquid surface can sink before air or gas can pass through the trap.

The seal is the vertical distance between the crown weir and the dip. The seal may be destroyed by:

a) direct air pressure or back pressure,

b) the capillary action of an absorbent material such as a string or cloth lying across the crown weir,

c) inertia of water passing rapidly through the trap,

d) evaporation, and

e) siphonage or self-siphonage.

4.19 Hydraulics of Traps

4.19.1 The strength or ability of a trap seal to resist the passage of air or gas through it is determined by a vertical height to which the water

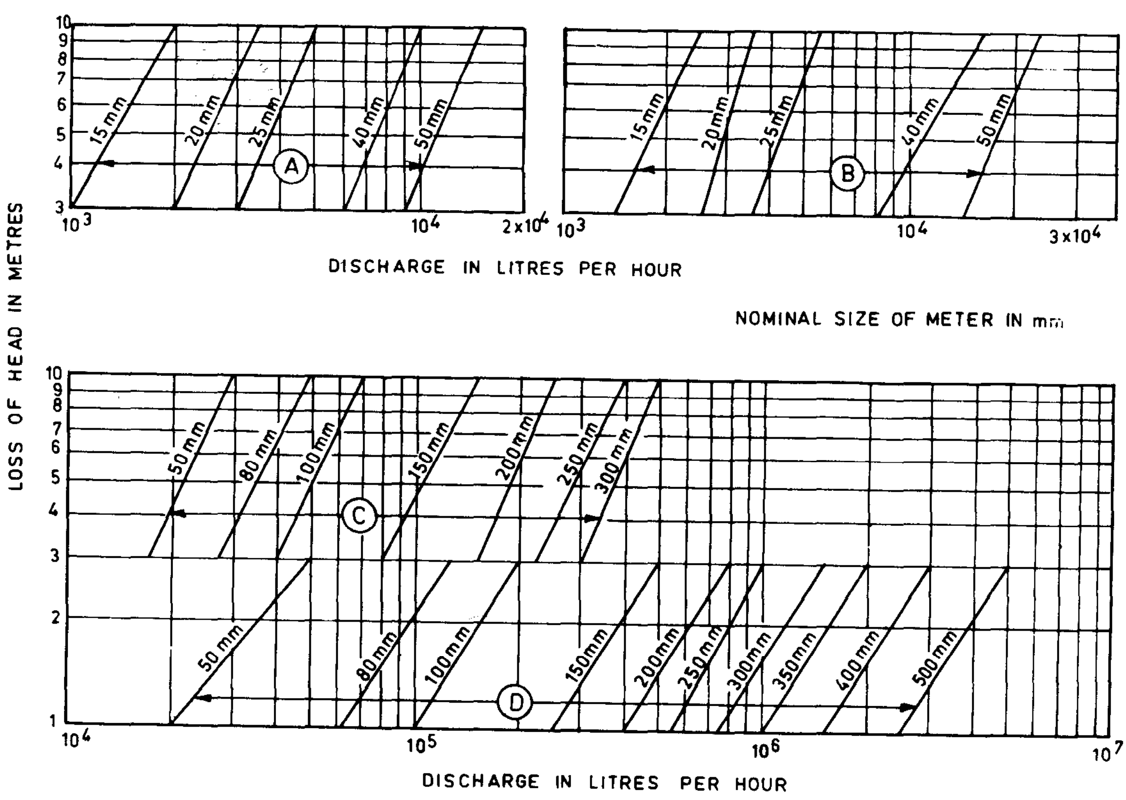


FIG. 5

in the trap can rise above the dip to resist this passage. The strength of a trap seal varies directly with its depth.

4.19.2 *Back Pressure* — Back pressure on a trap is pressure applied against the downstream free surface of water in the trap. This pressure tends to force the water up the drain pipe towards or into the fixture.

4.19.3 *Siphonage* — Siphonage is the reduction of the pressure against the downstream free surface of water in the trap so that the greater air pressure (atmospheric) on the upstream free surface forces water to flow from the trap into the drain pipe.

4.19.4 *Self-siphonage* — Self-siphonage is the reduction of pressure against the downstream free surface of water in the trap by the creation of an unvented column of water in the drain pipe continuous with and downstream from the water in the trap.

4.19.5 The intensity of siphonage or self-siphonage varies directly as the difference between the pressures on both sides of the trap. Siphonage and self-siphonage are more undesirable than back pressure because the former removes water from the trap so that the strength of the seal is weakened or destroyed whereas after back pressure is removed, water may flow from the fixture to restore the seal.

The strength of a trap seal may be weakened if the rhythm of impulses of back pressure or siphonage corresponds to the swinging period of water in the trap. Back pressure and siphonage are seldom slowly and steadily developed and applied. They often consist of sudden impulses of short duration alternating between pressure and siphonage.

Conditions affecting self-siphonage include seal, rate of discharge, momentum of mass of water causing self-siphonage, type of trap and vertical length of the downstream leg of the drain pipe which forms the lower leg of the siphon. To prevent or diminish self-siphonage, the downstream length of drain pipe below the crown weir should be short, the discharge should be at a low rate so as to be insufficient to fill the downstream pipe, the trap should be of the non-siphon type. The fixture should create a vortex as it discharges thus admitting air to break the siphonage and should have a flat bottom that will cause a low rate of flow towards the end of its discharge thus refilling the trap seal. Also the trap should be well vented.

SECTION 5

WATER SUPPLY

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SECTION 5
WATER SUPPLY

5.1 General

5.1.1 Buildings in which plumbing fixtures are installed shall be provided with ample supply of potable water by connection to a public water supply system. Where a public water supply system is not available, an approved source of private water supply shall be provided.

For a residential building a public water supply shall be deemed available when such a system is within 30 metres of the premises on which the dwelling is located measured along a street and a connection may be made lawfully thereto. For a non-residential building, the distance shall be 150 metres instead of 30 metres.

Only potable water shall be supplied to fixtures and equipment at which water is provided for purposes, such as drinking, cooking, food preparation, washing of dishes and kitchen utensils.

Non-potable water shall not be supplied to fixtures or equipment unless specially approved by the health authority having jurisdiction and the supply of non-potable water shall be limited to water-closets, urinals, and other fixtures and equipment which do not require potable water supply.

In the case of supply from a public water supply system, it shall be ensured that the system has been adequately designed to provide for a potable and adequate water supply made available at the street mains with adequate pressure supply to the building.

5.1.2 *Public Water Supply* — The public water supply system is usually designed to meet the requirements over a thirty-year period after their completion. The population to be served during such period will have to be estimated with due regard to all factors governing the future growth and development of the city in the industrial, commercial, educational, social and administrative spheres. Special factors causing sudden emigration or influx of population should also be foreseen to the extent possible.

Usually for a city with unlimited scope for expansion and where a constant rate of growth is anticipated, the geometrical progression method is adopted. Usually this is done graphically by plotting the population figures for the available census years, on a semi-log paper with the population figures read on the logarithmic scale and the years on the arithmetic scale; drawing the line of best fit for the plotted points and projecting the same for determining the population for the future years.

The thirty-year period may, however, be modified in regard to specific components of the project particularly the conveying mains and trunk mains of the distribution system depending upon their useful life or the facility for carrying out extensions when required so that expenditure far ahead of utility is avoided.

5.1.3 *Per Capita Supply* — Piped water supplies for communities should provide adequately for the following as applicable:

a) domestic needs, such as, drinking, cooking, bathing, washing, flushing of toilets, gardening and individual air-conditioning;

b) institutional needs:

c) public purposes, such as street washing or street watering, flushing of sewers and watering of public parks;

d) industrial and commercial uses including central air-conditioning;

e) fire fighting;

f) requirement for live-stock; and

g) likely waste amongst all users.

In assessing these requirements, due consideration should be given to the local needs, peoples' habits and standard of living, the industrial and commercial importance of the city, climatic conditions, availability of private water supplies, etc.

As a general rule, the Expert Committee of the Ministry of Health, in their Manual on Water Supply has recommended the following rates per capita per day for domestic and non-domestic needs:

a) For communities with population up to 10 000	70 to 100 litres
b) For communities with population 10 000 to 50 000	100 to 125 litres
c) For communities with population above 50 000	125 to 200 litres

The National Building Code of India 1983 has recommended a minimum of 135 litres per capita per day (lpcd) for all residences provided with full flushing system for excreta disposal. This figure may be adopted for the design of the water supply to the residences.

5.1.4 *Water Supply for Buildings other than Residences* — The requirements for water supply for buildings other than residences shall be as detailed in Table 12.

5.1.5 *Pressure Requirements* — Piped water supplies should be designed on a continuous 24 hours basis to distribute water to consumers at

TABLE 12 REQUIREMENTS FOR WATER SUPPLY FOR BUILDINGS OTHER THAN RESIDENCES

(*Clause* 5.1.4)

SL No.	TYPE OF BUILDING	CONSUMPTION PER DAY IN LITRES
(1)	(2)	(3)
i)	Factories where bathrooms are to be provided	45 per head
ii)	Factories where bathrooms are not to be provided	30 per head
iii)	Hospitals (including laundry)	
	a) Number of beds not exceeding 100	340 per bed
	b) Number of beds exceeding 100	450 per bed
iv)	Nurses' homes and medical quarters	135 per head
v)	Hostels	135 per head
vi)	Hotels	180 per bed
vii)	Offices	45 per head
viii)	Restaurants	70 per seat
ix)	Cinemas, concert halls and theatres	15 per seat
x)	Schools	
	a) Day schools	45 per head
	b) Boarding schools	135 per head
xi)	Railway and bus stations	
	a) Intermediate stations (excluding express and mail stops)	
	1) where bathing facilities are provided	45 per head
	2) where no bathing facilities are provided	23 per head
xii)	Junction stations and intermediate stations where mail or express stoppage is provided	
	a) where bathing facilities are provided	70 per head
	b) where no bathing facilities are provided	45 per head
xiii)	Terminal railway and bus stations	45 per head
xiv)	International and domestic airports	70 per head

NOTE — For items (xi) to (xiv), the number of persons shall be determined by the average number of passengers handled by the stations daily; due considerations may be given to the staff and vendors likely to use the facilities.

adequate pressure at all points. Intermittent supplies are neither desirable from the public health point of view nor economical.

The pressure requirements for the distribution system should be as given in **5.1.5.1**.

5.1.5.1 For towns where one-storeyed buildings are common and for supply to the ground level storage tanks in multi-storeyed buildings, the minimum residual pressure at the ferrule point should be 7 metres; for direct supply, where two-storeyed buildings are common, it may be 12 metres; and where 3-storeyed buildings are prevalent, 17 metres. The pressure required for fire fighting will have to be boosted by fire fighting units.

5.1.6 *Quality Requirements* — The water supplied should be free from pathogenic organisms, clear, palatable, free from undesirable taste and odour, of reasonable temperature, neither corrosive nor scale forming, and free from minerals which could produce undesirable physiological effects.

The standards, as have been set up by the Union Health Ministry, are given in **5.1.6.1** to **5.1.6.3**.

5.1.6.1 *Physical and chemical standards* — The physical and chemical quality of water should not exceed the limits shown in Table 13.

5.1.6.2 *Bacteriological standard*

a) Water entering the distribution system shall satisfy the following criteria:

Coliform count in any sample of 100 ml should be zero. A sample of the water entering the distribution system that does not conform to this standard calls for an immediate investigation into both the efficacy of the purification process and the method of sampling.

b) Water in the distribution system shall satisfy all the three criteria indicated below:
   1) E. Coli count in 100 ml of any sample should be zero.
   2) Coliform organisms not more than 10 per 100 ml shall be present in any sample.
   3) Coliform organisms should not be detectable in 100 ml of any two consecutive samples or more than 50 percent of the samples collected for the year.

If coliform organisms are found, re-sampling should be done. The repeated finding of 1 to 10 coliform organisms in 100 ml or the appearance of higher numbers in any sample should necessitate the investigation and removal of the source of pollution.

c) *Individual or small community supplies*

E. Coli count should be zero in any sample of 100 ml and coliform organisms should not be more than 3 per 100 ml. (If repeated samples show the presence of coliform organisms, steps should be taken to discover and remove the source of the pollution. If coliforms exceed 3 per 100 ml, the supply should be disinfected).

TABLE 13 PHYSICAL AND CHEMICAL STANDARDS

(*Clause* 5.1.6.1)

SL No.	CHARACTERISTICS	ACCEPTABLE*	CAUSE FOR REJECTION*
(1)	(2)	(3)	(4)
i)	Turbidity (units on J.T.U. scale)	2.5	10
ii)	Colour (units on platinum-cobalt scale)	5.0	25
iii)	Taste and odour	Unobjectionable	Unobjectionable
iv)	*p*H	7.0 to 8.5	6.5 to 9.2
v)	Total dissolved solids (mg/l)	500	1 500
vi)	Total hardness (as $CaCO_3$) (mg/l)	200	600
vii)	Chlorides (as Cl) (mg/l)	200	1 000
viii)	Sulphates (as SO_4) (mg/l)	200	400
ix)	Fluorides (as F) (mg/l)	1.0	1.5
x)	Nitrates (as NO_3) (mg/l)	45	45
xi)	Calcium (as Ca) (mg/l)	75	200
xii)	Magnesium (as Mg) (mg/l)	$\ngtr$ 30 (If there are 250 mg/l of sulphates, Mg content can be increased to a maximum of 125 mg/l with the reduction of sulphates at the rate of 1 unit per every 2.5 units of sulphates)	150
xiii)	Iron (as Fe) (mg/l)	0.1	1.0
xiv)	Manganese (as Mn) (mg/l)	0.05	0.5
xv)	Copper (as Cu) (mg/l)	0.05	1.5
xvi)	Zinc (as Zn) (mg/l)	5.0	15.0
xvii)	Phenolic compounds (as phenol) (mg/l)	0.001	0.002
xviii)	Anionic detergents (as MBAS) (mg/l)	0.2	1.0
xix)	Mineral oil (mg/l)	0.01	0.3
xx)	Arsenic (as As) (mg/l)	0.05	0.05
xxi)	Cadmium (as Cd) (mg/l)	0.01	0.01
xxii)	Chromium (as hexavalent Cr) (mg/l)	0.05	0.05
xxiii)	Cyanides (as CN) (mg/l)	0.05	0.05
xxiv)	Lead (as Pb) (mg/l)	0.1	0.1
xxv)	Selenium (as Se) (mg/l)	0.01	0.01
xxvi)	Mercury (total as Hg) (mg/l)	0.001	0.001
xxvii)	Polynuclear aromatic hydrocarbons (PAH)	0.2 $\mu g/l$	0.2 $\mu g/l$
xxviii)	Gross alpha activity	3 pCi/*l*	3 pCi/*l*
xxix)	Gross beta activity (pCi = pico Curie)	30 pCi/*l*	30 pCi/*l*

NOTE 1 — The figures indicated under the column 'acceptable' are the limits up to which the water is generally acceptable to the consumers.

NOTE 2 — It is possible that some mine and spring waters may exceed these radio activity limits and in such cases it is necessary to analyze the individual radionuclides in order to assess the acceptability or otherwise for public consumption.

*Figures in excess of those mentioned under 'acceptable' render the water not acceptable, but still may be tolerated in the absence of alternative and better source up to the limits indicated under column 'cause for rejection' above which the supply will have to be rejected.

5.1.6.3 *Virological aspects* — 0.5 mg/l of free chlorine residual for one hour is sufficient to inactivate virus, even in water that was originally polluted. This free chlorine residual is to be insisted in all disinfected supplies in areas suspected of endemicity of infectious hepatities to take care of the safety of the supply from virus point of view which incidentally takes care of the safety from the bacteriological point of view as well. For other areas 0.2 mg/l of free chlorine residual for half an hour should be insisted.

5.2 Sources of Water

5.2.1 *Kinds of Water Sources and their Characteristics* — The origin of all sources of water is the rainfall. Water can be collected as it falls as rain before it reaches the ground; or as surface water when it flows over the ground or is pooled in lakes or ponds; or as ground water when it percolates into the ground and flows or collects as ground water; or from the sea into which it finally flows.

5.2.1.1 *Water from precipitation* — Rain water collected from roofs or prepared catchments for storage in small or big reservoirs is soft, saturated with oxygen and corrosive. Microorganisms and other suspended matters in the air are entrapped but ordinarily the impurities are not significant, but the collecting cisterns or reservoirs are liable to contamination.

5.2.1.2 *Surface waters*

a) *Natural quiescent waters as in lakes and ponds* — These waters would be more uniform in quality than water from flowing streams. Long storage permits sedimentation of suspended matter, bleaching of colour and the removal of bacteria. Self-purification which is an inherent property of water to purify itself is usually less complete in smaller lakes than in larger ones. Deep lakes are also subject to periodic overturns which brings about a temporary stirring up of bottom sediments. The microscopic organisms may be heavy in such waters on occasions. If the catchment is protected and unerodible, the stored water may not require any treatment other than disinfection.

b) *Artificial quiescent waters as in impounding reservoirs* — Impounding reservoirs formed by hydraulic structures thrown across river valleys are subject more or less to the same conditions as natural lakes and ponds. While top layers of water are prone to develop algae, bottom layers of water may be high in turbidity, carbon dioxide, iron, manganese and on occasions hydrogen sulphide. Soil stripping before impounding of water would reduce the organic load in the water.

c) *Flowing waters as in rivers, streams and irrigation canals* — Water from rivers, streams and irrigation canals are generally more variable in quality and less satisfactory than those from lakes and impounding reservoirs. The quality of the water depends upon the character and area of the watershed, its geology and topography, the extent and nature of development by man, seasonal variations and weather conditions. In populated regions, pollution by sewage and industrial wastes will be direct. The natural and man-made pollution results in producing colour, turbidity, tastes and odours, hardness, bacterial, and other microorganisms in the water supplies.

d) *Sea Water* — Though this source is plentiful, it is difficult to extract economically water of potable quality because it contains 3.5 percent of salts in solution and it involves costly treatment to desalt the water. Yet it has to be adopted in places where sea water is the only source available and potable water has to be obtained from it such as ships on the high seas or a place where an industry has to be set up and there is no other source of supply.

e) *Waste water reclamation* — Sewage or other waste water of the community may be utilized for non-domestic purposes such as water for cooling, flushing, lawns, parks, fire fighting and for certain industrial purposes after giving the necessary treatment to suit the nature of use. The supply from this source to residences is prohibited because of the possible cross-connection with the potable water supply system.

5.2.1.3 *Ground waters*

a) *General* — Rain water percolating into the ground and escaping beyond the reach of vegetation and either collecting in underground basins or flowing underground in subsurface streams constitutes a ground water source.

The water as it seeps down comes into contact with organic and inorganic substances during its passage through the ground and acquires chemical characteristics representative of the strata passed through.

Generally ground waters are clear and colourless but are harder than the surface waters of the region in which they occur. In limestone formations ground waters are very hard, tends to form deposits in pipes and are relatively non-corrosive. In granite formations they are soft, low in dissolved minerals relatively high in free carbon dioxide and are actively corrosive. Bacterially ground waters are much better than surface waters except where subsurface pollution exists. Ground waters are generally of uniform quality although changes may occur in the quality with changes in the rate of draft.

While some of the chemical substances like fluorides and those causing brackishness are readily soluble in water, other such as those causing alkalinity and hardness are soluble in water containing carbon dioxide absorbed from the air or from decomposing organic matter in the soil. Such matter also removes the dissolved oxygen from the water percolating through. Water deficient in oxygen and high in carbon dioxide dissolves iron and manganese compounds in the soil. Percolation into the subsoil also results in the filtering out of bacteria and other living organisms. In fissured or creviced rock formations such as limestone, however, surface pollutions can be carried long distances without material change.

b) *Springs* — Springs are due to the emergence of ground water to the surface. Till it issues out on the surface as a spring, the ground water carries minerals acquired from the subsoil layers which may supply the nutrients to micro-organisms collected by the spring if it flows as a surface stream. Spring waters from shallow strata are more likely to be affected by surface pollutions than are deep seated waters.

c) *Saline intrusion* — Saline intrusion or salt water creep may occur in tidal estuaries or in ground water. The salt content of such river waters may also vary with the tides and it is essential to determine the periods when the supply should be tapped to have the minimum salt content.

Ground waters in coastal acquifers overlies the denser saline water. Every metre rise of the water table above the sea level corresponds to a depth of 41 metres of fresh water lens floating over the saline water. In such cases the pumping from wells has to be carefully controlled to avoid the salt water tongue entering the well and polluting the same.

5.2.2 *Development of Subsurface Sources* — The subsurface sources include springs, galleries and wells.

5.2.2.1 *Springs* — The outflow of ground water constitutes a spring. There are four kinds of springs:

a) outflow of ground water into a surface stream;

b) outflow of ground water over an outcropping, impervious stratum;

c) outflow of ground water from a confined acquifer through an impervious stratum into a overlying acquifer or above ground; if the flow is into an overlying acquifer, it is called a subartesian spring; and if the flow is above ground, it is called an artesian spring; and

d) outflow of ground water into the fissures of rock.

The first two types of spring are best developed by constructing a trench or by laying a line of drain tile at right angles to the direction of flow of ground water and by discharging the water into a collecting well which is also used as a pump suction pit. This type of construction constitutes an infiltration gallery. Springs of the third and fourth types can best be developed by the construction of a deep well at the site.

5.2.2.2 *Infiltration galleries* — An infiltration gallery is a porous barrel inserted within the acquifer either axially along or across the ground water flow with a collecting sump at the end from which the water is pumped out. The collecting well is the point at which the maximum head of depression is imposed under the pumping operation, the depression head being diffused throughout the length of the gallery to induce the ground water flow from the farthest reach. The normal cross-section of a gallery comprises loosely jointed or porous pipes or rows of pipes enveloped by filter media of graded sizes making up a total depth of about 2.5 metres and a width of 2.5 metres and above depending on the number of pipes used for the collection of the infiltered water. The enveloping media round the collecting pipe functions more as a graded plug whereby the water from the subsurface sandy layers are abstracted without drawing in fine particles of sand at the same time. The gallery has necessarily to be located sufficiently below the lowest ground water level in the acquifer under optimum conditions of pumping during adverse seasons. If located in a river bed the top of the gallery has to be much below the scouring zone in the river under high floods. The natural permeable layers of the acquifer over the gallery media serve as the initial filtering layers for the subsoil flow and also safeguards the gallery from scouring effect. The gallery pipes may be of stoneware or concrete pipes loosely jointed with cement lock fillets. Perforated PVC pipes can also be used. The pipes may be laid horizontally or with a gradient in the direction of flow. The coarse aggregate envelope consists of three layers followed by coarse and medium sand layers as detailed below:

a) Filtering medium — 38 mm broken stone near pipes

b) Second layer — 38 to 19 mm broken stone

c) Third layer — 12 to 6 mm broken stone

d) Fourth layer — Coarse sand passing through a sieve of 3.35 mm size and retained on a sieve of 1.7 mm size.

e) Fifth layer — Fine sand retained on 70 micron sieve and pass through 1.7 mm sieve.

5.2.2.3 *Wells* — The wells are masonry shafts or tubewells inserted into the ground to tap the subsurface flow of ground water. The wells may be shallow or deep. Shallow wells may be of the dug well type sunk or built, the bored type or the driven type. They are of utility in abstracting limited rates of yield from shallow pervious layers, overlying the first impermeable layer. Deep wells are wells taken into pervious layers below the first impermeable stratum. They can be of the sunk well type, the bored or the drilled type. They are of utility in abstracting comparatively larger supplies from different pervious layers below the first impervious layer. They yield a safer supply than shallow wells but generally contain more minerals.

The wells are classified according to construction as follows:

a) *Dug wells* — Dug well of the built type has a restricted application in semi-permeable hard formations. The depth and diameter are decided with reference to the area of seepage to be exposed for intercepting the required yield from the subsoil layers. Unsafe quality of water may result if care is not taken in the well construction. It is necessary to provide a water tight steining up to a few metres below the vertical zone of pollution which usually extends 3 to 5 m or more below natural ground surface. The steining should extend well above the ground surface and a water tight cover provided with water tight manholes. The bottom of the well should be at a level sufficiently below the lowest probable summer water table allowing also for an optimum draw down when water is drawn from the well. To facilitate infiltration into the well, either the steining is constructed in dry masonry or weepholes are left in the steining at suitable intervals. It is usual to insert cut lengths of pipe in the steining with the water end covered with a wire gauge and shrouded with gravel to arrest ingress of fine material.

b) *Sunk wells* — Sunk wells depend for their success on the water bearing formations which should be of adequate extent and porosity.

The yield of any form of well is dependent on the rate of flow of the ground water and area made tributary by the depression of the water level in the well rather than on the size or form of construction. The large well, however, has an advantage over the small well in its storage capacity and facility for placement of pump sets economically. There is less chance of fine material going into the well in the case of large wells than in the case of small ones. Wells for water suply are constructed of diameters ranging from 3 m and above. The minimum depth is determined by the depth necessary to reach and penetrate for an optimum distance the water bearing stratum allowing a margin for dry seasons for storage and for such draw down as may be necessary to secure the necessary yield.

The construction procedure is to have an open excavation up to the subsoil water table and thereafter to commence sinking the steining built in convenient heights over a wooden or RCC curb with a cutting edge at the bottom, the curb projecting 4 cm beyond the outside face by the steining to facilitate easy sinking. Mild steel holding-down rods are run from the bottom of the curb through the steining spaced about 2 m circumferentially with horizontal ties in steel or of concrete rings spaced about 2 m vertically. The material from the inside well is dredged and removed either mechanically of by manual labour using divers with diving equipment. Entry of water is usually at the bottom below the curb. In order to reduce the velocity of entry and to abstract a larger yield for the same draw down weepholes in the steining at suitable intervals horizontally and vertically would be useful.

In the case of infiltration wells sunk in sandy soils, a porous plug in the form of a reverse filter is placed at the bottom of the well after the initial training of the yield from such well to facilitate the abstraction of a greater yield as the plug would permit increased velocities of entry without sand blows. The graded plug is usually an inverted filter comprising coarse sand and broken metal of appropriate sizes to suit the texture of the subsoil layers in the acquifer immediately below the well tub. The depth and the composition of the porous plug will be designed to maintain the natural sandy layer immediately below the curb level undisturbed during pumping.

Radial strainer pipes are driven horizontally from the interior of the sunk wells into the water-bearing pervious strata as a measure of increasing the yield for the same draw down. They are also called 'radial collector wells.'

All wells should be covered so as to prevent direct pollution of water. In the case of wells sunk in streams, the top of well should be 1 metre above the maximum flood level. If the well top is below flood level, provisions should be made for ventilating the well.

c) *Driven wells* — The shallow tube-well also called a 'driven well' is sunk in various ways depending upon its size, depth of well and nature of soil met with. The closed end of a driven well comprises a tube of 40 to 100 mm in diameter closed and pointed at one end and perforated for some distance therefrom. The tube thus prepared is driven into the ground by a wooden block until it penetrates the water bearing stratum. The upper end is then connected to a pump and the well is complete. Where the material penetrated is sand, the perforated portion is covered with wire gauge of suitable size depending upon the fineness of sand. To prevent injury to gauze and closing of the perforations the head of the shoe is made larger than the tube or the gauze may be covered by a perforated jacket. Driven tubewells are adopted in soft or sandy ground for depths up to about 25 m. It is useful for temporary supplies generally and for community water standpost in rural areas.

Special care is necessary during construction to avoid surface pollution reaching the subsoil water directly through the passage between the pipe and the surrounding soil. The usual precaution is to have the perforations confined to the lower depths of the acquifer with the plain tubing extending over the top few metres of the soil. In addition a water tight concrete platform with a drain should be provided above ground level in order to deflect any surface pollution away from the pipe.

d) *Bored wells* — Bored wells are tubular wells drilled into permeable layers to facilitate abstraction of ground water through suitable strainers into the well extending over the required range or ranges of the water bearing strata. There are various ways of drilling such wells through different soils and for providing suitable strainers with a gravel shrouding, where necessary.

These wells are used for obtaining water from shallow as well as deep acquifers. Open end tubes are sunk by removing the material from the interior by different methods. For hard soils, the hydraulic rotary method and the percussion method of drilling are popular.

For soft soils the hydraulic jet method, the reverse rotary recirculation method are commonly used. With the hydraulic direct rotary method, drilling is accomplished by rotating suitable tools that cut, chip, and abrade the rock formations into small particles. The equipment used consists of a derrick, suitable cable and reels for handling the tools and lowering the casing into the hole, a rotary table for rotating the drill pipe and bit; pumps for handling the mud laden fluid and a suitable source of power. As the drill bit attached to the lower end of the drill pipe is rotated, circulating mud is pumped down the drill pipe, out through opening in the bit and up the surface through the space between the drill pipe and the walls of the hole. The mud laden fluid removes the drill cuttings from the hole and also prevents caving by plastering and supporting the formation that have been penetrated. For soft and moderately hard materials, a drilling tool shaped like the tail of a fish, the 'fish tail bit', is used. In hard rock, a rock bit or roller bit is substituted. This bit has a series of toothed cutting wheels that revolve as the drill pipe is rotated.

Water wells drilled by this method are generally cased after reaching the required depth, the complete string of casing being set in one continuous operation. If the water bearing formation lies so deep that it probably cannot be reached by a hole of uniform diameter, the hole is started in one or more sizes larger than the size desired through the water-bearing formation. Separate strings of casing are used as required through the separate sections of the hole. If the formation is so well consolidated that the hole will remain open without casing, a well may be finished with one string of casing and a well screen.

This method is more suitable for drilling deep holes in unconsolidated formations. It is unsuitable for drilling in boulders and hard rocks due to slow progress and high cost of bits.

In the percussion method of drilling, the hole is bored by the percussion and cutting action of a drilling bit that is alternately raised and dropped. The material loosened by the drill bit forms a sludge that is removed from the hole by a bailer or a sand pump. The drilling tools are operated by suitable machinery which is usually of the portable type mounted on a truck or a trailer so that it can be moved readily from job to job. This method is most suitable for drilling on boulders. Percussion drilling in hard rock is a slow process and is being gradually replaced by pneumatic rotary drilling because of economy and speed of completion regardless of the higher initial cost.

Hydraulic jet method is the best and most efficient for small diameter bores in soft soils. Water is pumped into the boring pipe fitted with a cutter at the bottom and escapes out through the annular space between the pipe and the bored hole. The pipe is rotated manually with the aid of the pipe wrenches with a steady downward pressure. The soil under the cutter gets softened and loosened by the action of the jet of water and is washed with it as the cutter proceeds down with the weight of the pipe. Additional lengths of pipe are added till the required depth is reached. The wash water emanating from the annular space indicates the type of soil that is being encountered by the cutter. When the desired depth is reached, the pipes are withdrawn and the well tube with the strainer is lowered by the same process using a plug cutter with the plug renewed instead of the ordinary steel cutter. When the pipe is in position, the plug is dropped down to seal the bottom. The tube-well is then cleaned by forcing water through a 20 mm pipe lowered right to the bottom of the tube-well. Then it is withdrawn and the pump fitted on top.

For bigger diameter tube-wells casing pipes are used and mechanically driven pump set is used for jetting. The tube-well pipe with the strainer is lowered into the casing pipe and the outer casing withdrawn. Generally compressed air is used for developing this well. To economize the use of water during the operation, the wash water drawn from the bore is led to a sump wherefrom the water is again drawn for being forced into the bore.

In the reverse rotary method, water is pumped out of the bore through the pipe and fed back into the annular space between the bore and the central pipe. This method is used in clayey soils with little or no sand and where no casing is required. This method is used for large dia bores up to 150 m depth. The cutting pipe is clamped to a turn-table which rotates slowly operating the cutter. The water pumped out of the tube contains the washings and is led into a series of sumps for effective sedimentation of the solid particles before the water is put back to flow into the bore. Bentonite or some clayey material which can adhere to the sides of the bore firmly is used from time to time. After the required depth is reached the pipe with the cutter is taken out of the bore and the well pipe with the strainer is then lowered into the hole. The annular space between the bore and the well screen is then shrouded with pea gravel.

Casing of wells in soft soils must be cased throughout. When bored in rock it is necessary to case the well atleast through the soft upper strata to prevent caving. Casing is also desirable for the purpose of excluding surface water and it should extend well into the solid stratum below. Where artesian condition exists and water will eventually stand higher in the well than the adjacent ground water, the casing must extend into and make a tight joint with the impervious stratum to prevent escape of water into the ground above.

Large casing is generally made of welded or riveted steel pipe. For smaller sizes of pipes which are to be driven, the standard wrought iron pipes are generally used; for heavy driving, extra strong pipe is necessary. The life of the pipe is affected by corrosion due to the carbonic acid encountered in some cases. The use of rust resisting alloys is advisable in such cases. Non-reinforced plastic, usually PVC casing up to 100 mm dia and reinforced plastic casing and fibre glass for longer dia up to 400 mm, are coming into vogue.

In providing the strainer arrangement whereby water is admitted and sand or gravel excluded, it is desirable to make the openings of the strainer as large as practicable to reduce friction while at the same time preventing entrance of any considerable amount of sand. Where the acquifer consists of particles that vary widely in size, however, the capacity of the well is improved by using strainer openings through which the finer particles are drawn into the well while the coarser ones are left behind with increased void space. The size of openings may be selected after a study of the mechanical analysis of the acquifer material to permit the passage of all fine particles representing a certain percentage, by weight, of the water bearing material. It is common practice to use openings that will pass about 70 percent or more of the sand grains in the material acquifer whose uniformity coefficient should range between 2 and 2.5. For soils with uniformity coefficient less than 1.5, gravel shroud should be used. The shape of the openings should prevent clogging and bridging which can be diminished by V-shaped openings with the larger ends towards the inside of the well. Long narrow horizontal or vertical slotted pipes are preferred for large diameters. The openings should be placed as close together as the strength of the screen will permit. The entrance velocity of water should be less than 4 to 6 cm per second with gravel shrouding. The thickness of this shroud varies to suit the size and depth of boring. It is usually 10 cm. The size of the gravel is decided by the particle size distribution in the layer penetrated and the slot size in the well screens proposed to be adopted.

5.2.3 *Rain Water Cisterns* — Rain water stored in a cistern and properly protected from contamination is used as a satisfactory source of water in regions where there is scarcity of water from other sources and storage of rain water is desirable. Cisterns are constructed below ground or under basement of buildings. Water in the cistern may become contaminated by ground water leaking into the cistern or through the deposition of the eggs of flying insects in the water. Cisterns offer an attractive environment for the breeding of mosquitoes. They must therefore be covered and ventilated by insect-proof ventilators. The rain water catchment area usually the house roof or terrace should receive periodical attention and cleared off leaves, bird's nests, dead animals, etc. The first rush of rain water on any catchment area will probably carry with it into the cistern much undesirable matter. This can be diverted by the use of a bypass valve in the rain water leader. When necessary a rain water filter may also be installed.

5.2.4 *Development of Surface Sources*

5.2.4.1 *Intakes* — A waterworks intake is a device or a structure placed in a surface water source to permit the withdrawal of water from the source. They are used to draw water from lakes, reservoirs or rivers in which there is either a wide fluctuation in water level or when it is proposed to draw water at the most desirable depth. A study of the currents in a lake or river should be made before the location of an intake is selected to ensure water of the best quality and the avoidance of the polluted water. An intake in an impounding reservoir should be placed in the deepest part of the reservoir which is ordinarily near the dam to take full advantage of the reservoir capacity available. The intake structure designs should provide for withdrawal of water from more than one level to cope up with seasonal variations of depth of water. Under sluices should be provided for release of less desirable water held in storage.

5.2.4.2 *Impounding reservoirs* — An impounding reservoir is a basin constructed in the valley of a stream by the construction of a dam to store water during excess stream flow and to supply water when the flow of the stream is insufficient to meet the demand. For water supply purposes, the reservoir should be full when the rate of flow of stream begins to become less than the rate of demand for water. A mass diagram can be drawn to determine the required storage. The catchment area should be prepared so that water from the collecting grounds can flow quickly into the reservoir instead of collecting in pools and swamps where it can pick up organic matter. The area to be submerged should be prepared by cutting all the trees and bushes and burning out the vegetation. Sources of pollution should be removed from the area to be flooded.

5.3 Treatment of Water

5.3.1 *Methods of Treatment* — The aim of water treatment is to produce and maintain water that is hygienically safe, aesthetically attractive and palatable in an economical manner. Though the treatment of water would achieve the desired quality, the evaluation of its quality should not be confined to the end of the treatment facilities but should be extended to the point of consumer use. The method of treatment to be employed depends on the nature of raw water and the desired standards of water quality. The unit operations in water treatment constitute aeration, flocculation, clarification, filtration, disinfection, softening, deferrization, defluoridation and water conditioning as may be required in any individual case.

In the case of a ground water and well protected surface water storage where the turbidity is below 10 JTU (Jackson Turbidity Unit) and where there is no colour and odour, plain disinfection by chlorination is sufficient. Where ground water contains excessive iron, dissolved carbon dioxide and odorous gases, aeration followed by floccuation, sedimentation, rapid gravity or pressure filtration and chlorination may be necessary. In case there is only carbon dioxide or odorous gases, aeration followed by disinfection may be sufficient. In surface waters with turbidities not exceeding 50 JTU and where sufficient area is available, plain sedimentation followed by slow sand filtration and disinfection could be sufficient. Conventional treatment including pre-chlorination, aeration, flocculation, sedimentation, rapid gravity filtration and post-chlorination are adopted for highly polluted surface waters laden with algae or microscopic organisms. Water with excessive hardness needs softening. This is generally adopted for ground waters used for washing clothes as in machine laundry. For removal of dissolved solids, demineralization by ion exchange may form a part of domestic or industrial water treatment units.

5.3.1.1 *Aeration*

a) Aeration is necessary to promote the exchange of gases between water and atmosphere. In water treatment, aeration is practised for three purposes:

   1) to add oxygen to water for imparting freshness as in the case of water from underground sources devoid of sufficient dissolved oxygen;

   2) to expel carbon dioxide, hydrogen sulphide and other volatile substances causing odour and taste as in the case of water from deeper layers of an impounding reservoir; and

3) to oxidize the iron and manganese from the basic ferrous states to the ferric states and thereby promote precipatation in the case of certain ground waters.

b) There are two main types of aerators, namely:

1) those forming drops or thin sheets of water exposed to the atmosphere as in the case of spray, waterfall or multiple tray or cascade or mechanical aerators; and

2) those in which air is bubbled through water as in diffusion aerators.

In the case of individual water supply units, spray aerators are adopted. In this case water is sprayed through nozzles upward into the atmosphere and broken up into a mist or droplets. The installation consists of trays and fixed nozzles or a pipe grid with necessary outlet arrangements. Nozzles usually have diameters varying from 10 to 40 mm spaced in the pipe at intervals of 0.5 to 1 m. Special type of nozzles which are corrosive resistant are sometimes used. In practice, the pressure at the nozzle varies from 2 to 9 m and the discharge ratings per nozzle vary from 300 to 600 lpm. Usually aerator area of 1.25 to 3.75×10^{-3} square metre per kld of design flow is provided.

c) *Water fall or multiple tray aerators* — Water is discharged through a riser pipe and distributed on to a series of trays or steps from which the water falls either through small openings to the bottom or over the edges of the trays. Water finally falls to a collection basin at the bottom. In most aerators, coarse media such as coke stone or ceramic balls ranging from 50 to 150 mm in dia are placed in the trays to increase the efficiency especially for removal of iron. The trays about 4 to 9 in number with a spacing of 300 to 750 mm are arranged in a structure 1 to 3 m high. With the media good turbulence is created and large water surface is exposed to the atmosphere. The space requirements vary from 0.3 to 1 m^2 per kld flow. Natural vantilation or forced draft is provided. Removal efficiency varying from 65 to 90 percent for carbon dioxide and 60 to 70 percent for hydrogen sulphide have been reported.

5.3.1.2 *Chemical treatment* — The chemicals are introduced into water for the purpose of coagulation and flocculation, disinfection, softening, corrosion control and algal control. As the treatment is a continuous process, the flow of chemicals is regulated and measured continuously through chemical feeders which can be either of the solution feed type or the dry feed type.

5.3.1.3 *Sedimentation* — Sedimentation tanks or settling basins are used to separate the settleable suspended solids from water. Sedimentation of water can be plain or aided by coagulants. The tanks are either of the horizontal flow or vertical flow types. They are either circular, square or rectangular. For plain sedimentation, the detention time varies from 3 to 4 hours while for coagulated water, it would be between 2 to 2.5 hours. For vertical flow tanks the detention time is from 1 to 1.5 hours. The depth varies from 2.5 to 4 metres. For effective settling the overflow rate, that is, the discharge rate divided by the plan area of the tank should not exceed the hydraulic subsidence value of the particles required to be removed. The overflow rate, also called surface loading, must necessarily vary to suit the character and the specific gravity of the particles to be settled.

In horizontal flow circular settling tanks the surface loading used varies from 30 to 40 m^3/d/m^2, while in vertical flow settling tanks the rate ranges from 40 to 50 m^3/d/m^2. Settling analysis must be conducted in the laboratory to arrive at the optimum rates. The overflow weir length relative to surface area determine the strength of the outlet current. Normal weir loadings are up to 300 m^3/d/m^2 settled sludge from the tanks is normally removed under hydrostatic pressure through pipes. For continuous removal of sludge in mechanized unit, pipes of 100 to 150 mm dia are adopted. For non-mechanized unit, pipes of atleast 200 mm dia are used. For manual cleaning the floor slope should be about 1 in 10. Where mechanical scrappers are provided, the slope should not be flatter than 1 in 12. In hopper bottom vertical flow tanks, the slope of the hopper sides should not be less than 60° to the horizontal to ensure smooth sliding of the sludge.

5.3.1.4 *Filtration* — Filtration is a physical and chemical process for separating suspended and colloidal impurities from water by passing through a porous bed, usually made of gravel and sand or other granular material. Three types of filters are commonly used.

a) *Slow sand filter* — It consists of a water tight basin containing a layer of sand 75 to 90 cm thick supported on a layer of gravel 20 to 30 cm thick. The gravel is underlain by a system of open joint under-drains which lead the water to a single point of outlet, where a device is generally located to control the rate of flow through the filter. The effective size of sand used is 0.2 to 0.3 mm and its uniformity coefficient is 2.0 to 3.0. The gravel is usually placed in 4 layers for a total depth of 30 cm graded from 2 to 45 mm. 30 to 40 cm long baked clay or concrete pipes are laid with open joints to form the under-drain system.

In operation the filter is filled with water to a depth of 1.0 to 1.5 m above the surface of the sand. The rate of filtration is usually

100 to 150 lph/m² and the maximum loss of head is 60 cm. When this head is reached, the filter is taken up for cleaning. The water is drained, the bed dried, and the surface scraped to a depth of 20 to 30 mm. The depth of sand is restored by addition of clean sand. A normal period of operation between cleanings may be about 6 weeks with the turbidity of the raw water not exceeding about 30 JTU. Continuous coagulation is not to be used for slow sand filtration. Sometimes where water is clear initial dosing with alum is done to form the mat on the surface. The rate of flow is regulated by a rate controller on the effluent pipe. Slow sand filters are highly efficient in the removal of bacteria, nevertheless the water should be disinfected. Slow sand filters are suitable where the turbidity of raw water is below 50 JTU.

b) *Rapid sand filtration* — In the case of rapid gravity filters the water receives preparatory treatment prior to its application to the filter. The water that enters the filter contains flocs in which are entrapped suspended organic and mineral matter. The standard rate of filtration through a rapid sand filter is usually 80 to 100 lpm/m². Practice is tending towards higher rates in conjunction with greater care in conditioning the water before filtration and with the use of coarser sand. A maximum area of 100 m² for a single unit of filter is recommended for plants of greater than 1 000 mld consisting of two halves each of 50 m² area. Also for flexibility of operation a minimum of 4 units should be provided which could be reduced to two for smaller plants. Where filters are located on both sides of a pipe gallery, the ratio of length to breadth of a filter box has been found to lie, in a number of installations, between 1.11 and 1.66 averaging about 1.25 to 1.33. A minimum overall depth of 2.6 m including a free board of 0.5 m is adopted. The filter shell may be in masonry or concrete to ensure a water tight structure. Except in locations where seasonal extremes of temperature are prevalent, it is not necessary to provide a roofing over the filter, the operating gallery alone being roofed over. The effective size of a filter sand shall be 0.45 to 0.70 mm and uniformity coefficient shall be neither more than 1.7 nor less than 1.3. The sand layer has a depth of 60 to 75 cm. The standing depth of water over filter varies between 1 and 2 m. The free board above the water level should be atleast 50 cm to provide for an additional quantity of 15 to 30 cm depth of water to overcome air binding problems. The under-drainage system of the filter is intended to collect the filtered water and distribute the wash water uniformly. The most common type of under-drain is a central manifold with laterals either perforated on the bottom or having umbrella type strainer on top. The perforations vary from 5 to 12 mm in dia. The spacing of perforations vary from 8 cm for perforations of 5 mm to 20 cm for perforations of 12 mm. Ratio of total area of perforations to the entire filter area may be about 0.3 percent. The ratio of length to dia of lateral should not exceed 60. Spacing of laterals closely approximates the spacing of orifices and shall be 30 cm. The cross-sectional area of the manifold should be preferably 1.5 to 2 times the total area of laterals to minimize frictional losses and to give best distribution. Other types of under-drainage systems such as false bottom floors with nozzles, porous slabs, etc, are also used. For more details the 'Manual on Water Supply' may be referred to.

Gravel is placed between the sand and under-drainage system to prevent sand from entering the under-drains and to aid uniform distribution of wash water. The gravel should accomplish both purposes without being displaced by the rising wash water. Sizes of gravel vary from 50 mm at the bottom to 2 to 5 mm at the top having 45 cm depth. The bottom of wash water gutters are placed 50 mm or more above the level of expanded sand. The troughs are designed as free falling weirs or spillways. Back wash is arranged at such a pressure that sand should expand to about 130 to 150 percent of its undisturbed volume. The pressure at which the wash water is applied is about 5 m head of water as measured in under-drains. Normal rate at which wash water is applied is 600 lpm/m² of filter surface equivalent to the rise in the filter box of 60 cm/min for a period of 10 minutes. For high rate wash the pressure in the under-drainage system should be 6 to 8 m with the wash water requirement being 700 lpm/m² for a duration of 6 to 10 min. Where air and water are used for backwashing the air may be forced through the under-drains before the wash water is introduced or through a separate piping system placed between the gravel and the sand layers. Free air of about 600 to 900 lpm/m² of the filter area at 0.35 kg/cm² is forced through the under-drains for about 5 minutes following which wash water is introduced at a rate of 400 to 600 lpm/m² of area. The supply of wash water can be made through an overhead storage tank or by direct pumping. The capacity of the storage tank must be sufficient to supply wash water to two filter units at a time where the units are four or more.

Surface wash — The upper layers of the filter bed become the dirtiest and any inadequate washing will lead to the formation of mud balls, cracks and clogged spots in the filters. These troubles are overcome by adequate surface wash which can be accomplished by stirring the expanded filter bed mechanically with rakes, hydraulically with jets of water directed into the suspended sand or pneumatically with air either during or more commonly before expansion. The latter are common.

Before starting a filter it is backwashed at increasing rates until the sand bed has been stratified vertically by the wash water which carries various sizes of sand to different levels. The loss of head immediately after washing should not exceed 15 cm. The head loss builts as the filter grows dirty during a run. A maximum filter head of 2 m is allowed before cleaning the filter. In no case a negative lead should be allowed to be developed within the filter media. The washing of a filter takes about 10 minutes. The quantity of wash water normally does not exceed 2 percent of the amount of water filtered. A freshly washed filter should give an effluent with turbidity not exceeding 1 JTU.

The uniform rate of filtration is essential and is maintained by a rate of flow controller. Filter gauges indicate the loss of head through the filter. However, recently some plants are designed to work on declining rate of filtration without the use of rate of flow controller. For more details the 'Manual on Water Supply' may be referred to.

c) *Pressure filters* — Based on the same principle as gravity type rapid sand filters, water is passed through the filter under pressure through a cylindrical tank usually made of steel or cast iron, where the underdrain, gravel and sand are placed. They are compact and can be prefabricated and moved to site. Economy is possible by avoiding double pumping. Pretreatment is essential. The tank axis may be vertical or horizontal.

Pressure filters suffer from the following disadvantages:

1) treatment of water under pressure seriously complicates effective feeding, mixing and flocculation of water to be filtered;

2) in case of direct supply from pressure filters, it is not possible to provide adequate contact time for chlorine;

3) water under filtration and the sand bed are out of sight and it is not possible to observe the effectivness of the backwash or the degree of agitation during washing process;

4) it is difficult to inspect, clean and replace the sand, gravel and under-drains of pressure filters; and

5) because the water is under pressure at the delivery end, on occasions when the pressure on the discharge main is released suddenly the entire sand bed might be disturbed violently with disastrous results to the filter effluent.

In view of the disadvantages, pressure filters are not recommended for community water supplies, particularly for large ones. They may, however, be used for industrial needs and swimming pools.

5.3.1.5 *Disinfection* — Measures to treat water by methods such as storage, coagulation, sedimentation and filtration would render the water chemically and aesthetically acceptable with some reduction in the bacterial content also. However, these cannot be relied on to provide a safe water and it is necessary to disinfect the water to destroy all the disease producing organisms. As the raw water sources are becoming increasingly prone to pollution by municipal and industrial wastes, the need for disinfection cannot be overemphasized to ensure the safety of the water supply.

Disinfection does not necessarily imply complete destruction of all living organisms which can only be achieved by sterilization. Disinfection of water supplies is carried out usually by chlorination. Chlorine may be applied in the form of compounds such as bleaching powder or by chlorine gas. Chlorine gas is applied through a chlorinator which regulates the flow of gas from the chlorine container at the desired rate of flow, indicates the flow rate of feeding and provides means of properly mixing the gas either with an auxiliary supply of water or with the main body of the liquid to be disinfected.

Moist chlorine unlike dry gas or liquid chlorine is highly corrosive. Pipeline valves and other fittings through which dry chlorine passes should be tightly closed when not in use to prevent absorption of the moisture from the air. Chlorine gas is greenish yellow in colour and is nearly 2.5 times heavier than air. Under pressure it is a liquid with an amber colour and oily nature and nearly 15 times as heavy as water. Liquid chlorine is marketed in cylinders. Liquid chlorine must be vaporized in order to be withdrawn as gas. At too high discharge rates, the liquid will be cooled excessively resulting in the formation of frost on the outside of the container. Chlorine gas is harmful to human being since it is a powerful irritant to lungs and eyes. The safety limit for a working environment permits the maximum allowable concentration of chlorine in the air of 1 ppm by volume for an exposure period of 8 hours. Chlorine reacts with water to form hypochlorous acid and hydrochloric acid. The former acts as the disinfectant. The chlorine existing in water as hypochlorous acid and hypochlorite ions is called the free available chlorine. The free chlorine reacts with compounds like ammonia, phenol, etc, that may be present in the water to form chloramines and chloro-derivatives which constitute the combined available chlorine. This combined available chlorine possesses some disinfecting properties though to a much lower degree than the free available chlorine.

Chlorine and chlorine compounds by virtue of their oxidizing power can be consumed by a variety of inorganic and organic materials present in water before any disinfection is achieved. Certain time the dose of chlorine is necessary to satisfy the various chemical reaction and leave some amount of unreacted chlorine as residual either in the form of free or combined chlorine adequate for killing the pathogenic organisms. The difference between the amount of chlorine added to water and the amount of residual chlorine after a specified contact period is defined as the chlorine demand. The usual tests practised for estimating the residual chlorine in water are orthotolidine test (OT) and orthotolidine arsenite test (OTA), the former used for total residual chlorine concentrations, and the latter for free available chlorine. Satisfactory disinfection is obtained by chlorination if a free available residual chlorine of 0.2 ppm is obtained in the effluent at normal *p*H values. Chlorine is applied to water normally by the addition of a weak solution prepared from bleaching powder for disinfecting small quantities of water or by the addition of chlorine either in a gaseous form or in the form of a solution made by dissolving gaseous chlorine in a small auxiliary flow of water, the chlorine being obtained from cylinders containing the gas under pressure. The latter method is used for all public water supplies of a large scale.

5.4 Storage of Water

5.4.1 *General* — Storage of water is necessitated either at the source or before or after treatment before pumping, or after pumping before distribution and finally at the building either at the ground level or in overhead reservoirs. The purpose of a storage reservoir is to even out a varying inflow and get a supply to suit the needs.

The pattern of supply as occurring in nature is dependent upon the run-off from the catchment in respect of time in case of surface sources. However, the pattern of supply as needed at the building is dependent upon the number and type of sanitary fixtures used to suit the needs of the residents of the house. The pattern of supply in both these cases are different. Further the supply of water from the source to the house undergoes different changes in the pattern of supply depending upon the various treatments given to it, and the hours and rate of pumping. Thus in the flow chart we come across different patterns of supply in different reaches and whenever there is a change in the pattern, storage is indicated. The storage capacity in any case is based on the modification needed to change from the existing pattern of supply to the one proposed. The run off from the catchment shows peak flows which will cause devastating floods at times and the run off may also dwindle down to insufficient flows for meeting the needs of the water supply to a town. In such cases a dam is thrown across the valley to impound flood flows and after moderation, the outflow is made to suit the average flow needed. This storage is impounding storage. If the supply is to be elevated the pattern can remain the same if pumping is done for all the 24 hours. If the normal hours of pumping are different, the pattern of supply changes and storage is indicated. These reservoirs may be storage-*cum*-settling reservoirs. From such reservoirs supply is usually drawn on a 24-hour basis to treatment works. The treated water has to be stored in clear water reservoirs before it is pumped again to elevated service reservoirs, the capacity of which is dependent upon the number of hours and rate of pumping as well as the rate of draw off from the service reservoir. The supply from the street main to the house is, as stated before, dependent upon the type and number of sanitary fixtures used at different times. However, the storage to be provided inside the house is based on approved thumb rules for conditions usually available. The storage inside the house premises is of two kinds, namely, the underground reservoir or the overhead reservoir. If the pressure in the main can supply the overhead reservoir, the supply from the street main feeds the overhead reservoir. Otherwise the supply from the street main is drawn into the underground reservoir from which the supply is pumped to the overhead reservoir.

5.4.2 *Storage Capacity*

5.4.2.1 *Impounding reservoir* — There are a number of ways of calculating the storage from draft and run off relationships in long term records of stream flow. These records should include at least the average monthly rates of discharge. Storage is determined either by analytical or by graphical methods.

a) Assuming that the reservoir is full at the beginning of the dry season or dry period, the maximum amount of water S that must be drawn from storage to maintain a draft or flow D equals the maximum cumulative difference between the draft and run-off Q subsequent to the beginning of the dry period or S = maximum value of $\Sigma(D - Q)$. To find S, therefore $\Sigma(D - Q)$ is calculated arithmetically or determined graphically. The last is done by finding $\Sigma(D - Q) = \Sigma D - \Sigma Q$ by the mass diagram or Ripple method.

b) The cumulative run off curve B has been drawn as shown in the Fig. 6.

The cumulative draft line for the area under consideration is also plotted in the same scale (line A) assuming constant draft of 23 million litres/km^2 of catchment area for a month of 30.4 days. The slope of line 'A' indicates the rate of draft.

The maximum deficit of run-off from the draft is obtained by drawing a straight line parallel to the cumulative draft curve at the crest and trough of the cumulative run-off curve tangentially. The vertical ordinate length intercepted between two such parallel lines tangential to the crest and trough gives the maximum deficit for the period between the points of intersection of the parallel lines with the mass curve. The maximum cumulative deficiency as observed from the mass curve (which could also be determined analytically as shown in Table 14) is 124 million litres/km^2 of catchment area. For the constant rate of draft of 23 million litres/km^2 of catchment area for a month of 30.4 days and for this cycle of run-off values, the impounded storage needed is for

$$\frac{124}{23} \times 30.4, \text{ that is, } 164 \text{ days}$$

(almost half a year).

c) Determination of the yield of catchment areas upon which storage reservoirs are already established is done by a modified mass diagram. In this to simplify graphical presentation, the cumulative departures from the mean annual flow rather than the cumulative flows themselves are plotted in Fig. 7. The resulting curve of flows hugs the horizontal reference line that represent the mean annual flow. Lines parallel to it and tangent to the curve establish the storage needed for full or maximum possible development of the stream. Partial utilization is indicated by lines that slope downward from left to right.

5.4.2.2 *Service reservoir* — The service or distribution reservoirs are hydraulically an

TABLE 14 CALCULATIOUS OF REQUIRED STORAGE (VOLUME OF WATER IN MILLION LITRES PER SQUARE KILOMETRE)

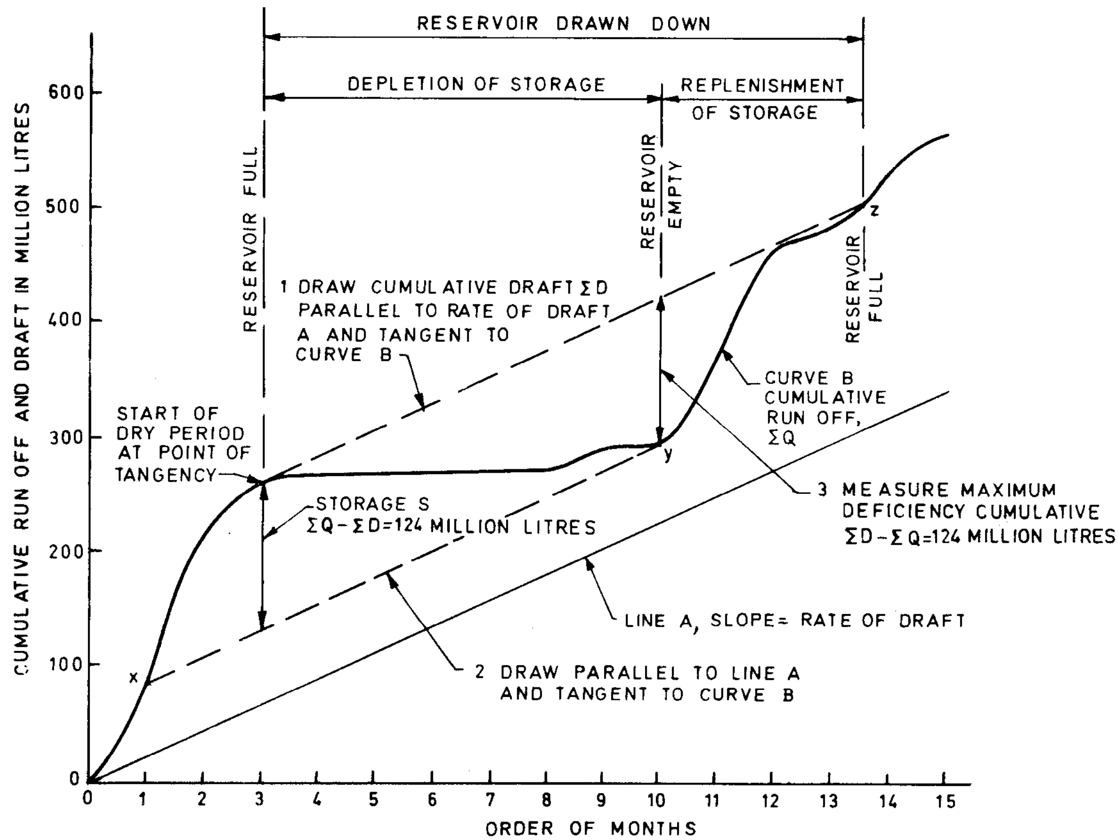
(*Clause* 5.4.2.1)

ORDER OF THE MONTH	RECORDED RUN OFF Q	ESTIMATED DRAFT D	CUMULATIVE RUN OFF Q	DEFICIENCY $D-Q$	CUMULATIVE DEFICIENCY $(D-Q)$	RESERVOIR STATE
(1)	(2)	(3)	(4) = Σ(2)	(5) = (3) − (2)	(6) = Σ(5)	(7)
1	94	23	94	−71	0(192)	
2	122	23	216	−99	0(121)	
3	45	23	261	−22	0(22)	Reservoir full at the
4	5	23	266	18	18*	beginning of dry
5	5	23	271	18	36	period
6	2	23	273	21	57	*Reservoir empties
7	0	23	273	23	80	
8	2	23	275	21	101	
9	16	23	291	7	108	
10	7	23	298	16	124	Maximum defi-
11	72	23	370	−49	75	ciency at the
12	92	23	462	−69	6	end of dry period
13	21	23	483	2	8	
14	55	23	538	−32	0(24)	Reservoir
15	33	23	571	−10	0(24)	refilled

NOTE 1 — Constant rate of draft is 23 million litres per square kilometre for an average month of 30.4 days, as given in col. 3.

NOTE 2 — Negative value indicates surplus in col 5.

NOTE 3 — In col 6, negative values are not included in $\Sigma(D-Q)$ until the beginning of dry period, that is, until water is lost from storage and there is room to store incoming flows. The surplus preceding the dry period, however, must equal or exceed the preceding maximum deficiency; otherwise the reservoir will not be full at the beginning of dry period. The cumulative surplus, calculated backwards from the beginning of dry period, is shown in brackets in col 6 and is seen to exceed 124 million litres/km^2 of catchment area.



X MUST INTERSECT RUN OFF CURVE, IF RESERVOIR IS TO BE FULL AT START OF DRY PERIOD
Y END OF DRY PERIOD AT POINT OF TANGENCY
Z MUST INTERSECT RUN OFF CURVE, IF RESERVOIR IS TO REFILL

FIG. 6 MASS DIAGRAM OF RIPPLE METHOD FOR THE DETERMINATION OF STORAGE REQUIRED IN IMPOUNDING RESERVOIRS

integral part of the distribution system and the supply conduits leading to them are generally so proportioned that they can deliver water at a rate sufficiently high to meet the 24-hour demand of the maximum day. Hourly demands in excess of this rate are supplied from storage. To this must be added the water reserves needed during a fire. Additional storage has to be provided to cater to any special hazards that are likely to cause any interruption in supply such as repair to conduits or works or pumping installations. The three major components of service storge are given below:

a) *Equalizing or operating storage* — If the planned rate of supply and the fluctuation in the rate of demand are known, the equalizing or operating storage that should be provided may be ascertained from a mass diagram as mentioned earlier. To construct a mass diagram the following procedure is adopted:

1) from past measurements of flow, determine the draft during each hour of the day and night for typical days (maximum, average and minimum);

2) calculate the amounts of water that are drawn up to certain times (that is) the cumulative draft;

3) plot the cumulative draft against time; and

4) plot the cumulative inflow or supply for the hours of supply.

The ordinates between the draft and the supply line measures the difference between demand and supply.

For capacity of storage refer Table 15 (*see* Fig. 8).

b) *Fire reserve* — It is usual to provide for fire fighting demand as a coincident draft on the distribution system along with the normal supply to the consumers as assumed. A provision in kilolitres per day based on the formula of $100\sqrt{P}$ where P is population in

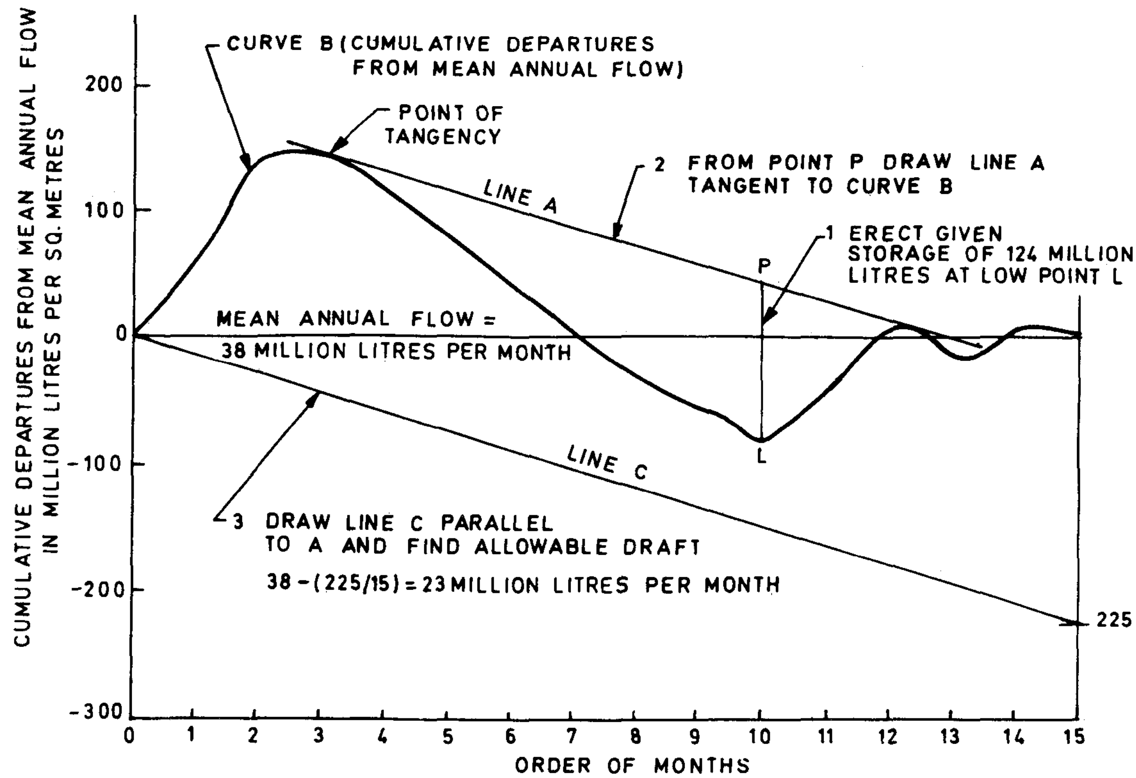


FIG. 7 MODIFIED MASS-DIAGRAM OR RIPPLE METHOD FOR DETERMINATION OF THE YIELD OF IMPOUNDING RESERVOIRS

TABLE 15 CAPACITY OF STORAGE RESERVOIR

(*Clause* 5.4.2.3)

Time From h	Time To h	Hourly Demand	Cumulative Demand	Average Rate of Pumping per Hour $= \frac{24 \times a}{16}$	Cumulative Pumping	Cumulative Deficit or Surplus {Surplus + ve, Deficit − ve}	Storage in Reservoir at the End of Period
0	4	0.2 *a*	0.8 *a*	1.5 *a*	6.0 *a*	+5.2 *a*	7.6 *a*
4	5	0.4 *a*	1.2 *a*	1.5 *a*	7.5 *a*	+6.3 *a*	8.7 *a*
5	6	0.8 *a*	2.0 *a*	1.5 *a*	9.0 *a*	+7.0 *a*	9.4 *a*
6	10	2.25 *a*	11.0 *a*	—	9.0 *a*	−2.0 *a*	0.4 *a*
10	12	*a*	13.0 *a*	1.5 *a*	12.0 *a*	−1.0 *a*	1.4 *a*
12	13	0.6 *a*	13.6 *a*	1.5 *a*	13.5 *a*	−0.1 *a*	2.3 *a*
13	14	2.25 *a*	15.85 *a*	1.5 *a*	15.0 *a*	−0.85 *a*	1.55 *a*
14	17	0.7 *a*	17.95 *a*	1.5 *a*	19.5 *a*	+1.55 *a*	3.95 *a*
17	18	2.25 *a*	20.20 *a*	1.5 *a*	21.0 *a*	+0.8 *a*	3.2 *a*
18	20	0.9 *a*	22.0 *a*	—	21.0 *a*	−1.0 *a*	1.4 *a*
20	22	0.7 *a*	23.4 *a*	—	21.0 *a*	−2.4 *a*	0
22	23	0.4 *a*	23.8 *a*	1.5 *a*	22.5 *a*	+1.3 *a*	1.1 *a*
23	24	0.2 *a*	24.0 *a*	1.5 *a*	24.0 *a*	0	2.4 *a*

Capacity of storage reservoir = maximum deficit + maximum surplus = $2.4a + 7.0a = 9.4a$

Reservoir will be empty at 2200 hours and will be full at 0600 hours when the pumping stops.

Maximum storage = $9.4a$, that is, 9.4 hours of average supply = $9.4 \times .09 = 0.846$ million liters = 39 percent of daily demand.

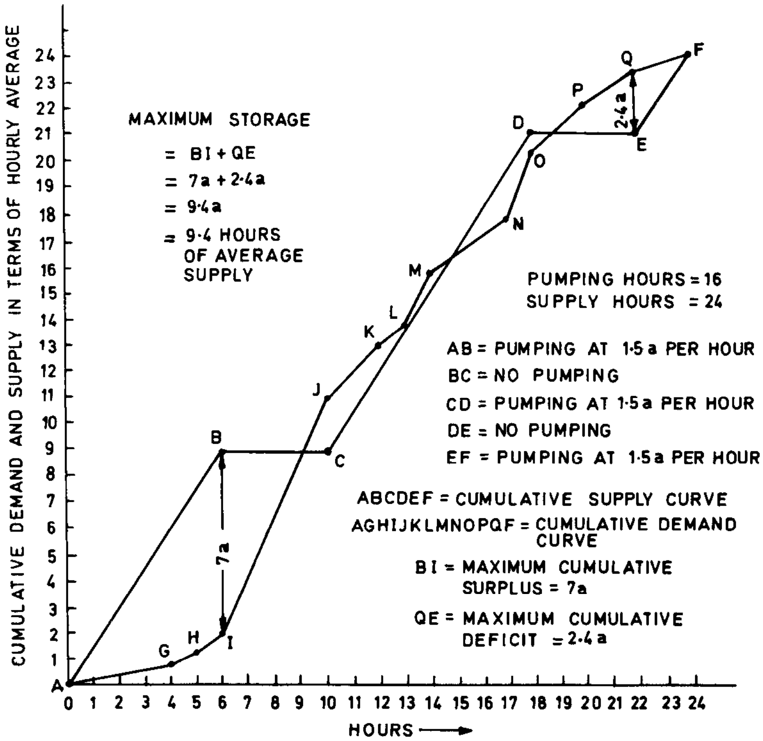


FIG. 8 DETERMINATION OF EQUALISING OR OPERATING STORAGE BY MASS DIAGRAM

thousands may be adopted for communities larger than 50 000. It is desirable that one-third of the fire fighting requirements form part of the service storage. The balance requirement may be distributed in several static tanks at strategic points. These static tanks may be filled from the nearby ponds, streams, canals by water tankers wherever feasible.

The above suggestions are based on the recommendations made in the 'Manual on Water Supply and Water Treatment' published by the Ministry of Works and Housing, New Delhi.

However, IS : 9668-1980 has recommended as follows:

The fire reserve should be provided at the rate of 1 800 l/min for every 50 000 population or part thereof for towns up to 3 lakhs population and an additional 1 800 l/mm for every 1 lakh population more than 3 lakhs. Further this quantity is to be made available within every 1 km^2 area of the city/town and equitably distributed. In the case of smaller towns with population of 1 lakh and below the total requirements should be doubled. For fire risk areas extra provision is to be made according to Indian Standards for fire safety in industrial buildings and byelaws of the local authority. In addition, there should be atleast one static tank of 220 000 litres capacity for every 1 km^2 area.

The fire reserve specified above should be maintained for atleast 4 hours. For civil defence towns/cities the scale as prescribed may be doubled both in respect of per minute and total requirements. The extra provision on this account shall be made in the form of static sources as far as possible.

It is for the local authority to take into consideration these recommendations and frame suitable byelaws in this regard based on the merits of each case.

c) *Emergency reserve* — The magnitude of this component of storage depends upon:

1) the danger of interruption of reservoir inflow by failure of supply works; and

2) the time needed to make repairs; if the shut down of the supply is confined to the time necessary for routine inspections and these are relegated to the hours of minimum draft, the emergency reserve is

sometimes taken as equal to 25 percent of the total storage capacity.

d) *Total storage* — The total amount of storage is desirably equal to the sum of the component requirements. In each instance, economic considerations determine the final choice. In pumped supplies, cost of storage must be balanced against the cost of pumping. Particular attention must be paid to the economics that can be effected by more uniform operation of pumps and by restricting pumping to a portion of the day. In all supplies cost of storage must be balanced against cost of supply lines, increased fire protection and more uniform pressures in the distribution system.

5.4.2.3 *Storage reservoir in building premises*

a) In a building provision is required to be made for storage of water for the following reasons to:

1) provide against interruption of the supply caused by repairs to mains, etc;

2) reduce the maximum rate of demand on the mains;

3) tide over periods of intermittent supply; and

4) maintain a storage for the fire fighting requirement of the building.

b) The quantity of water to be stored (*see* Table 15) shall be calculated taking into account the following factors:

1) hours of supply at sufficiently high pressure to fill up the overhead storage tanks;

2) frequency of replenishment of overhead tanks during 24 hours;

3) rate and regularity of supply;

4) consequences of exhausting storage particularly in case of public buildings like hospitals;

5) pattern of demand of the sanitary fixtures; and

6) fire fighting requirements.

c) The storge may be in a overhead reservoir directly fed from the street main or it may be in an overhead reservoir the supply to which is pumped from a ground level reservoir fed from the street main. While the provisions to be made for storage would depend on the factors given above, the capacities recommended for various types of occupancies are given in Table 16 for general guidance.

TABLE 16 RECOMMENDED STORAGE CAPACITIES

[*Clause* 5.4.2.3(c)]

Sl No.	Type of Building	Per	Storage in Litres
i)	Dwelling houses	Resident	70
ii)	Hostels	do	90
iii)	Hotels	do	135
iv)	Commercial buildings without canteens	Head	35
v)	Commercial buildings with canteens	Head	45
vi)	Restaurants	Meal	7
vii)	Day schools	Head	25
viii)	Boarding schools	Resident	90
ix)	Nurses homes and medical quarters	do	135

d) Where flushing cisterns are installed, the storage required for flushing purposes is calculated on the basis of water-closets seats installed in case of residential buildings and on the basis of water-closets seats and urinals in the case of public buildings as detailed in Table 17.

TABLE 17 STORAGE FOR FLUSHING PURPOSES

Sl No.	Classification of Building	Storage Capacity
i)	For tenements having common conveniences	900 litres net per WC seat
ii)	For residential premises other than tenements having common conveniences	270 litres net for one WC seat and 180 litres for each additional seat in the same flat.
iii)	For factories and workshops	900 litres per WC seat and 180 litres per urinal seat
iv)	For cinemas, public assembly halls, etc.	900 litres per WC seat and 350 litres per urinal seat

e) If the water supply is intermittent and the hours of supply are irregular, it is sometimes desirable to have a minimum storage of half a day's supply and a maximum of one day's supply for overhead tanks. The ground level tank where provided should have a minimum capacity of 50 percent of the overhead storage tank. If the first floor or other floors of the tenement receive continuous direct supply from the main throughout the day, there is no need to provide for any storage for these floors. The advantage of the ground level storage tank is that it can be fed continuously during low pressure hours and therefore the pump can be worked at any time of the day and the overhead storage may be replenished continuously. The pump also works at a steady head and there is no chance of overloading.

f) *Storage of water for fire fighting purposes* — Depending upon the construction, location and occupancy it may be necessary to have hydrant protection in some buildings over 15 m in height and this shall be decided in consultation with the authority concerned. Hydrants shall be installed in all buildings over 15 m in height. Each hydrant installation shall be fed by a pump rated to deliver 2 400 l/min as a normal fire fighting tanker cannot cope up with fires beyond an elevation of 15 m. The pump shall draw its water from a separate fire storage tank which shall have an effective capacity of not less than what is provided in National Building Code of India, Part IV Fire Protection.

5.5 Transmission of Water

5.5.1 *General* — Water supply involves transmission of water from the sources to the area of consumption through free flow channels or conduits or pressure mains. Depending on topography and local conditions, conveyance may be in free flow or pressure conduits. Transmission of water accounts for an appreciable part of the capital outlay and hence careful consideration of the economics is called for, before deciding on the best mode of conveyance. While water is being conveyed it is necessary to ensure that there is no possibility of pullution from surrounding areas.

5.5.2 *Sections of Channels and Mains*

5.5.2.1 *Canals* — Economical sections for canals are generally trapezoidal while rectangular sections prove economical where rock cutting is involved. Uniform flow occurs in channels where the dimensions of the cross-section, the slope and the nature of the surface are the same throughout the length of the channel and when the slope is just equal to that required to overcome the friction and other losses at the velocity at which the water is flowing. Open canals have a restricted use in water works practice in view of the losses due to percolation and evaporation as also the possibility of pollution and misuse of water.

5.5.2.2 *Gravity aqueducts and tunnels* — Aqueducts and tunnels are designed such that they flow three-quarter full at required capacity of supply in most circumstances. For structural and not hydraulic reasons, gravity tunnels are generally horse-shoe shaped.

Gravity flow tunnels are built to shorten the route, conserve the head and to reduce the cost of aqueducts traversing uneven terrain. They are usually lined to conserve head and reduce seepage but they may be left unlined when they are constructed after blasting through stable rock.

Mean velocities which will not erode channels after ageing range from 0.3 to 0.6 m/s for unlined canals and 1 to 2 m/s for lined canals.

5.5.2.3 *Pressure aqueducts and tunnels* — They are ordinarily circular in section. In the case of pressure tunnels, the weight of overburden is relied upon to resist internal pressure. When there is not enough counter balance to the internal pressure, steel cylinders or other reinforcing structures near tunnel portals, for example, provide necessary tightness and strength.

5.5.2.4 *Pipelines* — Pipelines are circular in section and normally follow the profile of the ground surface quite closely. Gravity pipelines have to be laid preferably below the hydraulic gradient.

5.5.3 *Types of Pipes*

5.5.3.1 Pipes represent a large proportion of the capital invested in water undertakings and therefore of particular importance. These are of various types and sizes consisting of spun or cast iron (CI) steel, reinforced cement concrete (RCC), prestressed reinforced concrete (PSC), and asbestos cement (AC). Polyethylene (low and high density) and polyvinyl chloride (rigid PVC) are particularly used for smaller size pipes. The determination of the suitability in all respects of the pipe or joints for any work is a matter of decision by the engineer responsible for the scheme.

5.5.3.2 *Choice of pipe material* — General technical factors affect the final choice of pipe material including internal pressures, hydraulic and operating conditions, maximum permissible diameters, external corrosion, and any special conditions of laying. Due to its strength and corrosion resistance, CI can be used in soils and for waters of slightly aggressive character. Their disadvantage lies in their being unsuitable for corrosive soils unless special steps are taken to combat them, their weight adding to tansportation problems in hilly and difficult terrains. Coating inside and outside of the pipe is always preferred. They are well suited for pressure mains and laterals where tappings are made for house connections.

Steel mains being light in weight are used for large dia especially greater than 900 mm where CI pipes become very heavy and costly. In undulating areas and where subsidence is likely to occur, they can be used because of their resilience but they are more subject to internal and external corrosion compared to other pipes.

Prestressed concrete pipes are ideal for a pressure range of 0.5 to 2.0 MPa (5 to 20 kgf/cm^2) where CI and steel are not economical.

AC pipes are relatively more corrosive resistant than steel or CI, light and easy to handle, and these are used in lateral and minor distribution systems. However, these pipes cannot take high internal pressures. In soils containing sulphates, concrete and AC pipes are liable to corrode.

Being more flexible and more corrosive resistant compared to metallic and concrete pipes, unplasticized PVC and polyethylene pipes can be extensively used in hotels and house service connections as also plumbing systems. The plasticized PVC is not recommended because of the uptake of lead by the water. PVC pipes are well suited for use in mountainous terrain and undulating areas. They have the advantage of ease and simple jointing unlike polyethylene. Polyethylene pipes can be used successfully in river crossings.

5.5.4 *CI and Spun Iron Pipes*

5.5.4.1 *General* — Most old CI pipes are cast vertically but this type has been largely superseded by spun iron manufactured up to a dia of 900 mm. The CI pipe has good lasting qualities. CI flanged pipes and fittings are usually cast in the larger diameters. Smaller sizes have loose flanges screwed in the ends of double spigot spun pipes. The method of CI pipe productions used universally today is to form the pipes by spinning or centrifugal action. Compared with vertically casting in sand moulds, the spun process results in faster production, longer pipes with vastly improved metal qualities, a smoother inner surface and reduced thickness and consequent light weight. The CI pipes vertically cast for water, gas and sewage are governed by IS : 1537-1976. This specification covers pipes of nominal dia from 80 to 1500 mm and in lengths from 3.66 to 5.5 metres. Up to 600 mm sizes the socket and spigot pipes are in 2 classes. Class A is for a test pressure of 2.0 MPa (20 kgf/cm^2) and Class B is for a test pressure of 2.5 MPa (25 kgf/cm^2). For sizes over 600 up to 1 000 mm, the test pressure for the two classes A and B are reduced to 1.5 to 2.0 MPa (15 and 20 kgf/cm^2) respectively. For sizes over 1 000 mm and up to 1 500 mm, the test pressures are further reduced to 1.0 and 1.5 MPa (10 and 15 kgf/cm^2) respectively. Cast (spun) iron pipes for water, gas and sewage are governed by IS : 1536-1976. This specification covers pipes of nominal diameters from 80 to 1 000 mm and in lengths from 3.66 to 6.0 metres for S and S (spigot and socket) pipe in classes LA, A and B. The classification of pipes is according to the thickness of pipe. Class LA is the basis for the series of pipes. Class A allows for a 10 percent increase in thickness over Class LA, and Class B allows for a 20 percent increase over Class LA. For special uses C, D and E, etc, classes may be arrived at after allowing corresponding increase in thickness of 30, 40 or 50 percent, etc, over Class LA.

The thickness of pipe barrel for Class LA is equal to $\frac{10}{12}(7 + 0.02\ DN)$

where DN is the nominal dia of the pipe.

A uniform hydrostatic test pressure of 3.5 MPa (35 kgf/cm^2) at works for all classes of pipes has been specified while the hydrostatic test pressure after installation for LA, A and B classes are fixed at 1.2, 1.8 and 2.4 MPa (12, 18 and 24 kgf/cm^2) respectively. For flanged pipes the corresponding test pressures are slightly less.

The metric pipes sizes have same external barrel diameter for any size irrespective of the classes. Also the internal socket dia is same for the same size irrespective of the class.

CI flanged pipes and fittings are usually cast in the larger diameters. Smaller sizes have loose flanges screwed on the end of double spigot spun pipes.

5.5.4.2 *Jointing of CI pipes* — Generally the pipes have spigot and socket (S and S) ends while for special purposes flanged ends are adopted. Jointing of pipes may be done in accordance with IS : 3114-1985 with any one of the following materials:

a) molten lead (under dry conditions),

b) lead wool (under wet conditions),

c) portland cement, and

d) tarred yarn (for sewers only where considered necessary).

Lead shall be heated in a melting pot kept in easy reach of the joint to be poured so that the molten metal will not be chilled in being carried from the melting pot to the joint and shall be brought to a proper temperature so that when stirred it will show a rapid change of colour. Before pouring, all scum shall be removed. Each joint shall be made with one continuous pour filling of the entire joint space with solid lead. The usual jointing for S and S pipes is by pig lead which has to be mainly imported. For several years now the use of pig lead had been discarded and alternatives brought into adoption both in USA and the UK in the jointing of CI pipes for water supply projects. In 1966 the Ministry of Health, Government of India, constituted a committee to examine the question of jointing of pipes with special reference to substitute material for lead in view of its acute shortage, etc. The Committee in its report dealt with the several alternatives. They are given below.

a) *Tyton joint* — This is a patented joint and involves the manufacture of spun C I pipes with a modified socket design and the use of a special rubber gasket to effect a sound and efficient joint. A rubber gasket of a special shape with a bulb and groove is kept compressed between the spigot and socket with a projecting head from the socket pressing against the groove in the gasket. The rubber ring is of two different qualities cast monolithic and provides water tightness by its shape and flexibility.

This joint is now adopted invariably in all projects.

b) *Screwed gland flexible joint* — Here the jointing is essentially a screwing arrangement to hold the rubber ring in position. Screw threads are cast inside the socket of pipe and on the outside of the CI gland. A flexible rubber ring is inserted in the joint and when the CI gland is screwed on to the socket the rubber ring is pressed tight in the annular space between the spigot and socket. The flexibility is claimed only up to 3° against 5° in the case of Tyton joint.

c) *Electrolite joint* — This is similar to the tyton joint but with a difference. In the tyton joint a projecting ring or bead from the socket presses against a groove in the rubber gasket compressed between the socket and spigot. In the electrolite joint, however, a projecting bead or lug in the rubber ring presses against a groove in the socket. The efficiency is yet to be established.

d) *Sulphur based compound joints* — Mineraliad is a plasticized hot pour sulphur compound jointing material used in the place of lead. It is not to be used under conditions which are corrosive to CI itself. Artite is yet another sulphur based compound.

Experience in this country does not favour these joints.

e) *Use of CI detachable joint after cutting the socket ends* — Rajasthan is reported to have adopted this method satisfactorily as an effective way of utilizing CI pipes with conventional S and S ends if already available in stock without going in for lead joints. In this method, the socket ends are cut and the pipes jointed in the same way as AC pressure pipes with CI detachable joints. The cost will be less than that of a lead joint and compares favourably with that of the tyton joint. The use of this joint is recommended where working pressure is greater than 30 m.

f) *Cement joints* — cement joints have been used successfully in the USA. The joint done in the same manner as for stoneware pipes except that the jute or hemp yarn must be free from oil or tar. Standard Portland cement is used neat and very dry in the proportion of 15 kg of cement to 1 kg of water. Practice in Karnataka State has been with cement mortar 1 : 1 mixed with asbestos fibre powder. The joints are caulked with special tools and cured for 10 days before subjecting to pressure. The joint may sweat in the beginning between the pores which may soon get filled up and the joint becomes water tight. Cement joints are rigid and necessitate a firm foundation for the pipe line for minimizing movements. Lead joints are used however at suitable intervals to give flexibility. The cement joint has given satisfactory results and is adopted in some states in India where the working pressure does not exceed 30 m.

5.5.4.3 *Testing of pipeline* — After a new pipe has been laid and jointed, it shall be subjected to the following two tests in accordance with IS : 3114-1965:

a) pressure test at a pressure of at least double the maximum working pressure, pipe and joints shall be absolutely watertight under the test; and

b) leakage test (to be conducted after the satisfactory completion of the pressure test) at a pressure to be specified by the Authority for a duration of two hours.

Before testing, the trench shall be partially back-filled except the joints.

Each valved section of the pipe shall be slowly filled with water and all air shall be expelled from the pipe through hydrants and blow offs. If these are not available at high places, necessary tapping may be made at points of highest elevation before the test is made and plugs inserted after the tests have been completed.

If the trench has been partially back-filled, the specified pressure based on the elevation of the lowest point of the line or section under test and corrected to the elevation of the test gauge, shall be applied by means of a pump connected to the pipe in a manner satisfactory to the Authority. The duration of the test shall not be less than 5 minutes.

Examination under pressure — All exposed pipes, fittings, valves, hydrants and joints should be carefully examined during the open-trench test. When the joints are made with lead, all such joints showing visible leaks shall be recaulked until tight. When the joints are made with cement and show seepage or slight leakage, such joints shall be cut out and replaced. Any cracked or defective pipes, fittings, valves or hydrants discovered in consequence of this pressure test shall be removed and replaced by sound material and the test shall be repeated until satisfactory results are obtained.

If the trench has been back-filled to the top, the section shall be first subjected to water pressure normal to the area and the exposed parts shall be carefully examined. If any defects are found, they shall be repaired and the pressure test repeated until no defects are found. The duration of the final pressure test shall be at least one hour.

Procedure for leakage test — Leakage is defined as the quantity of water to be supplied into the newly laid pipe, or any valved section thereof, necessary to maintain the specified leakage test pressure after the pipe has been filled with water and the air expelled.

No pipe installation shall be accepted until the leakage is less than the number of cm^3/h as determined by the formula:

$$q_l = \frac{ND\sqrt{P}}{3.3}$$

where

q_l = allowable leakage in cm^3/h,

N = number of joints in the length of the pipeline,

D = diameter in mm, and

P = the average test pressure during the leakage test in kg/cm^2.

5.5.5 *Steel Pipes*

5.5.5.1 *General* — Steel pipes of small diameter can be made from solid bar sections by hot or cold drawing processes and these tubes are referred to as seamless. The large sizes are made by welding together the edges of suitably curved plates, the sockets being formed later in a press. The thickness of the steel used is often controlled by the need to make the pipe stiff enough to keep its circular shape during storage, transport and laying as also to prevent excessive deflection under the load of the trench back-filling. The thickness of a steel pipe is, however, always considerably less than the thickness of the corresponding vertically cast or spun iron pipe owing to the higher tensile strength of the steel making it possible for steel pipes to be more than twice the length of CI pipes of the same class, with consequent saving in transport, pipe laying and jointing costs. Specials of all kinds can be fabricated without difficulty to suit the different site conditions. Due to their elasticity, steel pipes adopt themselves to changes in relative ground level without failure and hence are very suitable for laying in ground liable to subsidence. It must be borne in mind, however, that steel mains need protection from corrosion.

Electrically welded steel pipes for water, gas and sewage for sizes from 150 to 2 000 mm nominal dia are covered by IS : 3589-1981. The pipes are designated by the method of manufacture followed by a number corresponding to the minimum tensile strength in MPa as, for example, EFW410 indicates electric fusion (arc) welded steel pipes having a minimum tensile strength of 410 MPa.

The steel pipes shall have minimum specified wall thickness as given in Table 18.

TABLE 18 MINIMUM SPECIFIED THICKNESS OF PIPES

(*Clause* 5.5.5.1)

NOMINAL DIA OF PIPES mm	MINIMUM THICKNESS OF PLATE mm
200 to 400	5
450 to 700	6
800 to 900	7
1 000 to 1 200	8
1 400 to 2 000	10

5.5.5.2 *Laying and jointing* — Mild steel pipes can be of threaded ends with one socket. They are lowered down in the trenches and laid to alignment and gradient. The jointing materials for this type of pipes are white lead and spun yarn. The white lead is applied on the threaded end with spun yarn and inserted into socket of another pipe. The pipe is then turned to get it tightened. When these pipes are used in the construction of tube wells, the socketed ends after positioning without any jointing material are welded and lowered down. In the case of pipes lined and outcoated with cement concrete, dense cement mortar is applied by means of centrifugal process. While laying the pipes already stacked along the trenches are lowered down into the trenches with the help of a chain-pulley block. The formation of bed should be uniform. The pipes are laid true to the alignment and gradient before jointing. The ends of these pipes are butted against each other, welded and a coat of rich cement concrete is applied after welding.

Steel pipes may be joined with flexible joints or by welding but lead or other filler joints, hot or cold, are not recommended. The welded joint is to be preferred. In areas prone to subsidence, this joint is satisfactory but flexible joints must be provided to isolate valves and branches.

Type of joints and ends of pipes given in IS : 3589-1981 are:

a) plain ends or levelled ends for field butt welding, and

b) sleeve joint or swelled and plain ends for welding.

When welding is adopted, plain ended pipes may be jointed by butt welds or sleeved pipes by means of fillet welds. For laying long straight lengths of pipelines, butt joint technique may be employed. Where deflection is required, the short sleeve joint with fillet weld is preferable. The steel pipes used for water supply include hydraulic lap welded, electric fusion welded and spiral welded pipes, the latter being made from steel strip and at present available up to a size of 1 150 mm. For laying of welded steel pipes, IS : 5822-1970 should be followed.

5.5.6 *Concrete Pipes*

5.5.6.1 *General* — IS : 458-1971 gives the specification for reinforced concrete pipes with and without reinforcement and does not cover prestressed concrete pipes. The classification, test pressure, etc, of pipes are given in Table 19. Perforated concrete conforming to IS : 7319-1974 are used for under-drainage work in infilteration galleries, reclaiming water logged areas and for similar other purposes. Porous concrete pipes conforming to IS : 4350-1967 are also used for these purposes.

Reinforced concrete pipes either spun or cast shall be designed such that the maximum tensile stress in the circumferential steel due to the specified hydrostatic test pressure does not exceed the limit of 126.5 MPa (1 265 kgf/cm^2) in the case of MS rods and 140 mPa (1 400 kgf/cm^2) in the case of cold drawn steel wires. The barrel thickness is such as to restrict the maximum tensile stress in concrete to 2.0 MPa (20 kgf/cm^2) subject to the minimum thickness prescribed. RC pipes are suitable for low pressure mains because of the difficulty of having joints to withstand high pressures.

Smaller sizes can be used in distribution systems with infrequent house service connections.

5.5.6.2 *Laying and jointing* — The concrete pipes should be carefully loaded, transported and unloaded avoiding impact. The use of inclined plane or chain block is recommended. Trench shall provide sufficient free working space on each side of the pipe which shall not be greater than one-third dia of the pipe but not less than 15 cm on either side. Laying of a pipe shall preceed upgrade of a slope. If the pipes have spigot, socket joints, the socket ends shall face upstream. Where the natural foundation is inadequate, the pipe shall be laid in a concrete cradle supported on proper foundations, or any other suitable designed structure. If a concrete cradle is used, the depth of concrete below the bottom of the pipes shall be atleast one-fourth the internal diameter of the pipe with the range of 10-30 cm. It shall extend up to the sides of the pipe atleast to a distance of one-fourth the diameter for larger

TABLE 19 CLASSIFICATION OF CONCRETE PIPES

CLASS	DESCRIPTION	CONDITIONS WHERE NORMALLY USED	HYDRAULIC TEST PRESSURE IN kgf/cm^2 (in m Head)	INTERNAL DIAMETER	LENGTH
NP_1	Unreinforced concrete non-pressure pipes	For drainage and irrigation use above ground or in shallow trenches	0.7 MPa (7 m head)		
NP_2	Reinforced concrete light duty non-pressure pipes	For drainage and irrigation use for culverts carrying light traffic	do		
NP_3	Reinforced concrete heavy duty non-pressure pipes	For drainage and irrigation use for culverts carrying heavy traffic	do		
NP_4	do	For drainage and irrigation use for culverts carrying very heavy traffic such as Railway loadings	do		
P_1	Reinforced concrete pressure pipes tested to a hydrostatic pressure of 0.2 MPa. (20 m head)	For use on gravity mains the site test pressure not exceeding 2/3 of the hydrostatic test pressure.	0.2 MPa (20 m head)	80 to 1 200 mm (about 3″ to 48″)	2 m up to 350 mm dia and 2.5 m or 3.0 m for dia 300 to 1 200 mm
P_2	Reinforced concrete pressure pipes tested to a hydrostatic pressure of 0.4 MPa (40 m head)	For use on pumping mains the site test pressure not exceeding 1/2 of the hydrostatic test pressure.	0.4 MPa (40 m head)	80 to 600 mm (about 3″ to 24″)	2 m up to 350 mm dia and 2.5 m or 3.0 m for dia 300 to 600 mm.
P_3	Reinforced concrete pressure pipes tested to a hydrostatic pressure of 0.6 MPa (60 m head)	do	0.6 MPa (60 m head)	80 to 400 mm (about 3″ to 16″)	2 m for all sizes and 2.5 m and 3 m for sizes 300 to 400 mm.

than 30 cm. The pipes shall be laid in the concrete bedding before the concrete has set. Trenches shall be back-filled immediately after the pipe has been laid to a depth of 30 cm above the pipe subject to the condition that the jointing material has hardened (say 12 h at the most). The back-fill material shall be free from boulders, roots of trees, etc. The tamping shall be by hand or by hand operated mechanical means. The water content of the soil shall be as near optimum moisture content as possible. Filling of the trench shall be carried on simultaneously on both sides of the pipe to avoid development of unequal pressures. The back-fill shall be rammed in 150 mm layers up to 90 cm above the top of the pipe.

Jointing may be of any of the four types specified below:

a) bandage joint,

b) spigot and socket joint (rigid and semi-flexible),

c) collar joint (rigid and semi-flexible), and

d) flush joint (internal and external).

For jointing procedures IS : 783-1959 may be followed.

In all pressure pipelines, the recesses at the ends of pipe shall be filled with jute braiding dipped in hot bitumen. The quantity of jute and bitumen shall be just sufficient to fill the recess in the pipe when pressed hard by jacking or any other suitable method.

The number of pipes that shall be jacked together at a time depends upon the dia of the pipes and the bearing capacity of soil. For small pipes up to 250 mm dia, six pipes can be jacked together at a time.

Before and during jacking, care shall be taken to see that there is no offset at the joint. Loose collar shall be set up over the joint so as to have an even caulking space all round and into this caulking space shall be rammed a 1 : 1.5 mix of cement and sand just sufficiently moistened to hold together in the form a clod when compressed in the hand. The caulking shall be so firm that it shall be difficult to drive the point of a pen knife into it. The caulking shall be employed at both ends in a slope of 1 : 1. In the case of non-pressure pipes, the recess at the end of the pipes shall be filled with cement mortar 1 : 2 (1 cement: 2 sand), instead of jute braiding soaked in bitumen. It shall be kept wet for about 10 days for maturing.

5.5.6.3 *Pressure test* — When testing the pipeline hydraulically, the line shall be filled completely with water and kept filled for a week. The pressure shall then be increased gradually to full test pressure as indicated in **5.5.4.3** and maintained at this pressure during the period of test with the permissible allowances indicated therein.

5.5.7 *Steel Cylinder Reinforced Concrete Pipe* — Ordinary RC pipes being unsuitable for use in situations where relatively high water pressures are met with the steel cylinder, reinforced concrete pipes are used if concrete is unaffected by soil conditions. These pipes have the advantage that they provide the required rigidity even when very thin shells are used to form the steel cylinder.

Steel cylinder RC pipes conforming to IS : 1916-1963 are used in water mains and, to a limited extent, in the pressure sewer lines and irrigation works. When used for carrying highly acidic sewage or industrial wastes, necessary precautions should be taken to prevent exposure of steel cylinder to the action of sewage or industrial waste. When the pipes are likely to be in contact with corrosive soil, proper precautions are to be taken such as coating with bitumen on the outside, using richer mix and/or using sulphate resistant mixes.

5.5.7.1 *Sizes* — The nominal internal diameter may vary from 200 to 1 800 mm. The increment in size is 50 mm from 200 to 500 mm, 100 mm from 500 to 700 mm and 200 mm from 700 to 1 100 mm and 1 200 to 1 800 mm.

The ends are either spigot and socket or plain ends or slip in type ends suitable for field welding.

The classification and test pressures are as given in Table 20.

TABLE 20 CLASSIFICATIONS OF STEEL CYLINDER REINFORCED CONCRETE PIPES

Class	Test Pressure
1	0.5 MPa (or 50 m head of water)
2	1.0 MPa (or 100 m head of water)
3	1.5 MPa (or 150 m head of water)
4	2.0 MPa (or 200 m head of water)
5	2.5 MPa (or 250 m head of water)
Special	Above 2.5 MPa or above 250 m head of water (exact pressure is to be indicated)

The steel cylinder is to be made from steel plates satisfying IS : 226-1975 or IS : 2062-1980. Where the thickness of steel plate is greater than 20 mm, IS : 2062-1969 is to be followed.

The concrete and mortar shall have a minimum cement content of 380 kg for every cubic metre of concrete or mortar and a minimum compressive works cube strength of 20 N/mm^2 (200 kgf/cm^2) at 28 days. The maximum tensile stress in reinforcement under the specified hydrostatic test pressure should not be more than 200 N/mm^2 (2 000 kgf/cm^2), assuming no tension is taken by the concrete. The barrel thickness shall be such that under half the specified hydrostatic test pressure, the maximum tensile stress in concrete or mortar when considered as effective to take stress along with the tensile reinforcement should not be greater than 4.0 N/mm^2 (40 kgf/cm^2) (modular ratio of steel and concrete to be assumed as 15).

5.5.7.2 *Laying and jointing* — IS : 783-1959 for laying of concrete pipe applies to the steel cylinder reinforced concrete pipes also. The fillings and specials required for curves, bends, branches, manholes, air valves, blow offs and connection to main line valves are used conforming to IS : 7322-1974.

5.5.7.3 *Pressure testing* — The details as given in **5.5.4.3** applies to this kind of pipe also.

5.5.8 *Prestressed Concrete Pipes*

5.5.8.1 *General* — While ordinary RCC pipes can cater to the needs where pressures are up to 0.3 MPa (3.0 kgf/cm^2), and CI and steel pipes cater to the needs of higher pressures around 2.4 MPa (24 kgf/cm^2), the prestressed concrete pipes cater to the intermediate pressure range for which the metallic pipes are expensive while RCC pipes would not be suitable.

In these pipes, permanent internal stresses are deliberately introduced by tensional steel to counteract to the desired degree stresses caused in the pipe under service. These stresses are entirely independent of the stresses caused by external loads or internal pressures The sizes range from 80 to 1 800 mm. The lengths are 2 m for the sizes up to 400 mm dia and 2.5 m for the higher sizes. The pipes cannot be cut to size to close gaps in the pipe line. Special closure units consisting of a short double spigot piece and a plain ended concrete lined steel tube with a follower ring assembled at each end, are manufactured for this purpose. The closure unit (minimum length of 1.27 m) must be ordered specially to the exact length required. Specials such as bends taps, etc, are generally fabricated as mild steel fitting lined and coated with concrete.

IS : 784-1978 is to be followed for prestressed concrete pipes.

5.5.8.2 *Laying and jointing* — IS : 783-1959 for laying of concrete pipes applies to prestressed concrete pipes also.

5.5.8.3 *Pressure testing* — The details as given in **5.5.4.3** applies to prestressed concrete pipes also.

5.5.9 *Asbestos Cement Pipes*

5.5.9.1 *General* — The asbestos cement pipe is made of a mixture of asbestos and portland cement compressed by steel rollers to form a laminated material of great strength and density. Its carrying capacity remains substantially constant particularly in soft water districts since it is free from its effects. It is not affected by electrolytic action and is light in weight. It can be drilled and tapped from connections but has not the same strength or suitability for threading as iron and any leakage at the thread will become worse as time passes. However, this difficulty can be overcome by screwing the ferrules through malleable iron saddles fixed at the point of service connections as is the general practice. These pipes are not suitable for use in sulphate soils.

The available safety against bursting under pressure, though less than that for spun iron pipes, is nevertheless adequate and increases as the pipe ages. Good bedding of small bore asbestos cement pipes is important. The larger diameter pipes have ample beam strength for normal main laying conditions.

This pipe can meet general requirements of water supply undertakings for rising main as well as for distribution mains. IS : 1592-1980 should be followed. The sizes range from 80 to 600 mm. The length of pipes for all diameters is 3, 4 or 5 m.

Pipes are classified with respect to the hydraulic test pressure as given in Table 21.

TABLE 21 CLASSIFICATION OF ASBESTOS CEMENT PIPES

Class	Hydraulic Test Pressure
5	1.5 MPa (5 kgf/cm^2)
10	1.0 MPa (10 kgf/cm^2)
15	1.5 MPa (15 kgf/cm^2)
20	2.0 MPa (20 kgf/cm^2)
25	2.5 MPa (25 kgf/cm^2)

The working pressure is not to exceed 50 percent of the test pressure.

The relationship between the test pressure (TP), the bursting pressure (BP) and working pressure (WP) are given in Table 22.

TABLE 22 RELATIONSHIP BETWEEN HYDRAULIC TEST PRESSURE (TP) BURSTING PRESSURE (BP) AND HYDRAULIC WORKING PRESSURE (WP)

Nominal Dia mm	$\frac{BP}{TP}$	$\frac{BP}{WP}$
50 to 100	2	4
125 to 200	1.75	3.5
250 to 600	1.5	3.0

5.5.9.2 *Laying and jointing* — IS : 6530-1977 shall be followed for laying and jointing of asbestos cement pressure pipes. The width of the trench should be uniform throughout the length and greater than the outside dia of the pipe by 300 mm on either side of the pipe. The depth of the trench is usually kept 1 m on the top of the pipe. For heavy traffic, a cover of atleast 1.25 m is provided on the top of the pipe.

The AC pipes to be laid are stacked along the trenches on the side opposite to the spoils. Each pipe should be examined for any defects such as cracks, chipped ends, crusting of the sides, etc. The defective pipes are to be removed forthwith from the site to avoid mixing up with good pipes. Before use the inside of the pipes will have to be cleaned. The lighter pipes weighing less than 80 kg can be lowered in the trench by hand. If the sides of the trench slope is too much, ropes must be used. The pipes of medium weight up to 200 kg are lowered by means of ropes looped around both the ends. One end of the rope is fastened to a wooden or steel stack driven into the ground and the other end of the rope is held by men and is slowly released to lower the pipe into the trench. After lowering, the pipes are aligned for jointing the bed of the trench should be uniform.

There are two types of joints for AC pipes.

a) *CI detachable joint* — This consists of two CI flanges, a CI central collar and two rubber rings along with a set of bolts and nuts for the particular joint. For this joint, the AC pipe should have flush ends.

   Rubber rings positioned between the collar ends and flanges provide compression sealing. Compression is obtained by uniform tightening of the bolts.

b) *AC coupling joint* — This joint consists of an AC coupling with three inner grooves fitted with three special rubber rings. The pipes for these joints have chamferred ends. The rubber rings are positioned in the grooves inside the coupling. Then grease is applied on the chamferred end and the coupling pushed with the help of a jack against the pipe. The mouth of the second pipe is then placed in the mouth of the coupling and then pushed so as to bring the two chamferred ends close to one another.

   Wherever necessary, changeover from CI pipe to AC pipe or vice-versa is done with the help of suitable adapters.

5.5.9.3 *Pressure testing* — The testing shall be done according to IS : 5913-1970. The pipeline should be tested for soundness in portion as laying progresses. The procedure for the test as adopted generally is as follows:

a) at a time one section of the pipeline between two sluice valves is taken up for testing, the section usually taken is about 500 m long;

b) one of the valves is closed and water is admitted into the pipe through the other, manipulating air valves suitably; if there are no sluice valves in between the section, the end of the section can be sealed temporarily with an end cap having an outlet which can serve as an air relief vent or for filling the line as may be required; the pipeline after it is filled should be allowed to stand for 24 h before pressure testing.

c) after filling, the sluice valve is closed and the pipe section is isolated;

d) pressure gauges will be fitted at suitable intervals on the crown into the holes meant for the purpose;

e) pipe section is then connected to the delivery side of a pump through a small valve;

f) pump is then worked till the pressure inside reaches the desired value which can be read from the pressure gauges already fixed;

g) after the required pressure has been obtained, the valve is closed and the pump disconnected; and

h) pipe is then kept under desired pressure during inspection for any defect, that is, leakages at the joints, etc, and the water will then be emptied through scour valves and defects observed during the test will be rectified.

Pipelines carrying potable water shall be suitably disinfected before commissioning. For this purpose, guidance may be obtained from IS : 3114-1965 or IS : 5822-1970.

5.5.10 *Plastic pipes*

5.5.10.1 *General* — Plastic pipes are produced by extrusion process followed by calibration to ensure maintenance of accurate internal diameter with smooth internal bores. These pipes are of three kinds for potable water supplies. They are covered by Indian Standards as follows:

a) low density polyethylene pipes — IS : 3076-1968,

b) high density polyethylene pipes — IS : 4984-1978, and

c) unplasticized PVC pipes — IS : 4985-1968.

5.5.10.2 *Polyethylene pipes* — These are extruded from a compound consisting of virgin polyethylene in which carbon black and a suitable non-toxic anti-oxidant is evenly dispersed. Low density polyethylene shall have a density not greater than 0.93 g/ml and high density polyethylene shall have a density greater than 0.94 g/ml at 27°C. The compound for low density polyethylene shall have a melt flow index not greater than 2.6 and high density polyethylene pipes shall have a melt flow index not greater than 0.6. The test shall be conducted according to IS : 2530-1963. The anti-oxidant in the material should be physiologically harmless and not greater than 0.3 percent by weight. The other details regarding composition are as given in Table 23.

TABLE 23 CLASSIFICATION OF POLYETHYLENE PIPES

Working Pressure MPa(kgf/cm²)	Outside Dia Range, mm	
	Low Density Polyethylene	High Density Polyethylene
0.20 (2.0)	—	75-500
0.25 (2.5)	40-140	63-500
0.4 (4.0)	32-140	40-500
0.6 (6.0)	20-110	32-500
1.0 (10.0)	12-63	20-500

The polyethylene pipes are classified according to pressure ratings (working pressure), namely, 0.2, 0.25, 0.4, 0.6 and 1.0 MPa (2.0, 2.5, 4.0, 6.0 and 10.0 kgf/cm²).

The wall thickness of the pipes given in the tables of the specification are based on a safe working stress of 3.95 MPa (39.5 kgf/cm²) at 27°C for high density polyethylene pipes and 25.28 kgf/cm² at 27°C for low density polyethylene pipes. The safe working stress for high and low density polyethylene pipes are respectively 5.0 MPa (50 kgf/cm²) and 3.2 MPa (32 kgf/cm²) at 20°C. The safe stress is reduced by 3 percent per °C up to 38°C. The pipes are recommended for a maximum temperature of 45°C and 38°C for high and low density polythene pipes respectively. The minimum temperature recommended is −40°C for high and low density polyethylene pipes.

The low density pipes are to be generally supplied in coils of nominal lengths of 25, 50, 100, 150 and 200 metres. The high density pipes are to be generally supplied either as coils measuring 25 times the minimum dia of the pipes or in straight lengths of 5 to 20 m. Laying and jointing shall be done in accordance with IS : 7634 (Part 2)-1975.

5.5.10.3 *Unplasticized PVC pipes* — The material shall be substantially poly-vinyl chloride plus necessary additives for getting good surface finish, mechanical strength and capacity. These shall not cause toxicity and no detrimental effect in the composition of water passing through the pipes. The quantity of lead and other toxic substances shall not exceed as given in Table 24.

TABLE 24 CONCENTRATION OF LEAD AND OTHER TOXIC SUBSTANCES

Substance	Concentration
Lead (first extraction)	1 ppm by mass
Lead (third extraction)	0.3 ppm by mass
Dialkyl tin (as tin) (third extraction)	0.02 ppm by mass
Other toxic substances (third extraction)	0.01 ppm by mass

The pipes are classified according to ratings as in the case of polyethylene pipes as 0.25, 0.4, 0.6 and 1.0 MPa (2.5, 4.6 and 10 kgf/cm²) pipes. The temperature range recommended is 1 to 45°C. The maximum safe working stress is 10 MPa (100 kgf/cm²) at 20°C. At higher temperatures up to 45°C, the strength of pipe reduces and can be worked out according to IS : 4985-1981.

The pipes shall withstand a hydraulic pressure equal to 36.0 MPa (360 kgf/cm²) for one hour at 27°C. The range of diameter for various working pressures are as given in Table 25.

TABLE 25 RANGE OF DIAMETER FOR VARIOUS WORKING PRESSURES

Working Pressure MPa (kgf/cm²)	Range of Diameter mm
0.25 (2.5)	90-630
0.4 (4.0)	63-630
0.6 (6.0)	40-630
1.0 (10.0)	16-630

The wall thickness of pipes given in the standard are based on a safe working stress of 8.6 MPa (86 kgf/cm²) at 27°C. At higher temperatures the working pressure gets reduced.

Rigid PVC pipes and high density polyethylene pipes have been used for water distribution systems mostly ranging from 15 to 150 mm diameter and occasionally up to 350 mm.

The PVC pipes are much lighter than CI or AC pipes. Because of this light weight, they are easy to handle, transport and instal. Solvent cementing technique for jointing PVC pipe lengths is cheaper, more efficient and far simpler. PVC pipes do not become pitted or tuberculated and are unaffected by fungi and bacteria, and are resistant to a wide range of chemicals.

They are immune to galvanic and electrolytic attack, a problem frequently encountered in metal pipes especially when buried in corrosive soils or near brackish waters. PVC pipes have elastic properties and their resistance to deformation resulting from earth movements is superior compared to conventional pipe materials especially asbestos. In soils containing aromatic compounds, PVC pipes shall not be used. Plastic pipes are not suitable for hot water systems.

5.5.10.4 *Precautions in handling and storage* — Because of their light weight, there may be a tendency for the PVC pipes to be thrown much more than their metal counterparts. This should be discouraged and reasonable care should be taken in handling and storage to prevent damage to pipes. On no account should the pipes be dragged along the ground. Pipes should be given adequate support at all times. These pipes should not be stocked in large piles, specially under warm temperature conditions as the bottom pipes may be distorted thus giving rise to difficulty in pipe alignment and jointing. For temporary storage in the field where racks are not provided care should be taken that the ground is level, free from loose stones. Pipes stored should not exceed three layers and should be so stacked as to prevent movement. It is also recommended not to store one pipe inside another.

5.5.10.5 *Laying and jointing* — The trench bottom should be carefully examined for the presence of hard subjects such as flints, rock projections or tree roots. In uniform, relatively soft fine grained soils with the bottom of the trench brought to an even finish to provide a uniform support for the entire length of pipes, they may be laid directly on the trench bottom. In other cases the trench should be cut deeper and the pipes laid on a prepared underbedding which may be drawn from the excavated material, if suitable.

As a rule, trenching should not be carried out too far ahead of pipe laying. The trench should be as norrow as practicable. This may be kept from 0.3 m over the outside diameter of the pipe and depth may be kept at 0.6-1.0 m depending upon traffic conditions. Pipe lengths are placed end-to-end along the trench. The glued spigot and socket jointing technique, as mentioned later, is adopted. The jointed lengths are then lowered in the trench and when a sufficient length has been laid, the trench is filled.

If trucks, lorries or other heavy traffic will pass across the pipeline, concrete tiles 60 × 60 cm of suitable thickness and reinforcement should be laid about 2 m above the pipe to distribute the load. If the pipeline crosses a river, the pipe should be buried at least 2 m below bed level to protect the pipe.

For bending, the cleaned pipe is filled with sand and compacted by tapping with a wooden stick and the pipe ends plugged. The pipe section is heated with flame and the portion bent as required. The bend is then cooled with water, the plug removed, and the sand poured out and the pipe (bend) cooled again. Heating in hot air oven, hot oil bath, hot gas or other heating devices are also practised. Joints may be heat welded or flamed or made with rubber gaskets or solvent cement according to IS : 7634 (Part 2)-1975.

Satisfactory jointing plays an important role in successful application of these pipes. The commonly used joints are as follows:

a) *Solvent welded joints* — These are permanent in nature and strong in tension. They are used for service pipes of water mains. These joints are commonly used and economical for PVC pipe works.

   This technique is used with both spigot and socket type joints, in which the socket is made specially to form a close fit on the pipe end and with injection moulded fittings.

   The solvent welded joint may be achieved either by heat application method or by non-heat application method. The non-heat application method is easier and is recommended for water supply installations.

b) *Flanged joints* — These are used for jointing of PVC pipes particularly of larger sizes to valves and vessels, and larger size metal pipes where strength in tension is required. The joint is made by the compression of a gasket or a ring seal set in the face of the flange. The flange may be formed in several ways as under:

   1) By upsetting the pipe end on a mandrel after heating the pipe ends. A backing ring of metal or thermoset plastics compresses the upset pipe end on to the fitting face of the gasket. Crinkles are formed too easily in the collar and the whole unit loses much of its strength.

   2) By solvent cementing a plastic stub flange on to the pipe end and again using a backing ring. The pipe end may also be welded to the PVC flange.

   3) By solvent cementing a plastics full faced flange on to the pipe end and bolting this to the fitting face. A backing ring or wide washer should be used to distribute the bolt loads. This prevents the distortion of the PVC flange.

   Union joint — This is a form of flanged joint in which the faces are held together by a screwed connection. A composite metal and PVC socket union is a very satisfactory method of jointing PVC to screwed metallic fittings.

c) *Screwed joints* — These are similar to the joints used with metal pipes. If pipe has to be jointed by screw threads, only thick walled pipe should be used and cut with taper pipe treads. The die should be clean and the thread should be made in one pass. The threaded pipes shall not be subjected to pressures exceeding two-thirds of the pressure rating for unthreaded pipes.

Short pieces of thick walled pipe may be threaded at one end and solvent cemented on to normal walled pipe at the other end to make the connector pieces to screwed metal fittings. This system may be used up to 50 mm outside diameter pipes.

Jointing with hemp and paste shall not be used. The joint should be made to firm hand tightness using only strap trenches.

There is no well-defined increase in the tightness at assembly as there is with metal-to-metal fittings and these joints can therefore very easily be over-strained.

d) *Rubber ring joints* — Rubber ring joints can provide a water-tight seal but are not designed to resist pull. In these joints, the rubber and the fluid to be transported should be compatible. The material of rubber rings should conform to IS : 5382-1969. Where aggressive soils are met with, synthetic rubbers perform better. Generally speaking, rubber ring joints are used for large sized pipes (63 mm and above). Such joints may be provided on pipes which are buried in the ground and supported throughout on a bedding so that they are not subjected to movement and longitudinal pull.

The strength of a rubber ring joint to longitudinal forces is not high and for same joints a flange or a shoulder is made on the pipe end to provide the necessary strength in tension. For buried water supply mains, the installed pipes and joints are supported by the continuous bed of the trench and no tensile strength in the joint itself is necessary. However, care shall be taken to anchor the pipe and fittings at bends and at connections to valves. If used above ground, they shall be anchored to provide the required strength.

Unplasticized PVC pipes may be jointed by methods employing a rubber ring to provide the water tight seal. The ring may be housed in groove formed in a plastic or metallic housing. The rubber is compressed and makes a seal between the pipe and the housing. The ring shape and the method of compressing the ring vary considerably in different types of joints. Most joints often require the application of lubricating paste. Where natural rubber rings are used, mineral oils or petrol or grease of any type should, on no account, be used.

5.5.10.6 *Pressure testing* — Solvent jointed pipeline should not be pressure tested until at least 24 hours after the last solvent connected joint has been made. Testing shall be done in accordance with IS : 4985-1981.

5.5.11 *Pipes for House Plumbing and Sanitary Work*

5.5.11.1 Galvanized iron pipes are most commonly used for house plumbing work. Polyethylene and unplasticised PVC pipes are also used nowadays. Lead, brass and copper pipes are also to be mentioned but these are not generally used. Lead piping shall not be used to convey domestic water supply as most of the waters in India are plumbo-solvent and are liable to cause lead poisoning. Lead piping may, however, be used for flushing and overflow pipes. It is liable to corrosion on contact with fresh cement mortar or concrete and shall be protected by wrapping with a protective material which will also permit movement due to expansion and contraction. IS : 404 (Part 2)-1977 relates to lead pipe. Copper pipes may be used particularly in hot water installations, provided water is not capable of dissolving an undue amount of copper. IS : 1545-1982 covers this type of pipes as well as brass, aluminium-brass and aluminium-bronze pipes of outside diameter 5 to 80 mm for use in condensers, evaporaters, heaters and coolers. The tubes are tested hydraulically to an internal pressure given by the following formula or a hydraulic pressure of 7.5 MPa (75 kgf/cm²), whichever is less or as required.

$$P = \frac{Kt}{D}$$

where

P = internal test pressure in MPa,

K = a constant depending upon the alloy and condition of the pipe,

t = wall thickness of tube in cm, and

D = outside diameter of the tube in cm.

Brass tubes for general purposes are also covered by IS : 407-1981.

The tubes are tested pneumatically also to an air pressure of 0.42 MPa (4.2 kgf/cm²) while immersed in water and shall show no sign of leaking.

Mild steel tubes used in plumbing system shall be of medium class conforming to IS : 1239 (Part 1)-1979 and IS : 1239 (Part 2)-1982, elbows, tees, union reducers, etc, are dealt with in detail separately. Steel tubes for water wells are covered by IS : 4270-1983.

5.5.11.2 *Salt glazed stoneware pipes and fittings* — IS : 651-1980 relates to this. The pipes and fittings are of two classes, namely, Grade A and Grade AA.

Pipes which comply in every respect with the requirement of the standard but of which only 5 percent have been submitted to hydraulic test and found satisfactory are classified as Grade A. Fittings in this class are not subject to hydraulic test. If 100 percent of the pipes and fittings have satisfactorily passed the hydraulic test, they are graded as AA. The interior and exterior surfaces of the pipes and fittings which remain exposed after jointing shall be glazed. The glazing shall be obtained by the action of the fumes of volatilized common salt on the material of the pipes and fittings during the process of burning.

Straight pipes shall withstand an internal hydraulic test pressure of 0.15 MPa (1.5 kgf/cm^2) on the barrels. Fittings shall withstand test pressure of 0.075 MPa (0.75 kgf/cm^2) without showing signs of injury or leakage. The pressure shall be applied on pipes and fittings at a rate not exceeding 0.075 MPa (0.75 kgf/cm^2) in 5 seconds and full pressure shall be maintained for atleast 5 seconds. The pressure test is conducted at manufacturers' works. The pipes and fittings shall also be subjected to an absorption test and the amount absorbed shall be between 6 and 10 percent by weight for pieces 20 to 38 mm thick.

5.5.11.3 *Test for resistance to acids* — When tested with hydrochloric, sulphuric, nitric or acetic acids with normality 1.0, the percentage of acid soluble matter calculated as sulphates shall not exceed 0.25 percent.

5.5.11.4 *Test for resistance to action of magnesium sulphate* — After boiling in saturated solution of magnesium sulphate for five cycles, there shall be no pitting, cracking, softening or spalling.

The internal diamenter of pipes are 100, 150, 200, 230, 250, 300, 350, 400, 450, 500 and 600 mm. The mean thickness of barrel varies from 12 to 43 mm for sizes from 100 to 600 mm. The length of barrel of straight pipes, tapers, junctions and half-section channels shall be 60, 75 or 90 cm (excludes the internal depth of socket). The interior of sockets and exterior of spigots shall be grooved circumferentially. The length of grooving on spigots = 1.5 times the internal depth of socket.

a) Depth of grooves shall be not less than 1.5 mm;

b) Bends and half-section channels are for 1/4, 1/8 or 1/16 bends;

c) Taper bends are for either 1/4 or 1/8 bends; and

d) Laying of salt glazed stoneware pipes should be according to IS : 4127-1983.

5.5.12 *Appurtenances*

5.5.12.1 *General* — To isolate and drain pipeline sections for test, inspection, cleaning and repairs for satisfactory maintenance and regulating the flow, and for the evacuation of air in water main under pressure and for the exhaust of air when such mains are being charged with water and for ventilating the mains when they are being emptied of water, a number of appurtenances, such as sluice valves, flow-regulating valves, air valves, etc, are generally installed in the line.

5.5.12.2 *Sluice valves*

a) These are used for varying the flow or completely stopping the flow in a pipeline.

Gravity conduits are commonly provided with gate chambers at points strategic for the operation of the supply conduit, at the two ends of sag pipes and pressure tunnels, and wherever it is convenient to drain given sections. Sluice valves are normally installed in grade conduits particularly in large ones. In the case of pressure conduits, the valves are usually placed at major summits. Summits identify the sections of line that can be drained by gravity and pressures are least at these points permitting cheaper valves and easier operation.

For the sake of economy, valves smaller in diameter than the conduit itself are generally installed together with necessary reducers and increasers. Usually the size of the sluice valve is the same as the size of the main up to 300 mm diameter and for bigger diameters the size of the valve is about two-thirds the size of the mains subject to a minimum of 300 mm. The extra loss in head and the additional cost of the two taper pieces or tail pieces should be taken into consideration in each case.

In the case of large valves, the operation is made easier by by-pass valves. These are used with the main valves to relieve the upstream pressure on the gate and by equalizing the pressure on both sides.

In special situations, variation of sluice valves suited to the needs are used. Needle valves are preferred for fine control of flow. Butterfly valves are preferred for ease of operation. Cone valves are used for regulating the time of closure and controlling water hammer.

Sluice valves are not used for continuous throttling as otherwise erosion of the seats and body cavitation will occur. If small flows are required, the by-pass valve is more suitable.

Flow dividing valves ensure that the flow in a subsidiary main is always maintained. These are based on the principle that the diaphragm or other arrangement in the valves opens more or less depending upon the upstream pressure allowing the regulation of flow, irrespective of the downstream pressure conditions. Maximum demand controlling valves permit all flows up to a particular valve and automatically assumes control when the flow just exceeds this predetermined quantity, thus preventing excess drawals.

This form of controlling valve finds considerable use both in municipal and industrial installations where two or more users taking water from a common source are to be prevented from consuming more than a set figure.

Scour valves or blow-off valves are ordinary valves but used for a specific purpose of scouring or emptying the main. These are placed at the low points in the line on the scour branch from the mains and at all dead ends in a distribution system. They discharge into natural discharge channels or empty into a sump from which water can be pumped to waste. The size of a scour valve depends upon the time in which the given section of line is to be emptied and the resulting velocities of flow. Calculations are based upon orifice discharge under a falling head. Frequency of operation depends upon the gravity of the water carried especially with silt loads. One common practice in city distribution system is to provide a size equal to about half the size of the main. The specifications of sluice valves should conform to IS : 780-1980 for sluice valves of sizes 50 to 300 mm and to IS : 2906-1980 for sluice valves of sizes 350 to 1 200 mm.

b) *Structure of a sluice valve* — The material for different component parts of sluice valves shall conform to Table 26.

TABLE 26 MATERIALS FOR COMPONENT PARTS OF SLUICE VALVES

SL No.	COMPONENT	BASIC MATERIAL
(1)	(2)	(3)
i)	Body, bonnet, wedge stuffing bos, gland, hand-wheel cap	Grey cast iron
ii)	Stem	High tensile brass
iii)	Wedge nut	Leaded tin bronze
iv)	Body seat ring, wedge facing ring	Leaded tin bronze
v)	Bolts	Carbon steel
vi)	Nuts	Carbon steel
vii)	Bonnet gasket	Compressed fibre
viii)	Gland packing	Jute and hemp

The majority of sluice valves used in water works practice have inside screws. This totally enclosed construction, protects the spindle thread from external influences. Sometime, however, there are conditions such as erosive action or a tendency for deposits on metal surfaces from the water which are likely to be more damaging than external influences and the external screw valve is then to be preferred. The internal screw cannot, of course, be cleaned or lubricated in service, whilst the external screw can be maintained in perfect order especially in any station installation. The cost of external screw valves is somewhat higher than that of internal screw valves.

The direction of opening of a valve may be clockwise or counter-clockwise marked on the outer end of the spindle.

The valves are provided with caps or handwheels for operation. The valves are placed in valve chambers provided with suitable covers with a hole at the centre for the insertion of a valve key for operation of the valve. Instead of a valve chamber, sometimes a CI stool and MS protecting tube with a surface box is provided. It is not always appreciated that the maximum working pressure of a sluice valve equal to, say, half the specified test pressure has no relation with the unbalanced pressure against which the valve can be operated by hand. Standard sluice valves are not, in fact, designed for operation against high unbalanced pressures and when they are required for such conditions, antifriction devices and operating gearing may be necessary. Mitre wheel gearing is used to secure a plane of operation at right angle to the plane of rotation of the valve spindle end which may be either parallel or at right angles to the axis of the pipe. No mechanical advantage is obtained with mitre wheels which are, of course, of equal diameter. Otherwise gearing is used to give mechanical advantage in cases where the size of valve and unbalanced pressure against which it is to be operated are such that one man cannot conveniently apply directly sufficient effort to work the valve. Thus bevel gearing, spur gearing and worm gearing are used according to the gear ratio required. Spur and bevel gearing are used for gear ratios from 2 : 1 to 4 : 1, while worm gearing is used for gear ratios 20 : 1 to 22 : 1.

It is estimated that the standard sluice valve can be operated by one man exerting a simultaneous 'push and pull' of 12.7 kg (total effort 25.4 kg) at the ends of a tee key 90 cm long or at the rim of a handwheel. For worm gearing the effort is taken as 25.4 kg on the crank handle.

c) *Valve headstocks* — Headstocks are used for the operation of valves through extended spindles and rods or in cases where the operating position is not directly over the valve, through vertical and horizontal shafting, mitre gearing and flexible couplings. In some instances a headstock is bolted directly on to the valve hood.

d) *By-passes* — The object of a by-pass is to relieve the unbalanced pressure on a sluice valve gate and thus reduce the operating forces. In this way gearing and headstocks can often be lightened and the force on the valve gate is equal to the difference of water pressure on the two sides of the gate multiplied by the effective areas of the gate exposed to the pressure. When the gate is fully closed, there may be or may not be pressure on the downstream side.

This will depend on the contour of the mains and whether there are any open outlets. When the by-pass valve is opened the difference of pressure across the gauge of the main valve causes flow to the downstream side of the gate and pressure will build up on that side and reduce the load on the gate.

The actual reduction of load obtained depends upon the size of the by-pass connection, the total draw-off downstream and the consequent reduction of upstream pressure. In deciding the size of by-pass to be fitted to a valve, it is therefore, necessary to estimate the maximum possible draw-off through the by-pass and the effect of the draw-off upon pressures upstream and downstream of the main valve.

The minimum size of by-pass arrangements shall be as given in Table 27.

TABLE 27 SIZES OF BY-PASS ARRANGEMENTS

(Sizes in mm)

SL No.	NOMINAL SIZE OF SLUICE VALVE	SIZE OF BY-PASS ARRANGEMENT
(1)	(2)	(3)
i)	350	40
ii)	400	40
iii)	450	50
iv)	500	50
v)	600	65
vi)	700	80
vii)	750	80
viii)	800	80
ix)	900	100
x)	1 000	100
xi)	1 100	125
xii)	1 200	125

The by-pass valve is fitted to the main valve in the case of small sizes and in the case of larger by-pass, they are accommodated on the adjoining pipes or connecting pieces.

e) *Power operation of sluice valves* — Opening or closing an unloaded 60 cm valve by hand may take 15 minutes continuous effort and, if the valve be loaded, a still longer period. Power operation is employed to avoid the arduous efforts required for manual operation and to increase the speed of operation. Other important advantages include the possibility of automatic and the remote control of valves in ways suitable to different circumstances.

Modern power driven sluice valves include valves operated by hydraulic pressure, compressed air, steam and electricity.

f) *Automatic control* — Electrically operated sluice valves can readily be adapted to automatic control under different circumstances. Controlling factors may be time, pressure, velocity of flow, water level and mechanical or electrical synchronization.

5.5.12.3 *Valves for pressure or flow control*

a) Automatic pressure control and automatic flow control valves for pipelines, flow regulating valves for closed conduits, needle regulating valves for open discharge and various types of float valves are the different types that come under this category.

b) *Automatic valves* — Automatic regulating valves are actuated by changes of pressure or of flow. In the case of float operated valves they are actuated by changes of the free surface level of water. The automatic control valves are used in a water system which maintain a given regime of pressure or flow by self-adjustment from time to time as necessary under the action of forces arising from changes of pressure or flow in some part of the system, these changes tending to upset the regime but not doing so because of the resulting action of the control valve.

Some types of automatic control valves are given in Table 28.

c) Constant flow valves maintain a constant set rate of flow in what would otherwise be variable flow conditions. There are a number of different forms of module, some suitable for pipelines, others suitable for open channels, filter outlets and weir discharges. The controlling factor can be the differential head across a venturi tube, flow nozzle or similar device, the head on a weir or measuring flume or the pitot head resulting from velocity of flow.

A typical constant flow valve is operated by a diaphragm which is subjected to the differential head resulting from the passage of flow of water under control through a flow nozzle incorporated in the valve. In action the main valve element is normally in equilibrium at some partly open position, corresponding to the pressure conditions and the rate of flow for which the valve is set. Any tendency for the flow to increase, induces an increasing differential head which causes the valve to close down in compensation and conversely any falling off in the rate of flow induces a decreasing differential head which causes the valve to open up. In this way the valve

TABLE 28 TYPES OF AUTOMATIC CONTROL VALVES
[*Clause* 5.5.12.3(b)]

SL No.	REQUIREMENT	TYPE OF VALVE
i)	To obtain a constant outlet pressure from a higher constant or variable inlet pressure	Standard pressure reducing valve
ii)	To limit a variable inlet pressure to a definite minimum value or to keep an inlet pressure constant under varying flow condition	Pressure retaining valve
iii)	To prevent a raise of line pressure above a predetermined intensity	Pressure relief valve
iv)	To reduce a constant or variable inlet pressure by a fixed amount	Break pressure valve
v)	To maintain a constant rate of flow	Module
vi)	To divide a flow into two definite proportion	Proportional flow dividing valve
vii)	To mix two flows in definite proportion	Proportional flow mixing valve
viii)	To stop a flow when a given line pressure is reached as and when tank is full	Internal pressure actuated control valve
ix)	To stop flow in one system when a given pressure is reached in another system	External pressure actuated control valve

automatically maintains a constant rate of flow under widely varying pressure conditions. Means are provided for adjustment over a considerable range of the rate of flow for which the valve can be set. Such a valve is used to obtain a constant rate of flow through a rapid gravity filter under a constant head over the filter and with varying filter heads by allowing increased opening of outlet valve.

d) *Float valves or ball valves* — The float valve is essentially an automatic flow control valve in which the regulating principle is the level of some free water surface. A float valve may be arranged to allow water to flow until a predetermined level is reached, when the valve will shut and to open again as soon as the level drops as in the case of a float valve in a flushing cistern or it may be arranged to regulate flow of water so that a constant delivery level is maintained irrespective of variations of level (or of pressure) upstream as in the case of a float valve on the inlet side of a slow sand filter when the water is supplied from a storage tank with varying levels while the level in the slow sand filter is constant. Or it may be arranged to maintain a constant level in a tank with the varying inflow and equivalent outflow from the tank as in the case of a float valve in a break pressure tank, the opening of the valve depending upon the rate of flow through the tank. The movement of the float and the corresponding stroke of the valve may extend over the full range of variation of level so that progressive valve throttling occurs as the level rises as in the case of the float valve in the inlet side of the slow sand filter mentioned above or in the case of a break pressure tank where the maximum draw-off through the tank is when the valve is fully open, or the float action in the movement of the valve may be limited to a given distance below top water level; the valve remaining fully open whenever the water level is below the actuating range.

In general, the float valve is a direct acting valve in which the weight of the float and its buoyancy provide alternately, the actuating forces (either directly on the spindle or through a lever).

e) *Use of sluice valves* — Sluice valves are used in the transmission main as well as in the city distribution system. Sluice valves are generally placed at major summits of pressure conduits. Summits identify the sections of line that are drained by gravity and pressures are least at these points permitting cheaper valves and easier operation. In the distribution system sluice valves are located on at least three sides of a cross-junction. In long mains, one sluice valve is used for every kilometre of the pipeline. For the sake of economy, valves smaller in diameter than the conduit itself together with the necessary reducers and increasers are used for mains larger than 300 mm dia. Usually the size of the sluice valve shall be the same as the size of the main up to 300 mm dia and up to two-thirds the size of the main for bigger diameters. Large valves are often fitted with a by-pass valve to relieve the upstream pressure on the gate and for easier operation as already discussed.

Gravity conduits are commonly provided with gate chambers at points strategic for the operation of the supply conduit at the two ends of the sag pipe and pressure tunnels, and wherever it is convenient to drain given sections. Sluice gates are normally installed in grade conduits particularly in large ones. In special situations variations of sluice valves suited to the needs are used. Needle valves are preferred for fine control of flow, butterfly valves for ease of operation and cone valves for regulating the time of closure and controlling water hammer.

The butterfly valves with no sliding parts have the advantages of ease of operation, low cost, compact size, reduced size of chamber or valve house and improved closing and retarding characteristics. A maximum operation velocity of 5 m/s in the fully opened position is usually specified for rubber seated valves and 17 m/s for metal seated ones. These would involve slightly higher head losses than sluice valves and also are not suitable for continuous throttling. Sluice valves are not intended to be used for continuous throttling; otherwise erosion of the seats and body cavitation will occur. If small flows are required, the by-pass valve is more suitable.

f) *Scour valves* In pressure conduits, small gated take-offs known as blow-off or scour valves are provided at the low points in the line such that each section of the line between valves can be emptied and drained completely. They discharge into natural drainage channels or empty into a sump from which the water can be pumped to waste. There should be no direct connection to sewers or polluted water courses but through a specially designed trapped chamber or pit. Their sizes depend upon local circumstances especially upon the time in which a given section of line is designed to be emptied and upon the resulting velocities of flow. Calculations are based upon orifice discharge under a falling head equal to the differences in an elevation of the water surface in the conduit and the blow-off less the friction head. Frequency of operation depends upon the quality of the water carried especially on silt loads. In the distribution system scour valves are inserted in the scour branch from the main at low points and at all dead ends. The size of the scour valve depends upon the length of the main to be scoured. It is, however, about half the size of the main which is to be scoured. The scour branch takes off from the main through a scour tee which is a special tee with its branch connection having its invert at the same level as the main with a view to drain out the bottom sediments.

g) *Reflux valves* — Reflux valves are valves through which flow can proceed in one direction only. Any tendency for the flow to reverse causes a reflux valve to close and to remain closed until flow is re-established, in the unique direction. It should close without causing shock. They are also called non-return valves, check valves and retaining valves. In one application, a reflux valve can be described as a foot valve. The term check valve is generally restricted to small size mains and which are of the disc type. Check valves can be had for the vertical as well as horizontal flow conditions. They are used in the house plumbing system as well as in industrial installations. It has the advantage of rapid closure but has simultaneously the disadvantage of causing water hammer associated with rapid closure and causing high resistance to flow. Single door type reflux valves should conform to IS : 5312 (Part 1)-1984.

h) *Flap valves* Flap valves are the simplest form of reflux valves and have a single door or flap hinged so that when hanging freely the valve is closed. Flow in the forward direction causes the door to swing open, the amount of opening depending upon the velocity of flow and weight and disposition of the metal of the door. When the velocity of flow is high enough to raise the door to its full extent, a clear waterway is prescribed and the hydrualic resistance to flow is accordingly relatively low. As the forward velocity decreases, the valve door should approach its seat until at zero velocity the valve should be closed. Any tendency for the flow to reverse will then cause the flap to press against the seat with a force proportional to the difference of upstream and downstream pressures, the greater the difference the greater being the force holding the valve closed. The travel of a flap valve is relatively great compared with that of other types of reflux valves but this is not necessarily a disadvantage and the flap valve is, in fact, very widely used on account of its simplicity and economy, its effectiveness and the low hydraulic loss it causes at ordinary working velocities. Two patterns are available, one for horizontal mains and other for vertical mains. The valve seat is inclined to the valve axis. This ensures that, when the valve is installed with its axis horizontal, the flap cannot hang in a partly open position unless there is some flow through the valve. This point deserves attention in any case where flap valve is to be installed in a main sloping downwards in the direction of flow. They are normally constructed of cast iron with gun metal face on valve body and flap. Valves 10 cm and smaller have solid gun metal doors on which the faces are machined direct. In a single stroke pitcher suction pump or a force pump, the suction valve and the plunger valve are of the non-return type. They are described in detail later.

j) *Pressure-relief valves* These are used to keep the pressure in the line below a given value by causing water to flow to waste when the pressure builds up beyond the designed value. Usually they are spring or weight loaded and are not sufficiently responsive to rapid fluctuation of pressure to be used as surge protection devices. They are installed on the main near the pumping station and usually on the outside.

A special type of this valve, called the subsoil relief valve, is used to prevent the accumulation of pressure of water under the floor of any concrete structure, such as swimming pools, dry docks and concrete tanks which is built below the surface of the ground. This pressure, if allowed to accumulate, would tend to lift the structure or crack the floor.

Another type is the loaded equilibrium valve which is used for the purpose of maintaining a head on any pumping main when delivering to high level areas. The surplus water passes through the valve to the service reservoir. The present practice is to have the overhead service reservoir built as a balancing tank floating on the pipeline without any inlet control.

k) *Pressure reducing valves* — These are used to automatically maintain a reduced pressure within reasonable limits in the downstream side of the pipeline.

m) *Pressure sustaining valves* — These are similar to the pressure reducing valves and are used to maintain automatically the pressure on the upstream side of the pipeline.

5.5.12.4 *Air valves* — These are fitted to release the air automatically when a pipeline is being filled and also to permit air to enter the pipeline when it is being emptied. Additionally, air valves have also to release any entrained air which might accumulate at high points in the pipeline during normal operations. For most cases in water works and pumping practice, two types of air valves are required. These are known as large orifice and small orifice air valves.

a) *Large orifice air valves* — The purpose of this type of valve is to discharge air during filling or charging of mains and to admit air to mains while they are being emptied. They pass air at high rates of flow with small pressure differences either into or out of the pipes on which the valve is fixed. The ball which forms the valve element although buoyant is rigid being covered with vulcanite. During normal service condition, this ball is maintained in contact with its seating usually of leather backed rubber by the pressure in the main and cannot leave this seating except when the pressure falls practically to that of the atmosphere. This occurs at various sections of a main when it is either being charged or emptied. When the pipes carrying a large orifice air valve are empty, the valve is open and remains in that position until the ball is carried on to its seating by the arrival of water. Once on this seating and under pressure, the valve cannot open even if the pipe becomes full of air until the pressure drops. It will be seen, therefore, that this valve will not release air accumulations under conditions of normal working pressure. When such a valve is discharging at a high rate, as during the filling of a main, there is a risk that the ball although lying in a fully open position in the absence of water may nevertheless suddenly be caught in the escaping air stream and closed when it may refuse to open again until the pressure has been reduced. The ball of the valve in such a case would have to be held down during filling operation. This defect has been overcome in a large orifice air valve of the advanced design known as 'kinetic air valve'. In this the air or water enters from the bottom side of the ball and the air rushing around the ball exerts the pressure and loosens the contact with the top opening and allows the ball to drop down. When solid water reaches the ball, however, it is at once displaced and instantly closed.

b) *Small orifice air valve* — The purpose of this valve is to discharge air which may accumulate in sections of a main under working conditions, that is, under the running pressure in the main. The orifice is relatively quite small and is sealed by a floating rubber covered ball at all pressures above atmospheric except when air accumulates in this valve chamber. When air has accumulated to depress the water level sufficiently, the ball falls away from the outlet orifice and the air escapes through this orifice until the water level rises again causing the ball to re-seal the orifice. The diameter of the ball in a small orifice air valve is related to the maximum working pressure and for a given size of orifice increases with this pressure. The orifice is not less than 2.5 mm in diameter.

c) *Double air valves* — In many instances, both large and small orifice air valves are required at the same point on a main and it is usual in such cases to fit a combined or double air valve in a single fitting.

d) *Location of air valves* — Air valves are required at all peaks. Peaks are not judged solely with respect to a horizontal datum but also with respect to the maximum hydraulic gradient. The reason for this is that the hydraulic gradient is the virtual free water level along the pipeline. It may vary with changes of pipe diameter possibly with different condition of pipe surfaces and with variation of velocity caused by branch mains and local points of draw-off. Any portion of a pipeline running parallel with the hydraulic gradient above it constitutes a peak and air valves at each extremity of such a parallel stretch of main are necessary, in addition to intermediate ones for long length of main as shown in Fig. 9.

Air valves are necessary at all points where the pipeline approaching the hydraulic gradient changes its slope to recede from this gradient, thereby forming a peak which is not necessarily a peak with respect to the horizontal as shown in Fig. 10.

Air is liable to be trapped in a pipeline at any point where a downward grade increases as shown in Fig. 11. Although there is no peak as defined above, it is nevertheless desirable to instal a double air valve at every such point of change or atleast a small orifice air valve.

Air locks can similarly occur at any section of a pipeline where an upward grade changes down to a decreased upward grade as shown in Fig. 12.

Generally, air valves fitted at all the peaks should be double air valves comprising large orifice and small orifice units.

In long ascending stretches, additional air valves will be required primarily to ensure adequate discharge of air when filling the pipeline and ample ventilation when it is being drained (*see* Fig. 13).

Large orifice units should be installed at intervals from 1/2 to 3/4 km along the section. In long descending stretches also additional air valves should be installed at intervals from 1/2 to 3/4 km along the section as shown in Fig. 14. Double air valves should be used in this case.

Long horizontal stretches of main or long stretches with gradients of the order of 1 in 500 should, wherever possible, be avoided. If this cannot be done, double air valves will have to be provided along the main at intervals of from 1/2 to 3/4 km, in addition to those provided at the

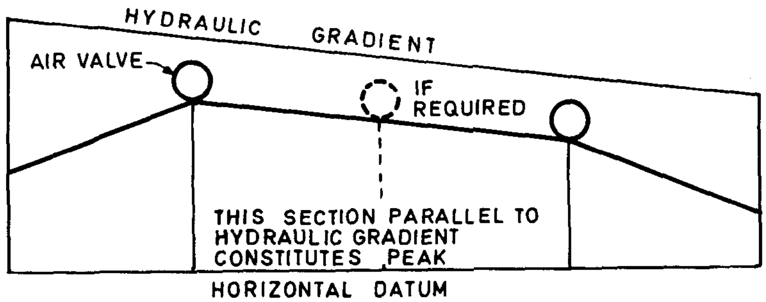


FIG. 9 SECTION OF PIPELINE RUNNING PARALLEL TO HYDRAULIC GRADIENT AND CONSTITUTING PEAK

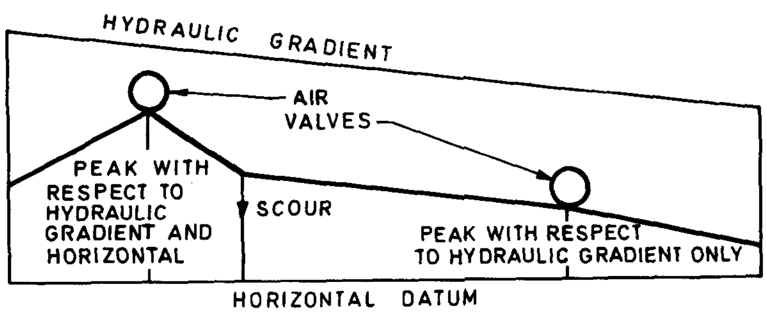


FIG. 10 SECTION OF PIPELINE FORMING PEAK WITH RESPECT TO HORIZONTAL AND ALSO TO HYDRAULIC GRADIENT, AND PEAK WITH RESPECT TO HYDRAULIC GRADIENT ONLY

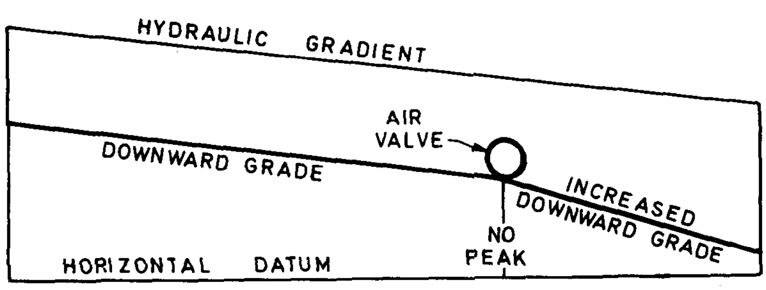


FIG. 11 SECTION OF PIPELINE HAVING DOWNWARD GRADE AND POINT OF INCREASE OF DOWNWARD GRADE

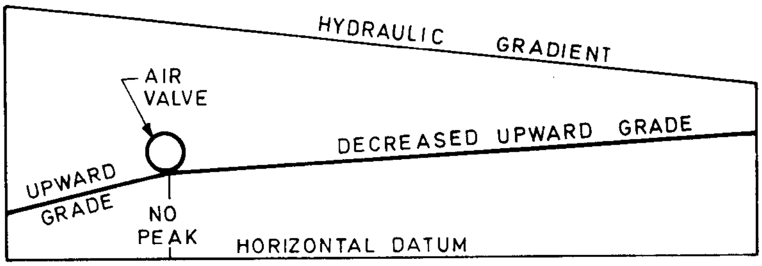


FIG. 12 SECTION OF PIPELINE HAVING UPWARD GRADE AND POINT OF DECREASE OF UPWARD GRADE

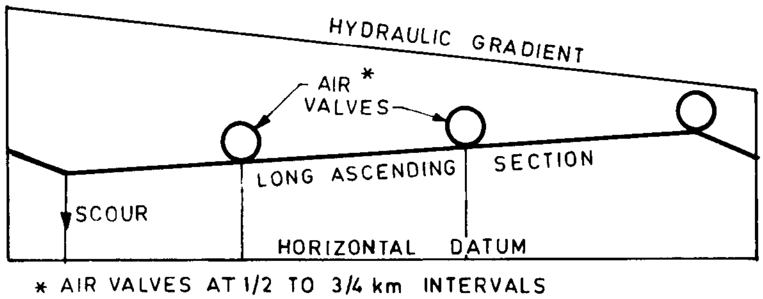


FIG. 13 LONG ASCENDING SECTION OF PIPELINE

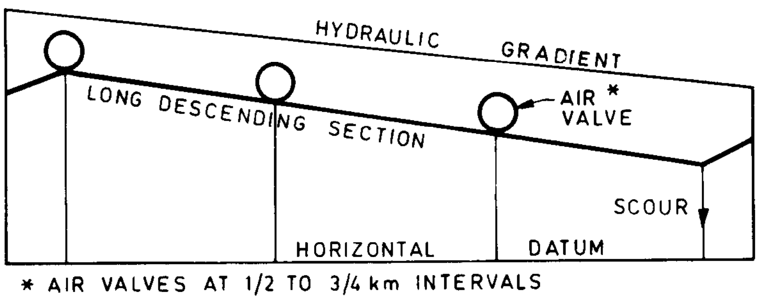


FIG. 14 LONG DESCENDING SECTION OF PIPELINE

ends of such horizontal or near horizontal stretches. The size of large orifice air valve is based upon the diameter of the main. A ratio of the branch diameter to the diameter of the main is about 1/6. This ratio for a small orifice air valve may be roughly 1/12.

5.5.12.5 *Surface boxes and protecting tubes for sluice valves* — Surface boxes provide access to underground valves installed on lines. The valves are located in brick masonry or concrete chambers which do not rest on the pipe and transmit the traffic loads to them. Surface boxes are provided on top. In some cases, instead of a chamber, the operating points or the spindles of valves are given protection from the surrounding earth by protecting tubes or vertical iron guard pipes and on top the surface box is provided.

Surface box is provided for covering the valve chamber for safety and easy identification of valves. Iron surface boxes shall conform to

IS : 3950-1979. If the surface box mounted on a guard pipe, is fixed over the underground valve merely to give access for operating the latter, the limited space provided by this arrangement will not permit the repacking of the stop valve gland or other repairs to be carried out without excavation. The guard pipe may be supported on bricks and not rest on the supply pipe.

5.5.12.6. *Selection, installation and maintenance of sluice valves* — These shall conform to IS : 2685-1971. A clear space of about 200 mm should be kept between the top of the sluice valve spindle and surface box so that valve cap may be easily provided, when the surface box is kept in flush with road level. If any leakage is detected at the valve seats, it should not be attempted to set right this by applying extra torque on the valve spindle but the valve seats should be scrapped or replaced, if need be. The direction of opening and closing should be indicated. Suitable identification plates should be provided as near to the actual location of valves as possible. A valve normally kept open or shut in a pipe should be operated once every three months to full travel of gate and any jamming developed should be freed. For T-key operation, the end of the key should have good fit on the square taper at the top of spindle. Oversize keys should not be used direct to the spindle as this may result in rounded square top and the key may eventually slip.

5.5.13 *Water Meter*

5.5.13.1 Water meters are generally used for measuring flows in the mains and house service connections. Domestic water meters are to be as per IS : 779-1978. They are up to size 50 mm and are usually of the inferential (horizontal flow) or semi-positive types, They are again of two types, the dry dial or wet dial types. In the dry dial type, the counter mechanism is isolated from water flowing through the meter. In the wet dial type, the complete counter unit is in contact with water flowing through the meter. In the inferential type, the meter measures the velocity of flow from which discharge is inferred, the counter being calibrated accordingly. In the semi-positive type, the meter volumetrically records practically down to zero flow of the water that has passed through, with a small unavoidable leakage.

The nominal sizes of meters are 15, 20, 25, 40 and 50 mm. The nominal size is the nominal bore of the inlet. The strainer fitted to the meter is of corrosive resistant material with area of holes not less than twice the area of the inlet bore. the range of registration of 15 to 25 mm meters is from 1 to 10 million litres and that for 40 and 50 mm meters, it is from 10 to 100 million litres. The meters are suitable for use up to 45°C. The meters are designed to withstand a hydrostatic test pressure of 2.0 MPa (20 kg/cm²). The discharges for the various sizes without the head loss not exceeding 10 m within the meter are given in Table 9.

The minimum discharges with the head loss exceeding 3 m within the meter for the various sizes are given in Table 9.

The minimum starting flow varies from 10 to 175 litres per hour according to the size and type of meter. The metering accuracy is ± 2 percent.

5.5.13.2 *Selection, installation and maintenance of domestic water meters* — These are covered by IS : 2401-1973.

The size is based on the flow to be measured and not on the size of the main. The maximum flow should not be greater than the nominal capacity of the meter.

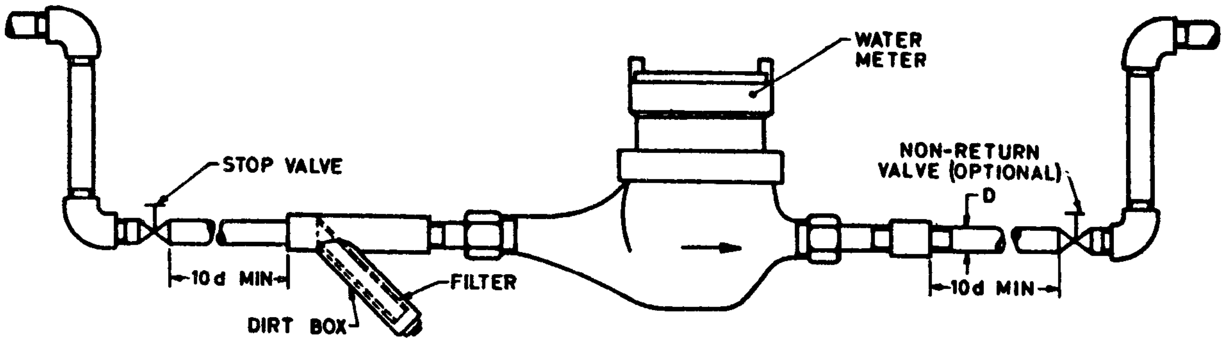
As the meter is not suitable for water containing sand, a filter or a dirt box is fitted on the upstream side of the meter. The normal strainer fitted inside a meter is not a filter and does not prevent sand from entering.

The meter shall be installed in such a way that it is always full of water. If the meter body or adjustment pipes become partially drained of water, accumulated air passing through the meter will give inaccurate reading. It is desirable to have the meter kept below the level of the communication pipe. Where backward flows are anticipated, non-return or reflux valves are to be provided. A stop valve on the upstream side is to be provided to isolate the meter when needed. The meter is to be placed horizontally with the dial facing upwards. To avoid turbulent flow which affects the accuracy of the meter, straight length of pipes are used upstream and downstream of meter for an equivalent length of 10 times the nominal diameter of the pipes. The meters are housed in meter boxes at a slightly higher level to prevent flooding of the chamber during rains. The position of water meter is to be as shown in Fig. 15. The method of testing water meters (domestic type) is given in IS : 6784-1973.

Water meter boxes of the domestic type are covered by IS : 2104-1981. They are of two sizes, Size 1 and Size 2. Size 1 shall be suitable for the installation of water meters of nominal sizes 15, 20 and 25 mm and Size 2 for meters of nominal sizes of 40 and 50 mm. The boxes shall be of oval or rectangular shape. The boxes are made of any suitable material, such as cast iron, mild steel or reinforced concrete.

The minimum inside clear dimension of water meter boxes are as given in Table 29.

The thickness of the CI box shall not be less than 8 mm for Size 1 and 10 mm for Size 2. The thickness of plates for mild steel boxes shall not be less than 3 mm. The thickness of wall of RC box shall not be less than 40 mm. A slot in the shape of an inverted *U* shall be provided on the



D = Nominal diameter of pipe.

FIG. 15 POSITIONING OF WATER METER

TABLE 29 DIMENSIONS OF WATER METER BOXES
(*Clause* 5.5.13.2)

SIZE	MINIMUM INSIDE CLEAR DIMENSION OF WATER METER BOXES (mm)		
	Length	Width	Height
1	600	600	500
2	900	600	600

short sides of the box along the centre line for the passage of the pipe. The height of the slot shall be half the clear inside height of the box and the width shall be 40 mm for Size 1 and 75 mm for Size 2 with a tolerance of ± 3 mm. Locking arrangement may be provided either with a dog and clamp arrangement with the dog to operate by an ordinary sluice valve key or by means of a padlock. Suitable anchorage for fixing the box to the concrete or masonry bed plate, on which the water meter would be installed, shall be provided.

5.5.13.3 *Water meters for distribution mains* — Water meters of the helical type are generally used and the available sizes range from 50 to 500 mm. They should have a metering accuracy of ± 2 percent at the lower limit of flow and should satisfy the minimum flows under specified head losses indicated in IS : 2373-1973.

5.6 Water Supply System within Building

5.6.1 *General* — The design of the pipe system from the point of off-take from the street main to the point of delivery at the fixture is based on the following principles. The total daily requirement of the building is calculated on the basis of the population to be served and the per capita rate of supply. For residential building units, the population may be calculated on the basis of five members per family and the number of dwelling units in the building. The per capita rate may be taken as 135 litres/head/day as the residences are to be provided with full flushing system. In the case of non-residential buildings the daily consumption per day in litres shall be as given in Table 12 and the population to be provided for shall be as per actuals in the building.

5.6.2 *Systems of Supply*

5.6.2.1 The total supply may be delivered to the building from the street main in one of the following ways:

a) In the upward distribution system or the direct supply system, the supply is given to the various floors directly from the street main which has enough pressure to feed them directly.

b) In the downtake supply or downfeed distribution, the supply from the street main is drawn either:

   1) direct into the overhead storage tank wherefrom the supply is drawn to several floors by gravity; or

   2) into a ground level storage tank wherefrom the supply is again pumped to an overhead storage tank and then the supply is drawn by gravity.

5.6.2.2 *Supply to high rise buildings* — In the case of high rise or multi-storeyed buildings, the downtake system may be one or combination of the following systems:

a) *Overhead storage system* — In this system the tanks are provided on the terrace of the building. A manifold downtake may be taken out from the storage tank which should be laid out horizontally in a loop in the terrace to carry a designed peak load demand. The pressure in the loop at the peak demand shall not become negative. Vertical downtakes as many as necessary may be taken out from the loop and should be linked to one downtake for a zone of four storeys at a time and designed for the peak demand it has to serve. A pressure reducing valve shall be provided in the downtakes to limit the head to a maximum of 25 m in easily accessible place like ducts, cat walks, etc. Appendix A illustrates the design of a water supply system in a building with water supply from a overhead tank on the building.

b) *Break pressure tank system* — In this system, the entire building is to be conveniently divided into suitable zones of 5 to 8 storeys each. For each such zone there shall be a break pressure tank, the capacity of which should be such that it holds 10 to 15 minutes supply of the floors it feeds below and shall be not less than 2 kilolitres each for flushing and other domestic purposes separately. The downtake from the master overhead tank feeds into the break pressure tank.

c) *Hydro-pneumatic system* — In this system, the supply is through a hydro-pneumatic pressure vessel fitted with accessories like non-return valves and pressure relief valves. Each zone of supply should be restricted to about seven storeys or 20 m, whichever is less.

The capacity of the pump should be such as to cope up with the peak demand. Normally 3 pumps called the lead pump, the supplementary pump and the standby pump respectively are provided. The last pump is preferably diesel driven to serve when there is a power failure. The hydro-pneumatic pressure vessel should be an air-tight vessel cylindrical in shape and fabricated from MS plates according to pressure tank fabrication code. The capacity should be equivalent to 3 minutes requirements. The air compressor is also necessary to feed air into the vessel so as to maintain the required air-water ratio in the vessel. As soon as the demand exceeds the capacity of the lead pump, the suplementary pump must start automatically.

5.6.2.3 *Fire fighting requirements* — For buildings not greater than 15 m in height, no separate provision is made for fire fighting purposes except that an underground static tank of capacity 50 000 litres is provided.

For buildings greater than 15 m and less than 24 m in height, hydrant protection to the building may be decided in accordance with National Building Code of India (Part IV) and in consultation with the fire services.

Each hydrant installation shall be fed by a pump at the rate of 2 400 l/min as the normal fire fighting tankers cannot cope with fires beyond an elevation of 15 m. The supply for fire fighting purposes shall be drawn from a separate ground level fire storage tank which shall have an effective capacity of not less than 100 kilolitres, in addition to replenishment of either direct from a street main or through an emergency water supply connection at the rate of 100 litres per minute. The overflow from the fire fighting tank should flow into the suction tank to maintain a continuous circulation in the static fire tank and also maintain a reserve storage for fire fighting purposes. The fire fighting pumps may be located in the basement to have a positive suction head and designed to deliver 2 400 l/min with a terminal pressure of 0.3 MPa (3 kg/cm²) at the top most floor.

5.6.2.4 To deal with cases when there is a power failure, the high rise buildings should be provided with independent electrical circuits, one connected to the normal external power and the other to the diesel-run generating set in the building. This generating set should automatically come into operation in the event of external power failure or fire in the building. The independent electric circuit from the generating set should be for all pump sets including fire pumps, emergency lights, lifts and lights in staircases and yards.

5.6.3 *Design of the Pipelines*

5.6.3.1 *General* — When the supply is available at sufficient pressure in the street main continuously all the 24 hours, the supply to the building may be on the upward distribution system or the direct supply system. Where the supply is intermittent or available for all through 24 hours but with inadequate pressure, it should be in a downfeed distribution system or a downtake supply system.

The data required for determining the size of the communication and service pipes are:

a) the maximum rate of discharge required;

b) the length of the pipe;

c) the head loss by friction in that length including the fitting; and

d) the roughness of the interior surface of the pipe.

As the pipeline tends to accumulate internal incrustation in course of time, normally an average value for the discharge coefficient C in the Hazen and William's formula is assumed (*see* **4.11, 4.14, 4.15, 4.17** and Fig. 2 and 3 for calculating the size of the pipe under pressure according to Hazen and William's formula).

5.6.3.2 *Maximum rate of discharge*

a) *General* — The rate of discharge for the design of the communication pipe will be based on the total supply required per day and the hours of supply in the main. As the flow is steady and uniform during the hours of supply into the ground level tank, there is no peak factor.

The design of supply pipe from the ground level storage tank to the overhead storage reservoir will be based on the hours of pumping and the total supply per day, if the pumping is at a uniform rate which is usually the case.

The capacity of the underground storage tank will be based on the hours and pattern of inflow, and the hours and pattern of pumping into overhead storage tank. The design of the overhead reservoir has been dealt with in detail in **5.4.2.3**.

If the water supply is intermittent and the hours of supply are irregular, it is sometimes desirable to have a minimum storage of half a day's supply and a maximum of 1 day's supply for overhead tanks. The ground level tank, where provided, should have a minimum capacity of 50 percent of the capacity of the overhead storage tank.

5.6.3.3 *Design of consumer's pipes based on fixture units* — The design of the consumers' pipes or the supply pipe to the fixtures is based on:

a) the number and kind of fixtures installed;

b) the fixture unit flow rate; and

c) the probable simultaneous use of these fixtures.

The rates at which water is desirably drawn into different types of fixtures are known. These rates become whole numbers of small size when they are expressed in cubic feet per minute. This unit has therefore been adopted as a matter of convenience of expression. A rate of 1 cubic feet/minute is called a fixture unit.

The total discharge flow in cubic feet/minute of a single fixture which provides the flow rate of that particular plumbing fixture as a unit of flow is called the fixture unit flow rate.

The fixture units for different sanitary appliances or groups of appliances are given in Table 30 and 31.

The fixture units for fixtures not listed above shall be estimated in accordance with Table 31.

Since all the fixtures in a given layout are not expected to be in operation at the same time, the total rate at which water will probably flow in main supply branches need not equal the sum of the requirements of the individual fixtures. A probability study made by Hunter suggests the relationship shown in Fig. 16 and Table 32. In the absence of similar studies in this country, the curves based on Hunter's study may be followed. In making use of these curves, special allowances are made as follows:

a) Demands for service sinks are ignored in calculating the total fixture demand.

b) Demands of supply outlets such as hose connections and air-conditioners through which water flows more or less continuously over a considerable length of time must be added to the probable flow rather than the fixture demand.

c) Fixtures supplied with both hot and cold water exert reduced demands upon main hot water and cold water branches (not fixture branches).

TABLE 30 FIXTURE UNITS FOR DIFFERENT SANITARY APPLIANCES AND THE SIZES OF THE FIXTURE BRANCHES

(*Clause* 5.6.3.3)

SL No	Type of Fixture	Fixture Unit Value as Load Factors	Minimum Normal Size of Fixture Branches
(1)	(2)	(3)	(4) mm
i)	Ablution tap	—	12
ii)	Bath tub (a shower head over a bath tub does not increase the fixture value)	3	15
iii)	Bidet	3	15
iv)	Combination sink-and-tray (drain board)	3	15
v)	Drinking fountain	0.5	9
vi)	Flushing tank (water closet inflow into the tank)	1	9
vii)	Kitchen sink, domestic	2	15
viii)	Wash basin, ordinary (wash basin with 32 and 40 mm trap have the same load valve)	1	9
ix)	Wash basin, surgeons	2	15
x)	Shower stall, domestic	2	15
xi)	Showers (group) per head	3	15
xii)	Urinal (wall lip or stall)	4	15
xiii)	Water closet, flush tank operated (inlet and outlet)	4	25
xiv)	Water closet, valve operated	8	25

TABLE 31 FIXTURE UNIT VALUES FOR FIXTURES BASED ON FIXTURE DRAIN OR TRAP SIZE

(*Clause* 5.6.3.3)

SL No.	Fixture Drain or Trap Size	Fixture Unit Value
(1)	(2) mm	(3)
i)	30 and smaller	1
ii)	40	2
iii)	50	3
iv)	65	4
v)	75	5
vi)	100	6

From Table 32 it is seen that in a system with flush tanks, the unit rates of flow or the probable demand load on water pipes in the building or the effective fixture units vary from about 10 percent to about 3.0 percent of the total fixture units up to 900 fixture units and for total units above this and up to 3 000 units, the percentage varies from about 3 percent to about 2 percent. In a system with flush valves, the unit rates of flow or the

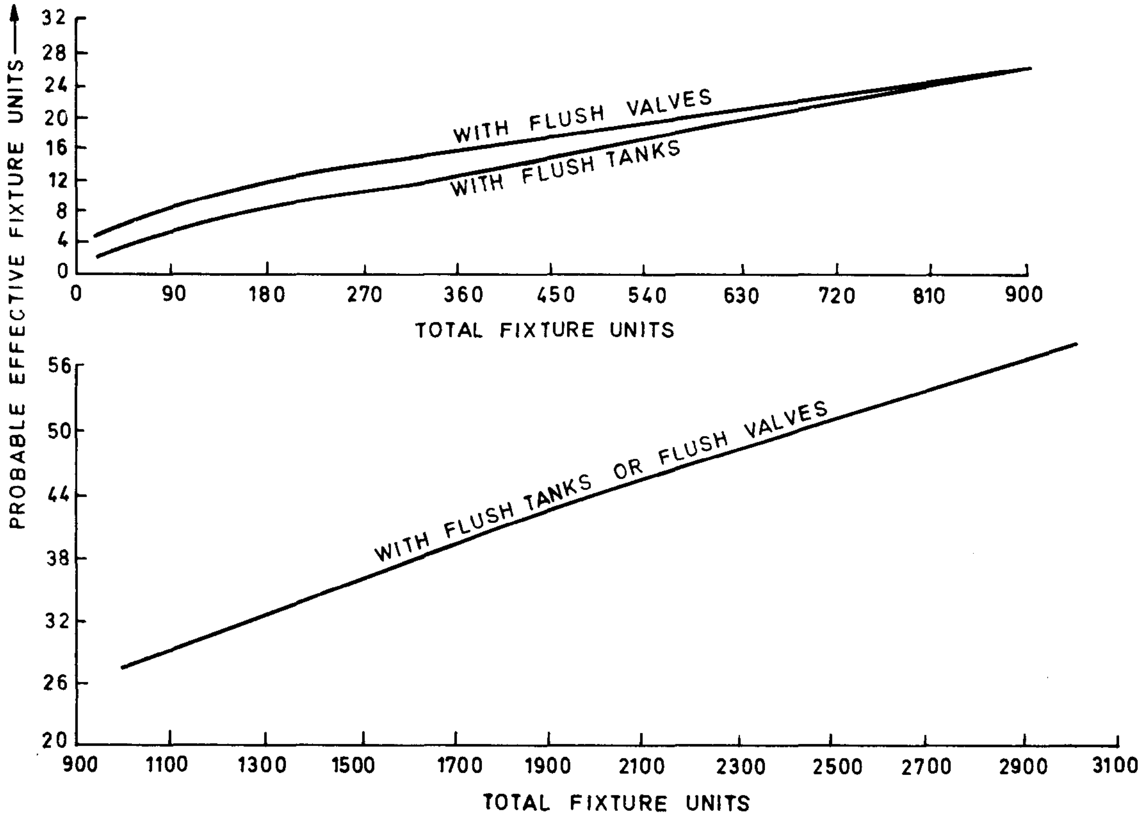


FIG. 16 PROBABLE DEMAND ON WATER PIPES IN BUILDINGS OR THE PROBABLE EFFECTIVE FIXTURE UNITS (AFTER HUNTER)

probable demand load on water pipes in the building or the effective fixture units vary from about 24 percent to about 3 percent of the total fixture units up to 900 total fixture units. Above this and up to 3 000 total fixture units, the percentage varies from about 3 percent to about 2 percent.

It will also be seen that for total number of units above 900, it is immaterial if the system is with flush tanks or with flush valves.

5.6.4 *House Service Connections*

5.6.4.1 *General* — The supply from the street main to the individual building is made through a house service connection. This consists of two parts, namely, the communication pipe and the supply pipe. The service connection is laid and maintained at the cost of the owner of the building with the approval of the Authority. But the communication pipe is laid and kept under the control of the Authority. The communication pipe extends from the ferrule on the street main up to and including the corporation stop cock near the boundary of the premises. The supply pipe runs inside the premises and extends from the corporation stop cock direct to the storage tank, either the underground storage tank or the overhead storage tank. Where the supply is drawn into the underground storage tank, the pipe from the underground storage tank to the suction side of the pumpset is called the suction pipe and the pipe from the delivery side of the pump set to the overhead storage tank is called the force main or the pumping main.

The pipe running from the corporation stop cock to the sanitary fitting is called the consumer's pipe.

The portion of the consumer's pipe delivering water to the storage tank is also called the supply pipe. The consumer's pipe running from the corporation stop cock to the sanitary fitting in the case of direct supply and the consumer's pipe from the overhead storage tank to the sanitary fitting is also called the distributing pipe. The distributing pipe generally consists of three parts, the main distributing pipe, the subsidiary distributing pipe and the fixture supply branch.

The service connection including the details of the internal plumbing system should conform generally to the National Building Code of India and particularly to the bye-laws of the concerned local authority. The systems of supply to a building are mentioned in **5.6.2**. In all cases only one connection is to be granted for any building unit to deliver the total domestic requirements of

TABLE 32 PROBABLE DEMAND LOAD ON WATER PIPES IN BUILDINGS
(*Clause* 5.6.3.3)

No. of Fixture Units	System with Flush Tanks Demand (Based on Fixture Units)		System with Flush Valves Demand (After Hunter)	
	Unit rates of Flow*	Litres per Minute	Unit rates of Flow*	Litres per Minute
(1)	(2)	(3)	(4)	(5)
20	2	56.6	4.7	132.5
40	3.3	94.6	6.3	177.9
60	4.3	121.1	7.4	208.2
80	5.1	143.8	8.3	234.7
100	5.7	162.8	9.1	257.4
120	6.4	181.7	9.8	276.3
140	7.1	200.6	10.4	295.2
160	7.6	215.7	11.0	310.4
180	8.2	230.9	11.6	329.3
200	8.6	242.2	12.3	348.2
220	9.2	261.2	12.7	359.6
240	9.6	272.5	13.1	370.9
300	11.4	321.7	14.7	416.4
400	14.0	397.4	17.0	480.7
500	16.7	473.1	19.0	537.5
600	19.4	548.8	21.1	598.0
700	21.4	605.6	23.0	651.0
800	24.1	681.3	24.5	692.7
900	26.1	738.1	26.1	738.1
1 000	28.1	794.9	28.1	794.9
1 500	36.1	1 022.0	36.1	1 022.0
2 000	43.9	1 241.5	43.9	1 241.5
2 500	51.1	1 445.9	51.1	1 445.9
3 000	57.8	1 635.1	57.8	1 635.1

*Unit rate of flow = Effective fixture units.
1 unit rate of flow = 1 cf/min = 28.316 litres per minute

the day. If there is, however, a non-domestic requirement in the building, then a separate connection shall be given.

Normally CI pipes are used for service connections. They have the advantage of low cost and high strength. They suffer from the disadvantage of short life in corrosive soils especially at the screwed joints or couplings. Bituminous covering for the pipe increases its life. Pipes are usually wrapped tightly with thick tapes of approved quality dipped and well coated with petroleum pitch or anticorrosive paint and again painted with a brush of the same coating. The carrying capacity of the pipe may also be reduced due to incrustation. Rigid PVC pipe as well as high density polyethylene pipes are also coming into use. These pipes are flexible and light, and carrying capacity is not reduced with age. They are, however, liable to be damaged easily. They also soften at temperatures above 65°C.

The supply is controlled by the Authority by a ferrule on the main or by the corporation stop cock fixed or the service connection near the boundary of the premises. Any temporary disconnection of the supply is made by the stop-cock and any permanent disconnection is made at the ferrule.

5.6.4.2 *Ferrules* — The ferrule is a draw-off appliance with a vertical inlet for screwing on to water main and a horizontal outlet and closed by means of a washer plate carrying a renewable washer which shuts against the water pressure on a seating at right angles to the axis of the threaded plug which operates it. The tapping of the street main should never be on the side or bottom. The ferrule should be as per IS : 2692-1978. The nominal sizes of ferrules are 8, 10, 15, 20, 25, 32, 40 and 50 mm. The nominal size of the ferrule is designated by the nominal bore of the inlet connection. The nominal size is usually about one half of the size of the communication pipe of the service connection. Some authorities fix the minimum size of the service connection as 20 mm and the size of the ferrule as 12 mm.

For service pipes less than 50 mm bore, the ferrule shall not be more than 25 mm bore. The service pipes of 50 mm bore and upward are preferably connected to special T-branches which have to be inserted into the line of the main. Special branch pipes shall also be used for service pipes of less than 50 mm bore where the bore of the main is not greater than thrice that of the service pipe.

Bronze ferrules are screwed into CI mains while special screwed saddles are fixed on cement asbestos or PVC pipes.

5.6.4.3 *Metering of house service connection* — All house service connections are preferably metered to reduce wastage and consequent loss of revenue to the local body. Where not possible, at least all non-domestic supply and domestic supply to bungalows with gardens, and big buildings with more than 2 families or where more than 2 supply points are needed, the supply should be metered. Where the supply is metered, there is no restriction on the number of supply points in the building. The types of meters, their selection and installation, etc, are discussed in **5.5.13**.

5.6.4.4 *Laying service pine* — Where the service connection crosses the storm water drain near the premises, it is protected by a suitable sleeve pipe to prevent damage to the service pipe and consequent cross-connection.

The service pipe shall pass into or beneath the building at a depth below the external ground level of not less than 75 cm (provided the foundation is deeper than 75 cm) and where it passes through the structure, it should be accommodated in a sleeve which should have been previously solidly built in the structure. The space between the pipe and the sleeve should be filled with bituminous or other suitable material for a minimum length of 15 cm at both ends. Nowadays it is becoming the practice not to carry the service pipe beneath a building where it could be avoided and carry it along the external wall either on its surface or in recesses specially provided for the purpose. Ducts or chases in walls for piping shall be provided during the building of the walls. It they are cut in existing walls, they shall be finished sufficiently smooth and large enough for fixing the piping. Where covers are provided to chases, they shall be fixed with screws for easy removal.

Cast iron pipes shall be secured by CI clips direct to woodwork or by similar bracket clips built into walls or screwed to plugs, the clips or holder bats being not more than 90 cm apart. Supports shall be invariably provided near the bends and tees. Demage to piping by the clamps shall be prevented by the insertion of small lead pads. Plastic pipes should be secured and supported in accordance with the recommendations given in IS : 7634 (Parts 1 to 3)-1975.

5.6.5 *Storage Tanks*

5.6.5.1 *General* — The storage of water has been dealt with in **5.4**. Storage reservoirs in building premises has been dealt with in **5.4.2.3**.

The basis of providing for the storage capacity has been dealt with as given below.

5.6.5.2 *Materials for the construction of storage tanks* — They shall be made from iron, wrought iron or mild steel plates or sheets and shall be made water-tight without the use of putty. The materials used shall be of sufficient strength and thickness. Reinforced cement concrete tank or tanks made of any other suitable building material may be allowed as storage tanks.

Tanks made of galvanized steel sheets may be of welded, riveted or pressed construction. The pressed steel tanks are normally 120 cm square, the thickness of sheet varying according to the depth of the tank. Tanks with external flanges are most convenient except where space is limited or where it is required to erect them direct on the a flat roof or floor. If of iron or steel, the metal shall be galvanized or coated internally with bituminous composition or other suitable material of a kind which does not impart a taste or odour to water especially if this has been chlorinated and externally with a good quality weather resisting paint. Lead lined tanks shall not be used. Rectangular pressed steel tanks shall conform to the requirements given in IS : 804-1967.

Every storage tank shall be made water-tight at all times and shall be properly covered with a close fitting dust, light and mosquito-proof lid fitted with a lock and key.

5.6.5.3 *Ball valves* — Every tank shall be provided with a sound and suitable ball valve conforming to IS : 1703-1977 securely fixed to the tank and set in such a position that the body of the ball valve cannot become submerged when the cistern is full up to the water line. Every valve shall be so adjusted as to limit the level of the water in the cistern to 25 mm below the lip of the warning or overflow pipe.

5.6.5.4 *Warning pipes of storage tanks* — Every tank shall be provided with an efficient mosquito-proof warning pipe. The outlet of the warning pipe shall be in such a position outside the building as will allow the discharge of water from such warning pipe being readily seen. The outlet of the warning pipe shall be not less than 60 cm above any drain, sink or gully over which the same may be fixed. No overflow pipe shall be allowed to be connected directly to any drain or sewer nor shall it discharge on to any street. All warning pipes shall be not less than 20 mm in bore so fixed that the bottom of the pipe will be 25 mm above the top water level. In every storage vessel, the water line shall be set below the overflowing level of the warning pipe or of the overflow pipe if there is no warning pipe at a distance of not less than 25 mm or of not less than the internal diameter of the pipe, whichever is greater.

5.6.5.5 *Provision of stop taps* — Storage tanks shall be provided with stop valve or stop tap conforming to IS : 781-1984 at every outlet other than overflow pipes so that there shall be no necessity to empty the vessel to enable repairs to be carried out to the downtake pipes, fittings, etc.

Such valves or taps shall preferably be full-way gate valves so as not to impose any undue obstruction to the flow of water. A stop-valve shall be provided on the inlet connection also to facilitate stopping of flow temporarily in the event of improper functioning of ball valve or for cleaning of storage tank.

5.6.5.6 *Position of storage tank* — Every storage tank used or fixed in connection with the water supplied by the Authority shall be easily accessible and placed in such a position as to admit of thorough inspection and cleaning and if placed within the house or building, it shall have a clear space of not less than 60 cm between the top of the cistern and ceiling, rafter or roof. If the capacity of the tank is bigger than 500 litres, a greater clear space shall be provided.

In cases where overhead storage tanks are supported on roof slab of the building, careful inspection and calculation shall be carried out to ascertain whether the structure of the building is of sufficient strength to take the increased load. The tanks shall be preferably supported on bearers so as to distribute the load. They shall be designed taking into account the load coming upon them.

5.6.5.7 *Grouping of storage tanks* — If the storage required is more than 5 000 litres, it is advantageous to arrange it in a series of tanks or in compartments so inter-connected that each can be isolated for cleaning and inspection without interfering with the supply of water. This can conveniently be done by the use of a header pipe to which each tank/compartment is connected and from which the distributing pipes branch off, each branch into and out of the header pipe being provided with a stop valve. Each tank/compartment shall have its own float operated valve and overflow pipe, and a draining valve to facilitate cleaning out. In large storage tanks, the outlet shall be at the end opposite the inlet to avoid stagnation of the water. In high rise buildings, storage tanks may be placed in different tiers as per **5.6.2.2** to ensure more equitable pressure distribution of water.

5.6.5.8 *Provision of outlets* — The outlet pipe shall be fixed 50 to 75 mm above the bottom of the tank and provided preferably with copper gauge strainers. The wash out or draining pipe shall be made flush at the bottom of the tank at its lowest point. The floor of the tank shall be erected so as to give a slight fall to the washout pipe for cleaning purposes.

5.6.5.9 *Underground storage tanks* — When buried or underground storage tanks are used for storage and reception of water for domestic purposes, the following requirements shall be complied with.

a) The tank shall project at least 30 cm above the highest flood level. Where this is not possible, the manhole cover shall be raised 30 cm above the highest flood level of the locality or ground level, whichever is higher.

b) The design of the tank shall be such as to provide for the draining of the tank when necessary and water shall not be allowed to collect around the tank.

c) The tank shall be perfectly water-tight.

d) The inner surface of the tank shall be rendered smooth as far as possible.

e) The top of the tank shall be so levelled as to prevent accumulation of water thereon.

f) The tank shall have a complete cement concrete cover leaving a manhole opening provided with a properly fitting mosquito-proof, hinged cast iron cover fitted with a leak proof cast iron frame. Where tank is of large size, adequate number of manholes shall be provided.

g) No gap shall be allowed to remain round the suction pipe and arrangements shall be provided for proper discharge of spill water from the electric pump by connecting the pump cabin to the water drain or by providing a small hole which will enable the water to flow out.

h) The overflow pipes or vent shafts, if provided, shall have a wire gauge cover of 1.5 mm mesh properly screwed tightly to the opening.

5.6.5.10 *Jointing of pipes to storage tanks* — For jointing a steel pipe to a storage tank, the end of the pipe shall be threaded, passed through a hole in the tank and secured by backnuts both inside and outside. The pipe end shall be flush with the face of the inside backnut to obviate the corrosion of the pipe threads. For joining copper pipes to steel or copper tank, a connector of non-ferrous metal shall be used having a shoulder to bear on the outside of the tank and secured by a backnut inside.

5.6.6 *Water Fittings and Appliances*

5.6.6.1 *General* — The pipes used for house plumbing for water supply have been dealt in **5.5.11.1**.

The pipe fittings are the connections, appliances and adjuncts designed to be used in connection with pipes such as couplings or sockets to connect two straight lengths and elbows, and bends to alter the direction of a pipe; tees and crosses to connect a branch with a main; plugs and caps to close an end; bushings, diminishers or reducing sockets to couple two pipes of different dimensions, etc.

The other fittings and appliances are union, stop, regulating and mixing valves, stop cocks, ferrules, taps and other appliances to which water is supplied, such as bath tubs, cisterns or storage tanks, hot water or geyser apparatus, urinals, wash basins and sinks.

5.6.6.2 *Fittings used in plumbing* — The fittings used in this connection are dealt below in detail.

Pipe, fixture, supply — In plumbing a water supply pipe connecting the fixture supply pipe with the fixture branch at the wall or floor line.

Pipe, flanged — A pipe provided with flanges so that the ends can be joined together by means of bolts.

Pipe, long — A pipeline whose length is usually in excess of 500 times its diameter. In such pipes the loss of head due to entrance and velocity head is negligible, and is usually disregarded.

Pipe, short — A pipeline whose length is usually less than 500 times the diameter. In such pipe the effect of entrance and velocity head may material and should be considered.

Pipe, offset — In plumbing, a combination of elbows or bends which brings one section of line of pipe out of line with another section and a pipe fitting in the approximate form of a reverse curve to accomplish the same purpose.

Pipe, outlet — A pipeline which conveys the effluent from a reservoir or other structure to its point of discharge.

Pipe, water service — The pipeline extending from the water main to the building served.

Tube, long — A tube inserted in an orifice whose length is greater than three times its diameter.

Tube, pitot — A device for measuring the velocity of flowing water using the velocity head of the stream as an index of velocity. It consists of an orifice held to a point upstream in the water connection with a tube in which the rise of water due to velocity head may be observed and measured.

Coupling — A socket device used to correct the threaded end pipe.

Gooseneck — A flexible coupling usually consisting of a short piece of lead or plastic pipe shaped like the letter 'S'. It is always used to connect the sanitary fixture like the flush tank of a water-closet or a wash basin tap to the fixture water supply pipe.

Union — It is the usual trade term for a device to connect pipes. It commonly consists of three pieces, which are first the thread end fitted with exterior and interior threads, second the bottoms end fitted with interior threads and a small exterior shoulder and third the ring which has an inside flange at one end while the other end has an inside thread like that on the exterior of the thread end. In use a gasket is placed between the thread and bottom ends which are drawn together by the ring. Gaskets are often supplanted by ground joints. Unions are used extensively because they permit connecting with little disturbance of the pipe position. They are used in long stretches of straight pipes in the beginning of a pipe system inside a room and near all appliances along with stop or regulating valves or cocks. These are used to control or stop the flow to appliances to enable them to be taken out for repairs without disturbing the supply to the other parts of the system.

Elbow — A pipe fitting that connects two pipes at an angle. The angle is always 90°, unless another angle is stated.

Bend — Lengths of pipe bent or cast into angle shapes. Standard deflections from a straight line are 5⅝°, 11¼°, 22½°, 45° and 90°. These shapes are also termed respectively 1/64, 1/32, 1/16, 1/8 and 1/4.

Adjutage — A tube inserted into an orifice.

Bellmouth — A rounded entrance to a pipe or orifice, a diverging section of a conduit.

Bell — (a) In pipe fitting, the recessed over-enlarged female end of a pipe into which the male end fits, also called 'Hub'; and (b) in plumbing the expanded female end of a wiped joint.

Tee — A pipe fitting either cast or wrought that has one side outlet at right angles to the run. A single outlet branch pipe.

Tee, reducing — Any tee having two different sizes of openings. It may reduce on the run or branch.

Cross — A pipe fitting with four branches arranged in pairs, each pair on one axis and the axis at right angles.

Reducer — A pipe fitting having a larger size at one end than at the other, used to connect two pipes of different diameters.

Nipple — A tubular pipe fitting usually threaded at both ends and under 30 cm in length. If lengths are over 30 cm these are considered as cut pipes.

Nipple, close — A nipple with two threaded ends for joining.

Nipple, short — A nipple with a length little greater than that of two threaded length or somewhat larger than a close nipple with some unthreaded shoulder between the two threads. The unthreaded shoulder is sometimes of an enlarged size and shaped as a nut to help joining. This is sometimes called a 'bar nipple'.

Cap — A fitting for the spigot or screw end of a metal pipe.

Plug — (a) A fitting for the bell end of CI pipe to close the opening; (b) a fitting that has an exterior pipe thread and a projecting head by which it is screwed into the opening of the fitting; and (c) the movable part of a tap, cock, valve, etc.

Bib cock/Bib valve — A tap or valve closed by screwing down a leather or a fibre washered disc on to a seat in the valve body.

Plug cock, plug valve, plug tap — A cock or a tap or a shut-off valve in which the liquid passageway is a hole in a rotatable plug fitted into the valve body. Rotation of the plug through a right angle stops or starts the flow.

Stop cock — A device for regulating or stopping the flow in a pipe made by a taper plug that may be rotated in a body.

Cock, corporation — A valve or a stop cock on the service connection at the boundary of the premises and under the control of the authority used for the temporary disconnection of the service.

Ferrule — A draw-off appliance with a vertical inlet for screwing on to water main and a horizontal outlet and closed by means of a washer plate carrying a renewable washer which shuts against the water pressure on a seating at right angles to the axis of the threaded plug which operates it. It cannot be operated from the surface.

Ferrules shall be of the nominal sizes: 8, 10, 15, 20, 25, 32, 40 and 50 mm. The nominal sizes of the ferrule shall be designated by the nominal bore of the inlet connections.

Ferrules shall conform to IS : 2692-1978.

Valve — (a) A device installed in a pipeline for the purpose of controlling the magnitude and direction of the flow; and (b) in a pump, a waterway, passage through which is controlled by a mechanism.

Valve-glove — A valve having a round ball-like shell and horizontal disc.

Valve-gate — A valve where the closing element consists of a disc which slides over the opening or cross-sectional area through which water passes and fits tightly against it.

Valve, foot — A valve placed in the bottom of the suction pipe of a pump which opens to allow water to enter the suction pipe but closes to prevent water from passing out of it at the bottom end.

Valve, float — A valve in which the flow is actuated by a float to control the flow into a tank.

Valve, check — A valve provided with a disc hinged on one edge so that it opens in the direction of normal flow and closes with reversal of flow.

Valve, by-pass — A small pilot valve used in connection with a larger valve to equalize the pressure on both sides of the disc of the larger valve before the larger valve is opened.

Valve, butterfly — A valve wherein the disc rotates as it opens or closes about a spindle supported by the frame of the valve. The valve is operated by a stem. At full opening the disc is in a position parallel to the axis of the conduit.

Valve, scour or blow-off — A valve installed in a low point or depression on a pipeline to allow drainage of the line.

Valve, air — A valve that releases air from a pipeline automatically without loss of water or introduces air into a line automatically if the internal pressure becomes less than the atmospheric pressure.

Tank, elevated — A tank used for storage purposes in a water distribution system which is raised above the surface of the ground and is supported by posts or columns.

Tank, automatic flush — A tank in which water is accumulated and discharged at intervals for flushing a closet or a urinal.

Tank, pressure — A tank used in connection with a water distribution system either for a single household or for several houses, which is air-tight and holds both air and water, and in which the air is compressed, the pressure so created being transmitted to the water.

5.6.6.3 *Terminal fittings in a water supply system*

a) *General* — The purpose of any water supply system is to supply water for various uses needed by any population. The uses may be one or more of the following:

1) To collect water for drinking, cooking, washing, etc. The fitting used is an ordinary tap, either a plug tap or a bib tap.

2) To discharge water through a tap only when operated and to close automatically when released.

   The fittings are self-closing taps.

3) To discharge water in a jet for direct drinking purposes.

   The fitting or appliance used is a drinking fountain.

4) To discharge water (hot or cold) in a wash basin for washing face or for cleaning teeth, etc, using the hand for operating the taps.

The fittings used are pillar taps.

5) To discharge water (hot or cold) in a wash basin using the elbow for operation of the tap when both hands are to be cleaned as in the case of a surgeon.

The fittings used are pillar taps with lever handles operated by the elbow.

6) To mix hot and cold water in suitable proportions for ablution and domestic purposes.

The fittings used are mixing valves.

7) To discharge water in a spray for bathing purposes.

The fitting used is a shower rose either of the fixed overhead type or the telephone receiver type fixed to a flexible type pipeline and controlled by a globe valve or wheel valve.

8) To discharge water into flush tanks (overhead or low level) with automatic function of stopping and starting the supply when the tank is full and empty respectively.

The fittings used are ball valves (horizontal plunger type).

9) To discharge water into storage tanks with automatic function of opening and closing the supply when the water level in the tank is below a certain level and when it reaches the maximum level respectively.

The fitting used is a float valve (vertical spindle type) or the fitting mentioned under item 8.

10) To supply water for heaters such as geysers, instantaneous water heaters, etc.

The fittings used are inlet wheel valves or globe valves.

11) To discharge water for direct flushing of water-closets.

The fittings used are flush valves.

12) To discharge water in a spray for watering lawns.

The fittings used are sprinklers of the fixed type.

13) To discharge water in a spray for watering plants.

The fittings used are a shower rose fitted to a flexible pipeline or hose.

14) to discharge water for fire fighting purposes.

The fittings used are the nozzles fitted to fire hose delivery pipe; fog nozzles for fire brigade use, and fire hydrants fitted to water supply pipelines; landing valves (internal hydrant), and overhead sprinklers in a pipeline operating automatically by the fusing of the outlet seals by the high temperature caused in the room by a fire, for the discharge of the water only.

15) To discharge water in sprays or jets in ornamental fountains.

The fittings used are perforated pipes fitted with spray or jet nozzles.

b) *Essentials in the design of terminal fittings*

1) In a protected water supply system, the potable water is supplied to the consumer through a water fitting. The moment the water comes out of the fitting, it is exposed to contamination if not protected further. If the tap is likely to be submerged by water issuing from the tap or by surface water by virtue of its location in a pit or in a receptacle, the tap is likely to suck back the water from the pit or receptacle when there is no supply in the system due to intermittent supply leading to the contamination of the protected water when the supply is restored in the system. Hence, no pit tap should be encouraged even though there is an improved supply position due to poor pressures in the supply system. The provision of reflux or non-return valve shall not be relied upon to prevent such backflows.

2) In all appliances where the water is supplied for use in several purposes, the outlet end of the supply pipe should be kept a distance above the flood level of the rim of the fixture or receptacle to provide an air gap specified for the particular fixture.

3) Where 'below-rim' potable water supply outlets have to be adopted, protective methods for use with such outlets shall be taken. Such outlets shall be individually equipped with approved vacuum breakers of the same nominal size as the fixture supply. Such vacuum breakers shall be located 10 cm above the flood level rim of the fixture or receptacle.

4) No boiler for generating steam or closed boilers of any description shall be supplied direct from a service or supply pipe. Every such boiler shall be supplied from a feed cistern.

5) Where a supply of wholesome water is required as an alternative or standby to a supply of less satisfactory water or is

required to be mixed with the latter, it shall be delivered only into a cistern and by a pipe or fitting discharging into the air gap at a height above the top edge of the cistern equal to twice its nominal bore and in no case less than 15 cm.

6) All fittings shall be designed, laid or fixed and maintained to remain water-tight, thereby avoiding waste of water, damage to property and the risk of contamination of the water conveyed. All washers and bushings should be periodically examined and changed to avoid wastage of water by dripping or leaks from the fittings.

c) *Important details of the fittings*

1) *Plug cocks for water supply purposes* — Plug cock is a shut-off device comprising a body having a taper seating into which is fitted a plug which can be turned to move its port relative to the body ports to control the flow of water. The plug is retained in the body by means of a washer, screw and nut at its smaller end. Plug cocks are of 15, 20 and 25 mm nominal sizes with a key head for underground use for water supply purposes. The nominal size of the plug cocks is denoted by the nominal bores of the end ports in the body. The area of the body ports and throat shall be not less than the area of a circle of a diameter equal to the nominal bore and adjacent to the plug, the waterway of the body port shall coincide with the plug port.

IS : 3004-1979 shall be followed in all respects.

2) *Screw-down bib taps and stop valve* — A bib tap is a draw-off tap with a horizontal inlet and a free outlet. A stop valve is a valve with suitable means of connection for insertion in a pipeline for controlling or stopping flow.

A bib tap or stop valve is closed by means of a disc carrying a renewable non-metallic washer which shuts against the water pressure on a seating at right angles to the axis of the threaded spindle which operates it. Bib taps are of the nominal sizes 8, 10, 15, 20 and 25 mm. Stop valves are of the nominal sizes 8, 10, 15, 20, 25, 32, 40 and 50 mm.

The nominal size of the fitting is the same as the nominal size of the bore of the socket or pipe outlet to which the tap or valve is normally fitted.

IS : 781-1977 Specification for cast copper alloy screw down bib taps and stop valves for water services shall be followed. For cast copper alloy fancy bib taps and stop valves, IS : 8931-1978 shall be followed. Washers used in fittings shall conform to IS : 4346-1982 for plastic bib taps and stop valves IS : 9763-1981 shall be followed.

3) *Self-closing taps* — A self-closing tap is a draw-off tap which remains in the open position so long as a lever handle is kept pressed up, down or sideways or a push button is kept pressed in and closes by itself, or when the button or the lever handle is released. The self-closing tap may incorporate a device which closes the tap even without the release of handle after a fixed quantity is discharged. They are of two nominal sizes of 15 and 20 mm. Nominal size is the same as nominal bore of the inlet connection.

The force required for operating the tap shall not exceed 70 N (7 kg). For self-closing taps which operate against heads exceeding 2 m, non-concussive function is essential and shall be provided in the design.

The handle operated self-closing taps may be designed to close without the release of the handle after discharging not less than 5 litres or more than 10 litres of water at a time by providing a capillary groove in the valve which shall slide in the bottom hollow chamber of the spindle or by any other equally suitable device.

Self-closing taps shall conform to IS : 1711-1970.

4) *Pillar taps for water supply purposes* — A pillar tap is a draw-off tap with a vertical inlet and an uptilted or horizontal free outlet. The nominal sizes are 15 and 20 mm which are the same as the nominal sizes of the bore of the outlet to which the taps are fitted. The taps are fixed to a wash basin by backnuts. Pillar taps shall be nickel-chromium plated, capable of taking high polish which will not tarnish or scale.

IS : 1795-1982 shall be followed in all respects. For cast copper alloy fancy pillar taps, IS : 8934-1978 shall be followed.

5) *Globe valve or screw-down stop valve or wheel valve* — It is a valve having generally a spherical body in which the body ends are in line with each other and the disc is lifted from or lowered to the body seat by a stem whose axis is at right angles to that of the body ends. In globe valves, the pressure acts on the underside of the valve disc and there is a change of direction of flow inside the valve body.

Hand wheels shall close the valve by turning in a clockwise direction when facing the wheel.

The nominal size are from 8 to 100 mm.

IS : 778-1980 shall be followed in all respects.

6) *Shower rose* — Shower roses shall be of vitreous china or stainless steel or galvanized steel. The size of the shower rose shall be 100 mm when measured across the diameter and the inlet connection shall be 15 mm. The number of holes to be provided in 100 mm size shower rose shall be 145 ± 10 (variation). The diameter of each hole in shower rose shall be 1.2 mm with ± 10 percent tolerance. The holes shall be suitably spaced so as to give a uniform shower and to satisfy the performance test, namely, the shower rose, when fitted at a height of 2 100 mm from the floor under a minimum of 3 m head, shall wet an area having 450 mm as its minimum dimension on the floor. IS : 2556 (Part 11)-1979 shall be followed in general for shower roses of vitreous china.

7) *Ball valve (horizontal plunger type)* — Ball valves are of two classes:

   i) *High pressure type* — These are designed for use on mains having pressure of 0.175 MPa or above.

   ii) *Low pressure type* — These are designed for use on mains having a pressure less than 0.175 MPa. These valves shall remain closed at a test pressure of 0.35 MPa.

   The nominal sizes are 15, 20, 25, 32, 40 and 50 mm.

   The inlet shank shall have an external parallel fastening thread of the same size as the nominal size of ball valve. The piston shall be capable of having uniform contact all around against the seat even when the washer is removed. The floats may be of copper or polyethylene and generally of a spherical shape. The back nuts shall be provided with parallel internal thread and shall be of the same size as the nominal size of the ball valves.

   IS : 1703-1977 shall be followed in all respects.

8) *Drinking fountains* — These are used in schools, parks and other public places.

   The jet is preferably inserted at the side.

   The arrangement shall be such that, when the fountain is operating without hindrance under normal conditions, the stream shall fall appreciably within area of the waste outlet.

   The jet of the fountain shall issue from a nozzle which shall be set at an angle from the vertical so as to prevent the backflow of water in the jet of the orifice. The nozzle and every other opening in the water pipe leading to the nozzle shall be above the edge of the basin so that they may not be flooded in case the fountain drain gets clogged. The nozzles shall be circular in cross-section and shall have a convergence which becomes more gradual as the outlet is approached. The length of the nozzle shall not exceed 2.5 times the diameter of the supply pipe and the diameter of the nozzle orifice shall not exceed one-third the diameter of the pipeline. The nozzle end shall be protected by a corrosion-resistant guard to prevent the mouth and nose of persons using the fountain from coming into contact with the nozzle. The water supply to the jet shall be controlled by a self-closing tap of 15 mm nominal size fixed at the right hand side of the connecting inlet pipe when viewed from the front.

   IS : 1700-1973 shall be followed in general.

9) *Mixing valve* — An appliance into which hot and cold water entering through separate valve ports are mixed in a specially formed chamber and then delivered through a single common outlet, the temperature of the mixed water being controlled through a nominal range by the operation of a single handle.

   Mixing valves are of sizes 15, 20 and 25 mm.

   The size of a mixing valve shall be denoted by the nominal size of the bore of the inlets which shall always be of equal diameters. The head loss through the mixing valve at different rates of flow should not exceed the following:

Size of Valve	*Rate of Flow*	*Maximum Permissible Head Loss in the Fitting*
mm	l/min	m
(1)	(2)	(3)
15	5	1.0
	10	1.5
	15	2.5
20	20	1.5
	25	2.0
	30	3.0
25	40	2.5
	45	3.0

   The head loss shall be the difference in pressure at the inlet and outlet connections with the flow control in the mid position, that is, between fully open and fully closed positions.

   IS : 1701-1960 shall be followed in general.

10) *Flush valves and fittings* — Flush valves are fittings which are directly connected to

pressure water pipes. When they are operated, they allow a limited quantity of water in order to flush water-closets and slowly close automatically.

The nominal sizes of the flush valve shall be 15, 25 and 32 mm. Nominal size is the nominal bore of supply pipe to which the valve is connected.

The flush valve is normally fixed at one metre height from the flooring in the case of European type of water-closet and one metre height from foot rests in case of Indian type of water closet.

The flush valve is provided with a push button or lever for operation.

The flush valve shall be adjustable to flush 5 to 10 litres of water in each discharge. It shall be capable of discharging the full capacity in a single operation. It shall be capable of working under a pressure of 1.5 to 5 kgf/cm^2.

IS : 9758-1981 shall be tollowed in general.

11) *Fire hydrant, landing valves for nozzles, etc.* — Hydrants are invariably used for fire fighting purposes to derive water from the street mains. The hydrants could be of the stand post type or the underground type. The hydrant incorporates a control valve and an outlet connection to which a stand pipe could be attached. The size is 80 mm in case of single outlet and 100 mm in case of double outlets. A duckfoot bend is used below the stand pipe

IS : 908-1975 and IS : 5714-1981 shall be followed for fire hydrants.

Landing valves, also called internal hydrants, are usually fitted inside the buildings. These are called landing valves because they are primarily intended for being installed at the staircase landings at each floor level from where fire hose could be laid out by the fire brigade or trained men for fighting fire on the concerned floor.

IS : 5290-1983 shall be followed for landing valves.

A nozzle is a piece of equipment which is screwed on to the end of the branch and controls the size of the stream directed on to the fire. A fog nozzle is a type of hand controlled branch in which the operator can apply water to a heated surface or fire in the form of either a fog (fine mist) or a jet. The added advantage over other hand controlled branches is that water fog aims at uniform cooling of the surface over which it is applied, provides maximum cooling effect and conserves water. The throw from a fog nozzle is considerably reduced when it is used for the application of fog. IS : 903-1984 and IS : 952-1969 shall be followed for branch pipes, nozzles and fog nozzles.

Controlled percolating hoses are used for fire fighting. These are used by fire services in circumstances where some degree of percolation is essential to prevent the hose from being scortched when used over hot surfaces and also where water damage because of percolation is of little or no consequence.

IS : 8423-1977 shall be followed for the controlled percolating hose.

Branches with revolving head for fire fighting are also used. The pressure required for the branch to start revolving shall be not more than 0.5 MPa (5.0 kgf/cm^2). The branch should rotate without showing any leakage or failure with pressure up to 1.0 MPa (10 kgf/cm^2) for 10 hours continuous operation.

IS : 906-1972 shall be followed for the branch with revolving head for fire fighting purposes.

5.7 Hot Water Supply

5.7.1 *General* — Hot water is needed for several purposes in residential buildings and in industrial establishments. Hot water supply is an essential need under cold climate conditions. Even in places where cold water is generally satisfactory for most of the purposes, hot water supply is needed for washing faces, hands and for bath and washing utensils especially those which are greasy, washing clothes especially those which are washed in machines and in hospitals.

5.7.2 *Temperature of Hot Water* — The designs of hot water supply system and its appliance shall be based upon the following temperatures in accordance with IS : 7558-1974.

Scalding—65°C
Supply to sink—60°C
Supply to wash basins—55°C
Supply for hot bath—43°C as run, for use at 41°C
Supply for warm bath—37°C
Supply for tepid bath—29.5°C
Hot water storage temperature—60°C

This may by increased to 65°C when soft water is used, and the storage capacity is limited. To minimize the danger of scalding, precipitation of scale from hard water to reduce standing losses, risk of steam formation and the possibility of damage to porcelain or other fittings and the surface finishes, a storage temperature of 60°C is recommended. Though a temperature of 70°C is desirable and economical for use with mechanical working units but to avoid the possibility of scalding the users, a maximum temperature of

60°C may be adopted. The temperature of the supply to wash basins and for baths including supply to bath tubs and for showers is preferably controlled by the use of a mixing valve generally conforming to IS : 1701-1960. The efficiency in a water heating system depends upon the measures taken to minimize heat losses which occur from the storage vessel and from the distributing pipe work and associated accessories.

5.7.3 *Systems of Hot Water Supply* — There are two systems of hot water supply—the instantaneous system and the storage system.

In the instantaneous system, water is heated at the moment it is needed. In the storage system, a tank full of hot water is maintained in readiness. The instantaneous system is much more economical if the demand for the hot water is irregular and sporadic. If hot water is likely to be needed at frequent intervals at a number of points throughout the day, the storage system is usually preferred.

5.7.4 *Rate of Flow* — The rate of flow of hot water depends upon the type of installation adopted for the provision of hot water. With storage type installation, the recommended minimum rate of flow for different types of fixtures are given in Table 33.

TABLE 33 RATE OF HOT WATER FLOW

Fixtures	Rate of Flow l/min
Bath tub	22.5
Kitchen sink	18.0
Wash basin	7
Shower (spray type)	7

In case of instantaneous type of installations, the rate of flow depends upon the size of the unit. For domestic use two main size are in general use:

a) a sink type of heater having a rate of flow of 4.54 litres/min, and

b) a bath type of heater having a rate of flow of 13.6 litres/min.

Both the types give water up to a temperature of 60°C.

5.7.5 *Hot Water Storge Capacity* — The size of the storage vessel is governed by the maximum short time demand of the domestic or industrial premises; depending on local conditions this shall be 50-75 litres at 60°C in a dwelling with a bath tub and 25 litres at 60°C for a shower or a tap (for bucket supply). The capacity of the storage vessel shall not be less than 20 percent in excess of the required maximum short time demand. In larger houses where a single hot water heater is supplying to more than one bath room or kitchen or both, the maximum short time demand shall be estimated and capacity decided accordingly. Small electric or gas storage heaters of 15-25 litres capacity may be used to supply one or two points of draw-off depending on type of use of hot water. Volume of hot water required for a bath, when hot and cold waters are mixed, is worked out in Example 5.

5.7.6 *Design of Storage Vessel* — In efficient storage water heaters, the hot water floats on the relatively cold water. This enables the hot water to be drawn-off even though a substantial quantity of cold feed water may have recently entered into the vessel.

Hot water storage tanks shall be oblong or cylindrical in shape and should be installed with the long side vertical in order to assist effective stratification or layering of hot on cold water. The ratio of height to width or diameter should not be less than 2 : 1. An inlet baffle should be fitted near the cold inflow pipe in order to spread the incoming cold water.

The material for the storage vessel should be resistant to chemical action of the water supplied to the heater. In general, tinned copper and certain other materials such as monel metal are suitable for most waters. The suitability of galvanized mild steel for storage tanks depends on the *p*H value of the water and the extent of its temporary hardness. For values of *p*H 7.2 or less, galvanized mild steel should not be used. For values of *p*H 7.3 and above, the galvanized mild steel may be used provided the corresponding temporary hardness is not lower than those given in Table 34.

TABLE 34 USE OF GALVANIZED METAL IN RELATION TO *p*H VALUE AND TEMPORARY HARDNESS OF WATER

*p*H Value	Minimum Temporary Hardness Required mg/l
7.3	>210
7.4	$\geqslant 150$
7.5	140
7.6	110
7.7	90
7.8	80
7.9 to 8.5	70

When water supplied is known to have appreciable salt content, galvanized mild steel vessels shall not be used. To minimize corrosion due to electrolytic action, each installation shall, as far as practicable, be restricted to one type of metal only such as all copper or all galvanized mild steel.

5.7.7 *Location of Storage Vessel* — The loss of heat increases in proportion to the length of pipe between the storage vessel and the hot water tap since each time water is drawn, the pipe is filled with hot water which then cools. The storage vessel shall, therefore, be so placed that the pipe runs to the most frequently used outlets are as short as possible.

5.7.8 *Thermal Insulation* — To ensure efficiency and economy in operation, the hot water storage vessel and pipes should be adequately insulated, wherever necessary, to minimize the heat loss. The whole external surface of the storage vessel including the cover to the handle should be provided with a covering equivalent, at least, to 75 mm thickness of thermal insulating material having a conductivity not exceeding 0.043 kcal/m²/h/°C/mm.

5.7.9 *Types of Hot Water Heaters*

5.7.9.1 *Heating in oven coil* — A more advanced and, at the same time, quite a simple device for obtaining hot water in small quantities is a heater coil installed in the kitchen stove that conveys hot water to a storage tank. The hot water storage reservoir is installed above the stove or under the ceiling. Coils made of steel tubing 38 to 50 mm in dia are used for heating water in stoves. Figure 17 shows a schematic drawing of hot-water supply with direct heating of water in open coil.

In open hot water supply systems in which the pressure is governed by the level of the water in an open tank, cold water from the external water main is conveyed by pipe (1) through globe valve (2) to small tank (3) and then by connecting pipe (4) to circulating pipeline (7) and heating coil (9). From the coil the hot water is carried by pipe (8) to hot water tank (5) and from there to hot water distribution pipeline (6).

5.7.9.2 *Heating by steam in a boiler* — There are more complex systems for delivering hot water heated in local plants. Figure 18 shows a schematic drawing of a hot water supply system which is connected directly to the external cold water main and is under the pressure head of the water in this pipeline. Steam from boiler (1) is conveyed by steam pipe (2) to coil (7) installed in boiler (5) connected to external water supply system (12) by pipe (8). On this pipe are fitted a non-return valve (10) and a shut-off valve (11). The non-return valve prevents hot water from boiler (5) from getting into external system (12) and the shut-off valve (11) makes it possible to cut-off the hot water system from the cold water system, should this be necessary. Hot water is conveyed to taps (3) and branch mains or risers (4) by distribution pipelines. The condensate from coil (7) is carried off to boiler (1) by pipe line (9).

5.7.9.3 *Gas water heaters* — These are more convenient and hygienic. They can be of the instantaneous or storage type. The instantaneous type may be multi-point supplying to more than one outlet or single-point supplying to one outlet only. The multi-point type may be connected to all hot water taps. When a tap is turned on, the flow

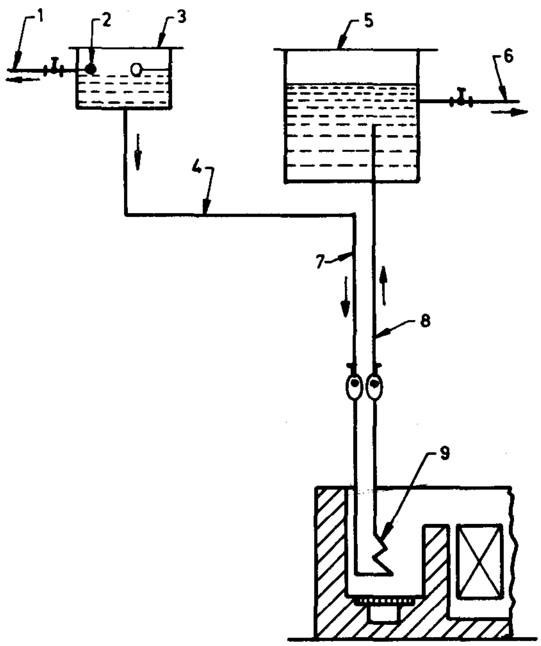


FIG. 17 SCHEMATIC DRAWING OF HOT-WATER SUPPLY WITH DIRECT HEATING OF WATER IN OVEN COIL

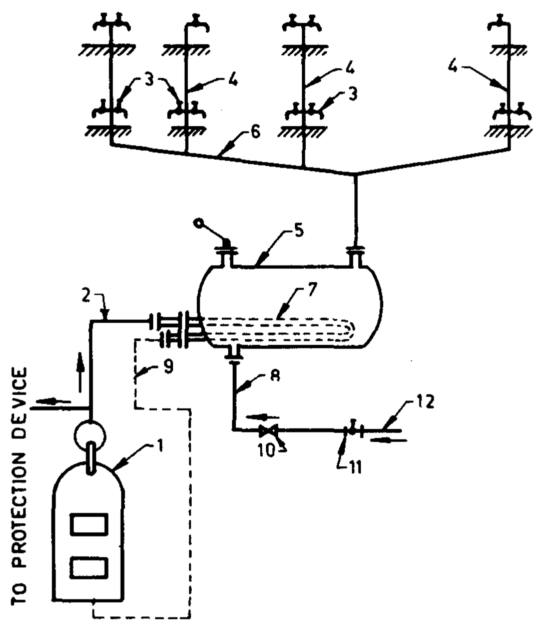


FIG. 18 SCHEMATIC DRAWING OF HOT-WATER SUPPLY WITH WATER HEATED BY STEAM IN A BOILER

of water opens the gas valve and the gas is ignited by the pilot flames. The cold water flowing through the appliance is heated immediately and the flow of hot water will continue as long as it is required. When the tap is turned off, the gas is extinguished except for the pilot jet. The quantity and temperature of water delivered per minute depends on the rate of flow of gas and its thermal properties and the rate of flow of water. A single-point instantaneous heater is controlled by a water tap on the inlet and the hot water outlet shall have an unobstructed discharge into the bath basin, sink, etc. The domestic storage type water heaters for use with LPG are governed by IS : 5115-1969.

In the storage type, water is heated and flows into the cylinder or tank until all the water is raised to a temperature between 60 and 65°C whereupon the gas rate is automatically reduced by a thermostat to that required to maintain the water at that temperature. When hot water is drawn from the cylinder or the tank, the thermostat valve opens and the full gas rate is resorted to until the incoming cold water has been heated.

Heaters of either type have an automatic water operated gas valve interlocking the gas and water tap.

5.7.9.4 *Electric water heaters*

a) As discussed in **5.7.3**, there are two kinds of hot water supply systems, namely, the instantaneous system and the storage system.

For residential buildings especially where there is an electric supply and a separate power line of sufficient carrying capacity to supply the needs of household electrical gadgets such as air-conditioning unit, an electric motor for pumping water from a ground level reservoir to an overhead reservoir, an electric hot plate for cooking, an electric iron for pressing clothes, an electric motor to run the frigidaire, an electric motor to run a wet or dry grinder, an electric motor for working a sewing machine and other electrical domestic appliances, a water heater of the instantaneous type can be adopted with advantage if the hot water supply is needed at one point. If the supply is needed at a number of points, storage system is to be preferred. The storage tank can be heated by an electric immersion heater. In the instantaneous type, as in the case of gas heaters, the control is by the inlet valve and the hot water outlet has an unobstructed discharge into the wash basin or tank, etc.

In the storage system, there are the following four kinds of electric storage heaters. They are:

1) Non-pressure or open outlet type;
2) Pressure type;
3) Cistern type; and
4) Dual heater type.

In type (1), the shape of the storage heater is cylindrical or rectangular. This type is controlled by a stop valve situated on the inlet pipe by heater. It may be fed directly from the water main of the undertaking or fed from a cistern. A non-return valve shall be fitted in the inlet pipe to prevent backflow of hot water into the cold water mains. In type (2), water heaters shall not be connected directly to the water mains but to the cisterns placed at an appropriate height. The heater is generally cylindrical in shape. In type (3), the shape of the storage heater is normally cylindrical or rectangular in shape as in type (1). It incorporates a feed tank with ball valve arranged for direct connection to the water main. An overflow arrangement is also provided. Type (4) is a displacement water heater having two heating units, one towards the top and the other near the bottom, the unit being independently controlled. The shape is generally cylindrical. The unit is provided with two heaters each controlled by a thermostat, one placed near the top of the tank is of low rating (usually 0.5 kW) to provide sufficient hot water for ordinary domestic use, the main heater of higher rating (usually 2.5 kW) is placed near the bottom of the tank and can be manually switched on before a bath is required. The complete unit as manufactured comprises a thermally insulated cylinder, electric heating element, thermostats and pipe connections.

b) The rated input of heater in kW for storage heaters of various rated capacity (in litres), as recommended in IS : 2082-1978, shall be as follows:

Rated Capacity in Litres	*Recommended Input in* kW
6	1
10	1
15	1
25	1
35	1.5
50	2
70	2
100	3
140	4
200	5

NOTE — For dual hot water heaters, the rated input includes the ratings of both the elements.

The instantaneous electric water heaters should conform to IS : 8978-1978.

c) If a domestic storage vessel is to be adopted to electric heating by an immersion heater and thermostat, the following recommendations shall be observed:

1) The immersion heater should be mounted with its axis horizontal.

2) In a tank with a flat bottom, a space of not less than 75 mm below the immersion heater and 50 mm below the cold feed connections shall be provided to allow for accumulation of sludge and scale and where it will not affect the working of the immersion heater.

3) In cylindrical storage vessel with inwardly dished bottom, the inlet pipe shall be arranged so that the incoming cold water is not deflected directly into the hot water zone. The lowest point of the immersion heater shall be 25 mm above the centre of the cold feed inlet which, in turn, is usually 100 mm above the cylinder rim.

4) Where the thermostat does not form an integral part of the immersion heater, it shall be mounted with its axis horizontal, at least 50 mm away from and not lower than the immersion heater.

5) In the case of the dual heater installation, one heater and its thermostat should be installed at a low level as indicated in (2) and (3). The second heater and its thermostat shall be similarly installed in the upper half of the cylinder at a level depending on the reserve of hot water desired for ordinary domestic use. The bottom heater shall be under separate switch control.

6) Adequate clearance shall be provided between the tank and the cubboard door or walls to allow the convenient insertion, adjustment of the immersion heater and thermostat, and to give space for thermal insulation.

5.7.10 *Cold Water Supply to Heaters*

5.7.10.1 *General* — A storage water heater (pressure type) shall be fed from a cold storage tank and under no circumstances connected directly from the water mains, excepting the type which incorporates a feed tank with ball valve and overflow pipe arrangement (cistern type heaters) or non-pressure type heaters.

5.7.10.2 *Storage cisterns*

a) The storage capacity of a cold water tank shall be at least twice the capacity of the hot water heater. The capacity of the storage tank may, however, be one and a half times when the number of heaters connected to one common tank exceeds ten.

b) The cold water storage tank for supply to hot water heaters shall be a separate tank, if practicable. In case of a common tank which also supplies cold water to the fixtures, this cold water supply connection shall be so arranged that 50 percent of the net capacity worked out as in (a) shall be available for supply to the hot water heaters.

c) In case of multi-storeyed buildings where a common overhead tank over the stair/lift well is generally installed, it is advisable to have one or more local tanks for supply to the hot water heaters. This arrangement shall help in reducing the length of the vent pipes.

d) In tall multi-storeyed buildings where the static pressure increases with the height, the total static water pressure on the hot water heaters on the lowest floor shall not exceed the rated working pressure of the hot water heater installed. Should the height of the building so require, additional tanks shall be provided on the intermediate floors to restrict the static head to permissible limits.

e) As an alternate to arrangements stated in (c) and (d), an individual storage tank in each flat may be provided for supply to hot water heaters.

5.7.11 *Piping Systems for Hot Water Supply*

5.7.11.1 *General* — Hot water piping can be laid out as a pressure system in which the pressure is provided from a source outside the building or the pressure may come from a tank open to the atmosphere and located at a high point in the building. In each of these systems, the piping may depend on non-continuous circulation by gravity or continuous gravity circulation without the use of a circulating pump or forced circulation with a pump. The main features of the systems are as follows:

a) The pumping system is simple requiring less pipe than the tank system.

b) In the tank system, no pressure can be built-up to cause an explosion.

c) Non-continuous circulation requires the least amount of piping but cold water may be drawn for sometime before hot water reaches the tap and heat is lost from hot water standing in the pipe. A non-continuous layout should not be used where the hot water pipes are long and there are numerous fixtures to be served. It is satisfactory only for short pipes between the heater and the hot water tap.

d) Continuous gravity circulation should be used where non-continuous circulation is unsuitable. However, it is not suitable for more than 2 or 3 storey buildings or for more than 2 or 3 apartments.

e) Continuous forced circulation can be used satisfactorily for the largest installation.

5.7.11.2 *Hot water pipe layouts*

a) In laying hot water piping systems, the pressures of the hot water and cold water should be made equal at each fixture, especially where mixing taps are to be used. Otherwise, there is the possibility that the higher pressure water will force itself into the lower pressure supply when the mixing tap is opened to both supplies. Commonly the hot water pressure is lower than that of the cold water owing to the more circuitous route followed by the hot water. This difficulty can be partly overcome by the use of larger and smoother pipes and long radius fittings on the hot water lines. On the other hand, sudden demands for cold water as by flush valves may so reduce the cold water pressure as to draw hot water into the cold water pipes. Such conditions can be avoided by an analysis of the systems to balance the head losses in each supply.

b) The hot water distributing system shall be so designed that the hot water runs quickly at the draw-off taps when opened to avoid the running to waste of an undue amount of water which has cooled while standing in the pipes when the taps are closed. With this end in view, a secondary circulation system with flow and return pipe from the hot water tank shall be used where justified. Whether such a system is used or not, the length of pipe to a hot water draw-off tap measured along the pipe from the tap to the hot water tank or the secondary circulation pipe shall not exceed the lengths given in Table 35.

TABLE 35 MAXIMUM PERMISSIBLE LENGTH OF HOT WATER DRAW-OFF PIPE

Sl No.	Largest Internal Diameter of Pipe mm	Length m
i)	Not exceeding 20	12
ii)	Exceeding 20 but not exceeding 25	7.5
iii)	Exceeding 25	3.0

NOTE — In the case of a composite pipe of different diameters, the largest diameter is to be taken.

c) When circulation is maintained by gravity, the following principles should be considered in design:

1) Hot water pipes should rise continuously from heater to taps or faucets. Only return-circulating water should descend. Exceptions to this rule permit a short descending spur from a riser pipe to a single fixture and in a multi-storey building a few fixtures on each floor may be supplied from the descending return pipe.

2) The riser pipe should have two or three times the cross-sectional area of the return pipe and no riser should be less than 20 mm in diameter, if of galvanized iron.

3) Riser pipes should rise continuously to the highest point in the system and return pipes should descend continuously to the bottom of the heater as shown in Fig. 19 or into the storage tank.

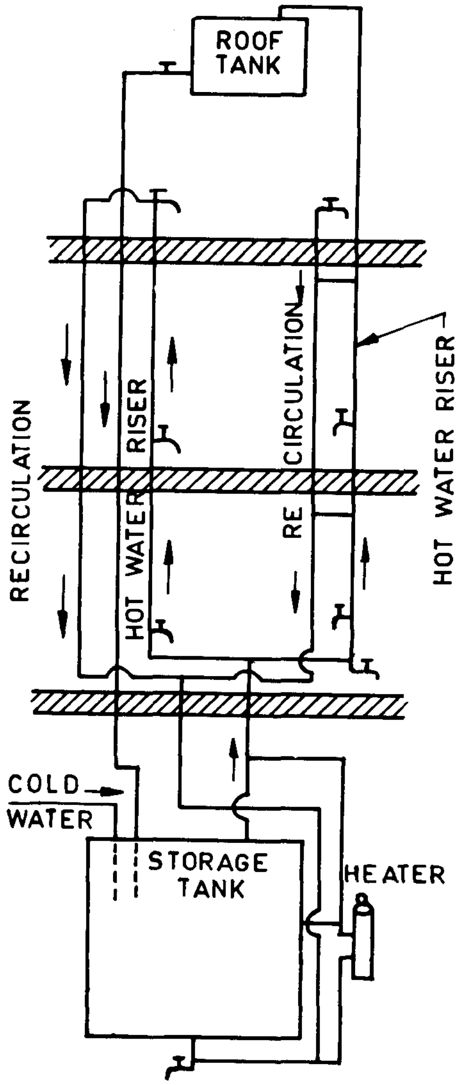


FIG. 19 HOT-WATER DISTRIBUTION AND CIRCULATION ONE HEATER AND STORAGE TANK, TWO RISERS AND A ROOF TANK

4) Multiple circulating loops connected to the same heater must be designed with approximately equal head differential from all causes. Otherwise the flow of hot water will be uneven among the loops. The condition can be remedied by the adjustment of valves by trial at the base of each riser or it can be avoided by proper design before the pipes are installed.

5) Air relief should be provided at the high point or points in the form of an air-relief valve, a tap or in a tank system, a pipe connected at the high point or points and terminating with an open end above the highest water level in the tank.

6) Provision must be made for washing water which may escape from the air-relief valve in the form of an indirect waste. Since the water may be scalding, there should be protection against possible injury.

5.7.11.3 The velocity of flow of water in the circulating pipes depends on the difference in weight of the water in the riser and the return pipes. The weight of a column of water can be formulated as:

$$W = HS$$

where

W = weight of column of water one square cm in cross-section in g,

H = height of column in cm, and

S = specific gravity of water at the particular temperature as given in Fig. 20.

The head of water causing flow is:

$$H_1 = \frac{H_a S_a - H_b S_b}{W_r}$$

where

H_1 = head of water causing flow in cm,

H_a and H_b = heights respectively in cm,

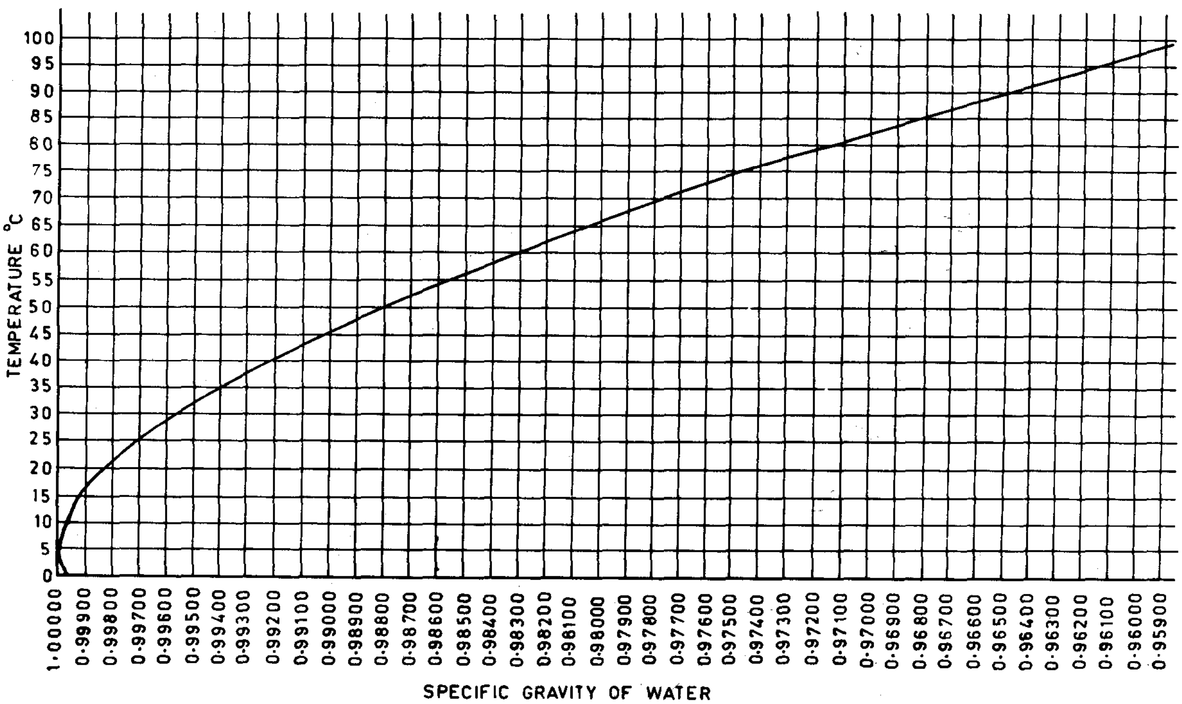
S_a and S_b = specific gravity respectively of water columns in riser and return pipes, and

W_r = weight of one cubic cm of water at average temperature in the two pipes in g.

The volume of flow will be $\sqrt{2gH_1}$

where g is acceleration due to gravity usually taken as 980.7 cm/s^2.

5.7.11.4 The tank in a tank distribution system should be placed as reasonably high as possible, above the water heater to assure good water pressure and to avoid a vapour lock due to the combination of steam and low pressure in the supply pipe.



(MASS OF 1cc OF WATER AT 4°C IS TAKEN AS UNITY)

FIG. 20 SPECIFIC GRAVITY OF WATER AT VARIOUS TEMPERATURE

5.7.11.5 When circulation is forced by a circulating pump, the capacity of the pump can be determined by dividing the total estimated heat losses or requirements expressed in calories per minute by 5.5 on the assumption that the return water is 5.5°C cooler than in the heater. The quotient will give the grams of water to be circulated per minute. The head pumped against should be 0.35 kgf/cm^2 greater than the cold water pressure and to this should be added the friction loss in the pipes.

5.7.11.6 A non-circulating supply is unsatisfactory in a tall building because of the length of piping involved. Well-balanced gravity or forced circulating systems must be provided. It is usual to provide water heaters for each floor separately fed by common water tanks serving about 7 or 8 floors each, especially when electric water heaters are employed.

5.7.12 *Hot Water Piping*

5.7.12.1 *General* — The materials used for the pipes should be resistant to the chemical action of the water used in the pipes. In general, tinned copper and certain other materials such as monel are suitable for most waters. The use of galvanized mild steel pipes is governed by the *p*H value of the water as in the case of material of the storage vessel detailed in **5.7.6**. Lead should not be used for hot water because it dissolves too rapidly and it softens so much that at higher temperatures it is not safe, particularly at the joints, from internal pressure. Loss of heat can be reduced by covering the pipes with insulation, sometimes called 'lagging'. A valuable effect of insulation is to minimize expansion and contraction. Insulating materials include asbestos, wool felt, magnesia, cork, etc. The asbestos covering is usually 25 mm thick to give satisfactory results.

5.7.12.2 *Vent pipes* — Each pressure type hot water heater or cylinder shall be provided with a vent pipe of not less than 20 mm bore. The vent pipe shall rise above the water line of the cold water tank by atleast 15 + 1 cm for every 30 cm height of the water line above the bottom of the heater. The vent shall discharge at a level higher than cold water tank and preferably in the cold water tank supplying the hot water heaters. Care shall be taken to ensure that any accidental discharge from the vent does not hurt or scald any passer-by or persons in the vicinity.

The vent pipe shall be connected to the highest point of the heater vessel and it shall not project downwards inside it as otherwise air may be trapped inside, resulting in surging and consequent noises.

At no point, after leaving the vessel, shall the vent pipe dip below level of the connection.

A vent pipe may, however, be used for supply of hot water to any point between the cold water tank and the hot water heaters.

Vent pipe shall not be provided with any valve or check valves.

5.7.12.3 *Hot water delivery pipe* — The common hot water delivery pipe shall leave the hot water heater near its top and shall be of not less than 20 mm bore generally and not less than 25 mm, if there are hot water taps in the same storey as that on which the hot water heater is situated.

Whenever mixing of hot and cold water is done by a mixing fitting, that is, hot and cold stop cocks delivering to a common outlet of mixed water (that is, showers, basin or bath supply fittings), the pressure in the hot and cold water system shall be equal. This can be achieved by connecting the cold supply from an overhead tank at the same static height as the overhead tank supplying cold water to the hot water heaters. In case this is not possible, hot and cold water should be supplied to the fixtures by separate supply taps.

Hot water taps shall be of types causing minimum friction or alternatively oversized tap may be provided such as 20 mm tap on a 15 mm pipe.

5.8 Pumping of Water

5.8.1 *Purpose of Pumps* — If the source of water is at a lower elevation than the points of delivery, the water has to be lifted or pumped. Pumps are also required to boost the pressure in a system to enable the supply being made to higher elevations. Pumps are needed to force the water through treatment units, to drain settling tanks and other units, and to operate equipment for pumping chemical solutions to treatment units.

5.8.2 *Types of Pumps* — Based on the mechanical principles involved, pumps may be classified as:

a) displacement pumps (reciprocating, rotary and chain pumps);

b) velocity pumps (centrifugal, turbine and jet pumps);

c) buoyancy pumps (air lift pumps); and

d) impulse pumps (hydraulic rams).

Of these the centrifugal and reciprocating pumps are the popular ones. Hand pumps are used for domestic and small public water supplies. Pumps are also classified as lift or suction or force pumps according to the nature of pumping.

5.8.3 *Prime Movers* — The prime movers to operate the pumps are generally steam engines, internal combustion engines and electric motors. Steam engines are going out of use on account of the large initial cost for the bulky installation of boilers, engines, etc. and the scarcity of two fuels — oil and coal. Electrical and internal combustion engines are more commonly used though water power and wind power also find use in specific circumstances.

In the case of large pumping stations where electrical power is available to run motors, standby oil engine sets are also used to prevent interruption in water supply during failure of electric power supply. Manual power is used for operating hand pumps. Animal power is also used in rural parts where animal power is easily available.

5.8.4 *Suction Pumps* — The depth from which water may be raised by an ordinary suction pump is limited to the ability of the pressure of the atmosphere to support a column of water in a vacuum.

When the barometer stands at 762 mm of mercury, the height of water column will be 762 × 13.6 (specific gravity of mercury) = 10.36 m.

A pump will, however, not work at this theoretical height. Allowances must be made for: (a) variations in atmospheric pressure, (b) lowering of water level in the well or pump wherefrom it has to be lifted and (c) the efficiency of the pump which is never cent percent and variation in the power supplied. A total allowance of atleast 2.44 m must be made for these. Thus 7.93 m is the maximum height at which a pump can be expected to work satisfactorily at all times. However, the suction lift of an average pump is limited to a maximum of 4.5 m especially with centrifugal pumps. Figure 21 gives the practical suction lift for various atmospheric pressures and for different types of pumps. The possible suction lift will decrease about 1.1 m for every 10°C increase in water temperature above 15.5°C. If the water is at a greater depth than this below the surface, a 'suction and lift' pump (often improperly called a lift and force pump) must be installed within 7.93 m of the water, preferably within 4.5 m. A delivery pipe may be taken from this to the required point of discharge.

5.8.5 *Power Required for Pumping* — Capacity of pumps is usually expressed in terms of litres per minute. Computation of the power required to drive a pump necessitates knowledge of the amount of water pumped and the total head pumped against. The total dynamic head includes the actual lift between the water level at the intake and the level of the elevated tank which receives the water plus the velocity head and the friction head overcome in the process, all expressed in metres of head of water.

1 m head of water = 0.1 kgf/cm2 of pressure
1 kgf/cm2 = 10 m head of water

The actual lift includes: (a) the discharge head H_d and (b) the suction head H_s (positive pressure) or the suction lift (negative pressure) or vacuum and

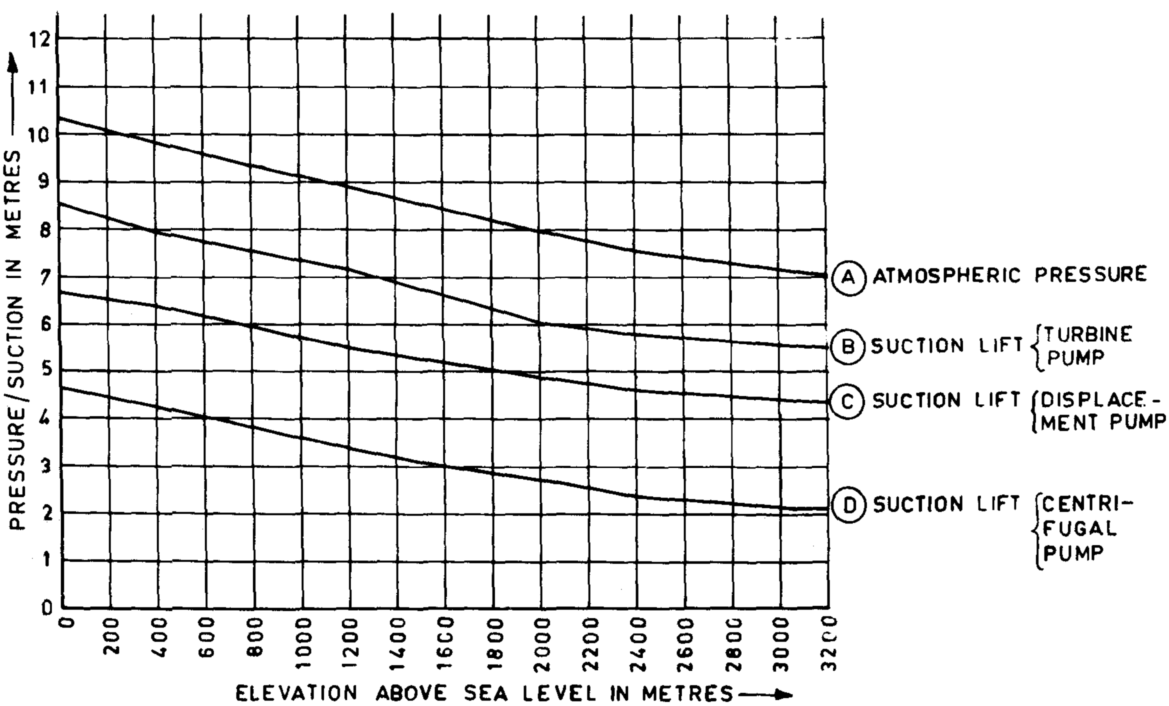


FIG. 21

the difference in elevation between the suction and discharge gauges d

Lift $= H_d - H_s + d$ (if H_s is positive)

$= H_d + H_s + d$ (if H_s is negative or vacuum).

The CGS unit of work is that required to raise 1 g weight or 981 dynes through 1 cm and is equal to 981 ergs. The power is the rate of doing work. The unit is 1 watt and is the power required working at 1 joule/second (1 joule $= 10^7$ ergs when 1 litre of water is pumped per minute against a head of h metres, the theoretical or the water power required:

$$= 1 \times 1000 \text{ g} \times h \times 100 \text{ cm}$$

$$= 1h \times 10^5 \text{ g cm/minute}$$

$$= 1h \times 10^5 \times \frac{981 \times 10}{60} \text{ joules/s}$$

$$= 0.163\,51\ h \text{ watts}$$

The actual power is obtained by dividing this theoretical or water power by the efficiency of the pumping set which is n of pump $\times$ n of motor).

1 hp = 746 watts

or 1 kW = 1.34 hp

Power developed in watts

$= EI$ (for direct current E in volts and I in amperes)

$= EI \cos \phi$ (for alternating current, E in volts and I in amperes, $\cos \phi$ = power factor)

5.8.6 *Reciprocating Piston Pumps* — These are the most common type of constant displacement pumps. They use the up and down or forward and backward (reciprocating) movement of a piston or plunger to displace water in a cylinder. The flow in and out of the cylinder is controlled by valves. These pumps are manufactured in both the surface and deep well types and may be manually or engine operated. A manually operated surface-type piston pump is commonly known as a pitcher pump. These are useful to lift waters from a sump or cistern or dug wells where there is but little or no suction lift and the elevation of the discharge point is not higher than the point of application of power. These pumps must be primed at each use unless the moving plunger or diaphragm fits snugly or is submerged. Single stroke or single acting pumps will deliver water on one stroke only, usually the upstroke of the moving valve in the pump. This results in an intermittent flow of water from the pump and an uneven application of power during one complete operation. In a double acting pump, water is drawn into and discharged from the pump in both the upstroke and downstroke. Capacities of hand operated reciprocating pumps cannot be expected to exceed 20 litres per minute which gets reduced as the lift increases. Power driven reciprocating pumps are available in large capacities with the discharge pressures limited only by the strength of the parts of the pump and the power available. If the discharge valve of a reciprocating pump is closed during operation, pressure relief should be provided to avoid damage to the pump or motor. An air chamber can be used in the discharge pipe of a reciprocating pump to diminish fluctuations in the rate of flow and to minimize water hammer. The capacity of air chamber should be about 3 times the volume of water discharged on the upstroke of this pump. Air must occasionally be supplied to the chambers as it dissolves in or is carried away by the water. Air can be admitted to the chambers by draining them when the pump is not operating or by opening a small valve on the suction side of the pump when the pump is operating. The air admitted in this manner is caught in the air chambers. Power driven reciprocating well pumps are not often used because of superior characteristics of centrifugal jet and air-lift pumps. They are, however, particularly suited to the pumping of small quantities of water against high heads. Small reciprocating well pumps are used because of availability, relatively low initial cost and suitability for hand operation.

5.8.7 *Hand Pump or Pitcher Pump* — For small pumping installations, the manpower is usually employed to operate pumps to lift water from wells to a ground level storage tank or for direct delivery at ground level itself. A manually operated surface type of piston pump, as already mentioned, is known as a pitcher pump.

A pitcher pump operates as follows. When the handle is pressed down, the plunger rises. The plunger fits closely to the walls of the cylinder with the aid of a 'cup' washer which could be changed at intervals. In the piston there is a central 'poppet' valve that lifts bodily during the downward stroke of the piston and is kept tight against the seat by the pressure of water above during the upward stroke. The water-tightness is ensured by a circular washer fitted to the underside of the valve. The upward stroke of the piston, that is, when the handle is pressed down, the water collected above the poppet valve in the cylinder is forced out through the spout. At the base of the cylinder is 'swing check valve' which is weighed at the centre. During upward stroke, the vacuum created below the poppet valve opens the swing check valve upwards allowing the water to rise into the cylinder. During downward stroke of the piston, this swing check valve is pressed tight on to its seat and the water collected above is forced out through the poppet valve which is lifted up by the water flowing through it and the process is continued. In the maintenance of these pumps, difficulty is sometimes caused by the wearing of the cup washer in the moving plunger, by leakage through the valves or by the catching of some object in the pump so as to hold the valve open. When this happens, the pump will not prime itself. They can be primed by filling the pump barrel with water so as to cover the moving plunger or the packing and valves can be repaired to make the pumps self-priming. Shallow well hand pumps should conform to IS : 8035-1976 and deep well hand pumps should conform to IS : 9301-1982.

5.8.8 *Air Lift Pump* — Air lift pump is an apparatus for raising water from wells through a discharge or reduction pipe extending from the surface of the ground downward within the well to proper depth to secure the greatest efficiency. Compressed air is conducted through an air pipe downward within the well and discharged into the foot piece at or near the bottom of the reduction pipe so as to mix air with the water in small or large bubbles. The compressed air enters the discharge pipe near the bottom at a pressure only slightly above hydrostatic pressure. The column of water within the discharge pipe moves upward. The air bubbles continue to expand until the outlet is reached and atmospheric pressure prevails. The mixture of air with the water lessens its specific gravity and since it is lighter than the column of water outside the reduction pipe, it moves upward.

A section through an air lift is shown in Fig. 22.

The various terms indicated in Fig. 22 are defined below:

a) *Depth of water table* — The normal water level in well, when not pumping, measured from surface of ground.

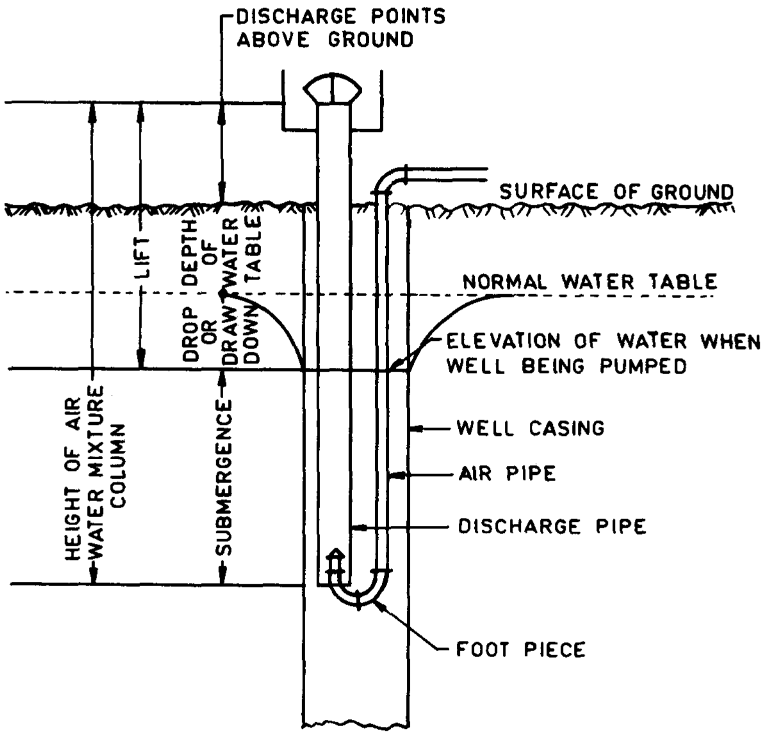
b) *Drop or drawdown* — The depression in the water table when well is being pumped.

c) *Lift* — The distance the water is elevated from level in well when pumping to the point of discharge.

d) *Submergence* — The distance below the pumping level at which air is admitted to the foot piece at or near the lower end of the discharge pipe.

e) *Height of air water mixture column* — The distance from the point air is introduced to the point of discharge on top.

Submergence practically governs the starting and the working pressure required. Maximum efficiency is secured when the submergence is nearly 2.25 times the 'lift', being low for low lifts and high for high lifts. The relation between submergence and lift may also be expressed as



SECTION THROUGH AN AIR LIFT

FIG. 22

some percent of the total distance between the level of the foot piece and the point of discharge. This varies from 40 percent for lifts of 122 m (400 ft) to about 65 percent for a lift of 15 m (50 ft).

Air-lift pumps are used principally in wells with capacities greater than 100 litres per minute. In general, the greater the capacity of an air lift, the greater its efficiency. Air-lift pumps have the advantage over all other types of pumps except possibly the deep well jet pump, in the simplicity of their parts and in their freedom from moving parts in the well.

They are able to discharge more water from a well than any other type of pump that can be placed in the well, provided there is water available in the ground. They give long service, low maintenance cost and reliability. However, they usually necessitate digging the well deeper than otherwise would be needed because of the submergence required at the end of the air pipe. If water must be raised to an appreciable height above the ground surface, additional pumping equipment is desirable at the surface since the air lift is not suitable for the discharge of water under pressure. The aeration of water may increase its corrosiveness or it may be advantageous by precipitating dissolved minerals such as iron from the water. The air lift is specially suited to wells of small diameter which are crooked and prevent the use of rods or shafting in the well, and where the water has to be lifted more than 60 m and where the water contains much sand. If should discharge to vertical piping only as in horizontal or even inclined piping, the air in the air-water mixture separates or tends to pass along the upper side of the pipe, thus permitting water in the lower part to lag or decrease in velocity or even slip back.

5.8.9 *Centrifugal Pumps*

5.8.9.1 *General* — Centrifugal pumps are of several types depending upon the design of the impeller. Water is drawn through the suction pipe into the pump casing and rotated in the pump by an impeller inside the pump casing. The energy is converted from velocity head primarily into pressure head. In the submerged vertically driven turbine type pump or line shaft pump used to pump water out of a well, the centrifugal pump is in the well casing below the water level in the well, and the electric motor is at ground level. If the head against which a centrifugal pump operates is increased beyond that for which it is designed and the speed remains the same, then the quantity of water will decrease. On the other hand, if the head against which a centrifugal pump operates is less than that for which it is designed, then the quantity of water delivered will be increased. This may cause the load on the motor to be increased and hence the overloading of the electric motor, unless the motor selected is large enough to take care of this contingency. Sometimes two centrifugal pumps are connected in series so that the discharge of the first pump is the suction for the second. Under such an arrangement, the discharging capacity of the two pumps together is only equal to the discharging capacity of the first pump but the head will be the sum of the discharge heads of both pumps. Doubling the speed of a centrifugal pump impeller doubles the quantity of water pumped produces a head four times as great and requires eight times as much power to drive the pump. In other words, the quantity of water pumped varies directly with the speed, the head varies as the square of the speed and the power as the cube of the speed. It is the usual practice to plot the pump characteristic curves for the conditions studied on a graph to anticipate operating results. The centrifugal pump has no valves or pistons. There is no internal lubrication. It takes up less room and is relatively quiet. A single-stage centrifugal pump is generally used where the suction lift is less than 4.5 metres and the total head not over 60 metres. For higher heads, a pump having two or more stages or two or more impellers or pumps in series should be used as they are more efficient than the single-stage pumps. The efficiency of centrifugal pumps varies from about 20 to 85 percent, the higher efficiencies are realized with pumps of capacity 2 250 litres/min. The pecularities of the water system and effect they might produce or pumping cost should be studied from pump characteristic curves. Horizontal centrifugal for clear, cold, fresh water should conform to IS : 1520-1980. Self-pruning centrifugal pumps should conform to IS : 8418-1977.

5.8.9.2 *Submersible pumps* — When the power source, that is, the electric motor is fitted immediately below the pump and submerged with it in the water, the pump is called a submersible pump. Shafts in these pump sets extend only from the submerged motor to the top most impeller. There is no shaft between the pump and the ground surface as is necessary in deep well turbine or line shaft pumps. This feature provides submersible pumps with one of their more important advantages over line shaft or vertically driven deep well turbine pumps. Further, unlike line shaft pumps, no separate pump houses are necessary. The operation of the motor at a depth of several metres in the well also considerably reduce noise levels. The entire pump and motor must, however, be withdrawn to effect repairs and service the motor. The need to do so, however, arises very infrequently. Submersible pumps should conform to IS : 8034-1976.

5.8.9.3 *Jet centrifugal pumps* — These are also called water-ejector pumps. This pump is actually a combination of a centrifugal pump and a water ejector down in a well below or near the water level. The pump and motor can be located some distance away from the well but the pipelines should slope up to the pump in an upward gradient of 1 in 160. In this type of pump, part of the water raised is diverted back down into the well through a separate pipe. This pipe has an upturned ejector or nozzle attached to it at the bottom and a venturi connected to a discharge riser pipe which is open at the bottom. Water from the centrifugal pump coming under a pressure is converted into velocity energy in a nozzle and this high velocity jet of water from the nozzle is forced through a venturi. The venturi is fitted concentric to the nozzle in the jet body. The movement of the nozzle jet within the venturi creates a partial vacuum within the venturi annular space. This entrains the external liquid in the well through a foot valve along a separate path in the jet housing into the annular space surrounding the venturi area. The entrained water is accelerated up to the throat or the straight portion of the venturi along a converging path. The entrained water gets a portion of the nozzle water energy as kinetic energy. This mixing process occurs within the straight portions of the venturi called the 'throat'. During the mixing process, much energy is lost due to eddies or turbulance. The kinetic energy in the entrained water is converted into pressure energy for lifting the water from the jet pumps up to the centrifugal pump suction. The efficiency of a jet pump alone is about 30 to 40 percent. When the net jet pump head is only about 80 percent of the driving centrifugal pump head, the efficiency of the system is roughly 90 percent of the centrifugal pump efficiency. When the net jet pump head is equal to the centrifugal pump head, the overall pump efficiency is about 50 percent of the centrifugal pump efficiency alone. Thus it is seen that when the delivery head is more and more compared to the suction lift of the system, the greater is the overall efficiency.

It is reported that jet centrifugal pumps give very good service compared to submersible pumps especially for 10 cm bores.

5.8.10 *Hydraulic Rams* — A hydraulic ram is a type of pump where the energy of water flowing in a pipe is used to elevate a smaller quantity of water to a higher elevation or in other words the pump is actuated by water hammer created in the drive pipe. An air chamber and weighted check valve are an integral part of a ram. Hydraulic rams are suitable where there is no electricity and the available water supply is adequate to furnish the energy necessary to raise the required quantity of water to the desired level. Double acting rams can make use of a non-potable water to pump a potable water. The minimum flow of water required is about 10 litres per minute with a minimum fall of 1 metre. A ratio of lift to fall of 4 : 1 can give an efficiency of 72 percent, a ratio of 8 : 1 can give an efficiency of 52 percent, a ratio of 12 : 1 an efficiency of 37 percent, and a ratio of 24 : 1 an efficiency of 4 percent. Rams are known to operate under supply heads up to 30 metres and a lift or delivery heads up to 150 metres. In general, a ram will discharge from 1/7 to 1/10 of the water delivered to it. In general, the length of the drive pipe is about 7 times its fall, it may vary between 5 and 10 times depending on conditions of delivery. From a practical standpoint, it is found that the drive pipe conducting water from the source to the ram should be atleast 9 to 12 metres long for the water in the pipe to have adequate momentum or energy to drive the ram. It should not, however, be on a slope greater than about 12° with the horizontal. The diameter of the delivery pipe is usually about one-half the diameter of the drive pipe. Where the drive pipe is too long, pressure relief may be provided by the installation of an impulser. This consists of a standpipe or closed air chamber which allows water that is above it in the drive pipe to run into the impulser, when water hammer is created in the drive pipe between the impulser and the ram. During the next cycle, the impulser will return water to the drive pipe. The delivery pipe may discharge into a storage reservoir with provision made for overflow. The rate of discharge from a ram can be controlled by adjusting the cycle rate. The cycle or the number of strokes per minute can be varied between 40 and 300, the more rapid the strokes, the lower is the rate of discharge and the less the amount of water wasted in the operation of the ram. The higher the lift, the greater is the ratio of water wasted to water lifted.

5.8.11 *Windmill Pumps* — Windmills are used for driving well and cistern pumps of relatively small capacities. The wind power offers a cheap power, next to manpower for operation of small pumping plants. Windmills usually require the availability of winds at sustained speeds of more than 8 kilometres per hour. Towers are normally used to raise the windmills 5 to 7 metres above the surrounding obstacles in order to provide a clear sweep of wind to the mills. Windmills usually drive reciprocating pumps through a connection of the pump rod from the mill to the piston rod of the pump. Provision may also be made for pumping by hand during long periods of relative calm. It is good practice to provide adequate elevated storage to maintain the water supply during periods when there is insufficient wind. Windmills are normally manufactured in sizes expressed in terms of the diameters of their wheels. The operation and maintenance costs of windmills are usually very negligible and strongly influence their use in communities whose financial resources are inadequate to operate and maintain motor or engine driven pumps.

The effect of wind at various velocities on windmills is given in Table 36.

5.8.12 *Priming of Pumps* — Priming is the name given to the process by which water is added to a pump in order to displace any air trapped in the pump and its suction pipe during shut down periods. In other words, priming results in a continuous body of water from the inlet eye of the pump impeller downward through the suction pipe. Without the continuous body of water, a centrifugal pump will not deliver water after the engine or motor has been started.

TABLE 36 EFFECT OF WIND VELOCITIES ON WINDMILLS

(*Clause* 5.8.11)

VELOCITY OF WIND km/h	DESCRIPTION OF WIND	EFFECT ON WINDMILL
5	Calm	Will not move
13	Light air	Just starts
21	Light breeze	Pumps well
29	Gentle breeze	Excellent work
37	Moderate breeze	Excellent work
45	Fresh breeze	Maximum results
54	Strong breeze	Too fast, the windmill would be thrown out of service

Positive displacement type of pumps are less affected and need priming only to the extent necessary to seal leakage past pistons, valves and other working parts.

Many devices and procedures used in obtaining and maintaining a primed condition in pumps generally involve one or a combination of the following:

a) a foot valve to retain water in the pump during shut down periods;

b) a vent to permit the escape of trapped air;

c) an auxiliary pump or other device (pipe from an overhead tank) to fill the pump with water; and

d) use of a self-priming type of construction in the pump, self-priming pumps usually have an auxiliary chamber integrated into the pump structure in such a way that the trapped air is exhausted as the pump circulates the priming water.

5.8.13 *Selection of Pumps* — The proper selection of a pump for installation at a well involves the consideration of several factors. The following are some of the more important factors which are to be emphasized as they are very often overlooked.

a) *Yield of the well* — There is no way of extracting more water from a well than that determined by its maximum yield.

b) *The pumping hours* — Consideration may be given to the use of several hours of storage capacity and a high pumping rate in order to keep the number of pumping hours as low as possible. The advantage of so doing should be weighed against the use of lower pumping rate for extended hours of pumping and the provision of lower storage capacity. The availability of electric power only during limited periods of the day or night would also influence the decision.

c) *The depth of the expected pumping water level below ground or the suction lift involved* — Having chosen a pumping rate, the expected draw-down in the well for that rate can be estimated by dividing it by the specific capacity of the well. Adding the depth of the static water table to this draw-down will give the depth of the expected pumping water level below ground. The fluctuations in the water during several seasons and the possible interference from other wells have to be taken into account.

d) *The type of pump (surface type or deep well type)* — The user of deep well pumps would be indicated where the depth to the pumping water level is 7.5 metres or more and the well is deep enough and large enough in diameter to accommodate a suitable pump. Surface type pumps will otherwise be used with limited pumping rates, if necessary.

e) *Total pumping head* — This includes the total vertical lift from the pumping water level to the point of delivery of the water and the total friction losses occurring in the suction and delivery pipes and the velocity head which is negligible in the case of small wells.

f) the comparative cost of purchase of the probable available alternatives, and the cost of maintenance of the pump sets. The availability of spares and the facility for repairs are the salient features of the pump. The cost of maintenance and operation may be capitalized and added to the cost of installation and the total costs compared with a view to select the cheapest alternative which may be checked in respect of other factors before a final selection is made.

5.8.14 *Selection of Power Source*

5.8.14.1 The cost of power can and often does constitute a major part of the cost of the pumping. The four main sources of power are manpower, wind power, electric motors and internal combustion engines.

5.8.14.2 *Manpower* — Manpower is, in many places, not only a cheap source but sometimes the only one available for operating pumps on wells. Its use is suited to individual water supply systems with small intermittent demands. Sometimes elevated storage is provided to maintain a continuous supply. The use of manpower is usually restricted to pumping rates not exceeding 45 litres per minutes and suction lifts of not more than about 6 metres. Hand pumps, such as pitcher pumps subjected to repeated use by the general public, can often have abnormal maintenance problems due to the fracturing of the hand lever and cylinder, and excessive wear of the inner wall of the cylinder particularly when water contains sand.

5.8.14.3 *Wind power* — As already stated in **5.8.11**, wind power is a cheap source of power for small community. Water supply systems based on wind power may be considered for places where winds are available at sustained speeds of 13 km/h. Maximum results are obtained at wind velocity of 45 km/h. When the velocity goes above 54 km/h, the windmill must be thrown out of service as otherwise it will be wrecked. The pumps used, when this power is used, are the reciprocating type of pumps. The towers are usually 5 to 7 metres high to provide a clear sweep of wind to the mills.

5.8.14.4 *Pneumatic power* — Air-lift pumps discussed in **5.8.8** use compressed air to raise water to ground level from deep wells. These are used where it is found economical to adopt them in preference to electrically driven or other pumps and for conditions peculiar to the borewell.

5.8.14.5 *Water power* — Hydraulically driven pumps such as water wheels are used where two water supplies are available, one of relatively poor quality but in large quantity and the other of good quality but possible restricted quantity. An hydraulic ram, actuated by water hammer created in drive pipe and discussed in **5.8.10,** is another example of water power being used for raising water. By these means, it is possible to discharge water at a higher pressure or to a higher elevation than is available in the water supply being used for power purposes. In hilly terrains, where perennial streams are available, the hamlets on the banks of the stream located at higher elevation may be supplied with water lifted from the stream flowing at a lower elevation. This power is cheap and maintenance cost is low.

5.8.14.6 *Internal cumbustion engines* — Internal cumbustion engines (gasoline, diesel or kerosine) are often used in areas where electric power is not available and other powers are not feasible. Diesel engines, though costly to instal, are generally the best from the point of view of operation and maintenance though they need more maintenance than electric motors and need a full time operator. They are usually constant low-speed units. They are used to drive reciprocating pumps. Gasoline engines are satisfactory as portable and standby power units. The initial cost is low but the operating cost is high. Good service is obtained if a regular routine maintenance programme is followed and a supply of spare parts is always available for these internal combustion engines.

5.8.14.7 *Steam power* — Steam power should be considered if pumps are located near existing boilers. The direct acting steam pumps can be used with advantage in such cases. Where exhaust steam is available, a steam turbine to drive a centrifugal pump can also be used.

5.8.14.8 *Electric motors* — Electricity, where available from a central supply at a reasonable cost, is to be preferred over other sources of power. It would, however, be unwise to instal electric generators simply to provide a supply for operating a small pump. Electricity's great advantage is the fact that it can be used to provide a continuous, automatically controlled supply of water. The power source must be reliable and not subject to significant voltage variation. Small electric motors are usually low in initial cost, require little maintenance and are cheap to operate.

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SECTION 6

DRAINAGE

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SECTION 6
DRAINAGE

6.1 General

6.1.1 The safe and protected water is supplied to the premises at the plumbing fixtures through a number of terminal fixtures. The drainage system commences within the premises at the plumbing fixtures, where the water that is supplied to them is used or washed and is then drained into the drainage pipes and finally into the public sewer or to an individual waste disposal system. Thus, in any building, there is both the beginning of the sewerage or drainage system and the termination of the water supply system. Sewage being water carrying body wastes must at some point receive the water of which it is composed. It is because water and waste must have a common meeting place in order to become sewage, that greatest caution must be exercised lest the continuous cycle of incoming water and the outgoing sewage is not reversed. The reversal of this cycle is possible due to the peculiar character of water and sewer systems. The water system is a closed system of pipes from the water main at the purification plant to the faucet in the premises and is under pressure. The sewer system is a closed system of pipes from the waste receptacle to the final disposal point either on land or into a body of water and the flow is gravitational or free flow and not under pressure as in the case of water supply pipes. More or less it can be said that where one system begins the other ends, and where one ends the other begins. Because of the close relationship of these two systems, they may even be considered as two parts of one large system, the water supply part being the in-going phase and the sewer part as the out-going phase. In order, for this system, to function adequately in so far as health is concerned, it becomes imperative that the direction of the cycle does not become reversed. The sewage disposal end must be guarded against sewage becoming water supply by treating sewage properly at disposal plants and treating water properly at purification plants. The water consuming end must be guarded against sewage entering the water supply. This could happen by the installation of plumbing which would allow the back flow of sewage into the water supply. The two systems must be kept open only at their terminals since, of the two systems joined each other at terminals into a closed system, any material increase in the pressure in the sewerage system or decrease in the water pressure in the water supply system could cause a reversal in the flow of the liquid and a contamination of water supply.

Also in the case of intermittent supplies, the possibility of the sewage leaking from sewers through joints and gaining access into the water supply mains at leaky joints has to be avoided. Safe and unsafe systems for water supply and sewerage are shown in Fig. 23.

6.1.2 *Systems of Drainage or Sewerage* — The liquid wastes collected within the premises consists of sanitary sewage; sullage or wastes from bath rooms, kitchen, washing places, etc, and storm or rain water. The storm water is either collected separately and taken to public storm water drains or sewers; or partly or wholly mixed with the sanitary sewage and taken into the public sewerage system.

If the storm water is completely excluded from the sanitary sewage, the sewerage system is called a separate system. If part of the storm water is mixed with the sanitary sewage, the sewerage system is called a partially separate system. If the storm water is completely mixed with the sanitary sewage, the sewerage system is called a combined system.

6.2 What is Contamination — Diseases like typhoid, cholera, diarrhoea, dysentery, hookworm and roundworm infestation, and jaundice are communicable from man to man through the medium of faeces. The faeces of persons suffering from these diseases should not be left exposed for flies to sit upon; or for being washed by rain into stream courses, the water of which are used for drinking; or to allow the eggs or worms present in faeces to be hatched in the soil. Diseases like cholera and typhoid are more serious while the worm infestation diseases are more mild in nature. Apart from cases where the persons suffering from these diseases will be well known, there are persons who harbour these pathogenic organisms without suffering from these diseases. Such persons, called carriers, are really dangerous to society. Instead of dealing with the faeces of such selected persons alone which is beset with difficulties, if the faeces of all persons are properly collected, conveyed and disposed off the chain of transmission will be cut and the diseases will not spread. In towns where the density of population is higher than in rural areas and where there are protected water supply systems, the construction of sanitary latrines is all the more imperative to prevent contamination of food, water and soil which may engulf the entire urban population in a preventable epidemic.

6.3 Ideal Sanitary Latrine (Water-closet) — The design of a sanitary latrine is to provide a safe and convenient place for defaecation and the system of collection, conveying and disposal of the faeces made absolutely safe and hygienic without offending the people employed in this behalf. The best method is, of course, the use of water-closets connected to a water carriage system of the town. In this method, each man's faeces are carried away quickly by flushing into the sewers and then to the final disposal works. Every town has to aim at providing a satisfactory water carriage system for the purpose along with its water supply

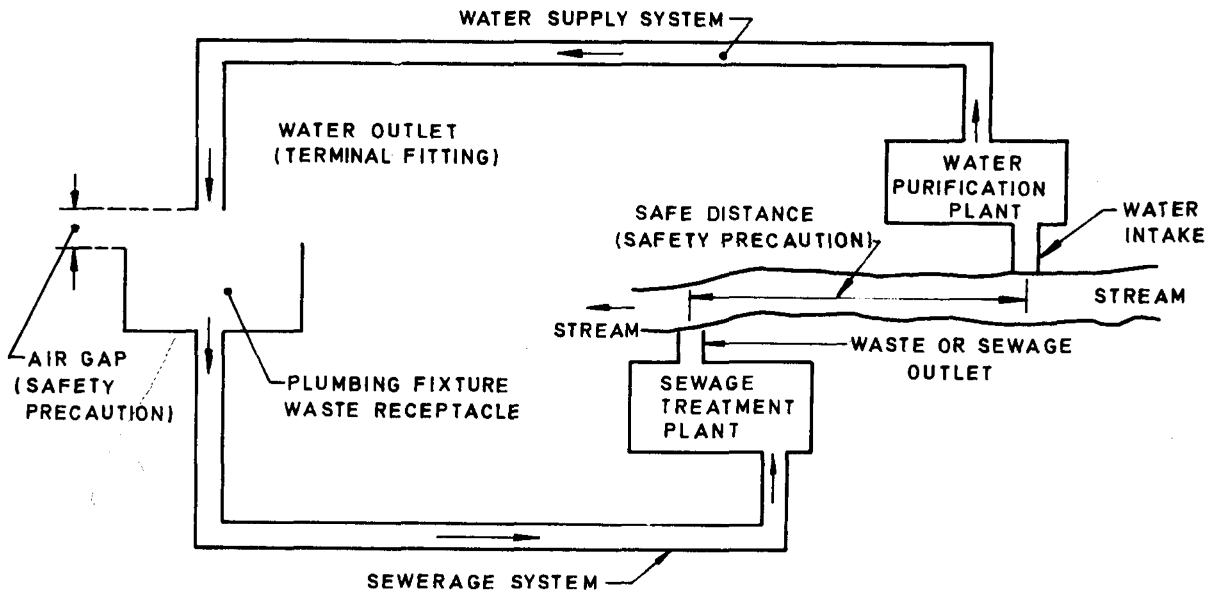


FIG. 23A SAFE SYSTEM FOR SEWAGE AND WATER WITH SAFETY PRECAUTIONS AT EACH TERMINAL TO PREVENT REVERSE. FLOW

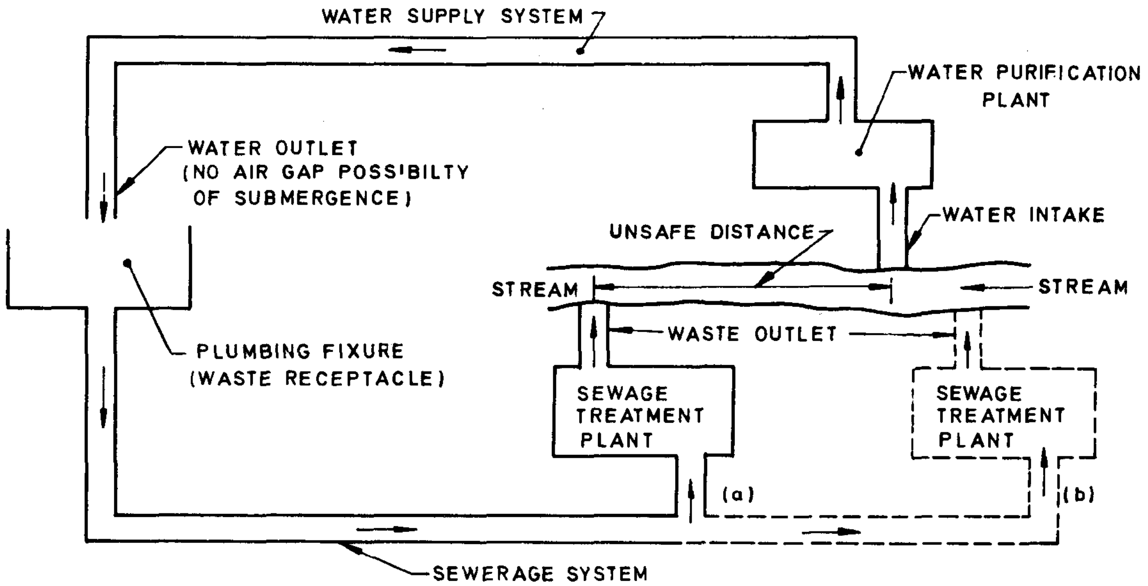


FIG. 23B UNSAFE SYSTEM FOR SEWAGE AND WATER WITH POSSIBILITY OF REVERSE FLOW AT THE PLUMBING FIXTURE AND IN THE STREAM WITH THE SEWAGE DISPOSAL POINT LOCATED CLOSE AND AT AN UNSAFE DISTANCE FROM THE WATER INTAKE AS AT (a) AND WITH DIRECT CONTAMINATION AS AT (b).

FIG. 23 SAFF AND UNSAFE SYSTEMS FOR WATER SUPPLY AND SEWAGE installation. Even where a sewerage system is existing, it is not always that all the houses are connected to the system. It takes a lot of time to derive the full benefit of the system. Every local body has to enforce the provision of house connection statutorily and help the house owner, where necessary, by financing the works and then recovering the cost in easy instalments.

Where there is no sewerage system and where the houses are located in isolated places and which cannot be connected to a sewerage system economically, water closets can still be constructed and connected to an individual household septic tank disposal system. The effluent from the tank may be dispersed into a subsoil dispersion trench. This must be done carefully without contaminating any underground water supply. This subject is further dealt with in detail.

6.4 Sanitary Appliances

6.4.1 *General* — The appliances for the collection and discharge of soil or waste matter are called sanitary appliances. A sanitary appliance for the collection and discharge of excretory matter is called a soil appliance.

A sanitary appliance for the collection and discharge of water after use for ablutionary, culinary and other domestic purposes, is called a waste appliance.

The soil appliances are the several kinds of water-closets, urinals, bidets and slop sinks.

The waste appliances are drinking fountains, wash basins, kitchen sinks, laboratory sinks and bath tubs.

6.4.2 *Water-Closets*

6.4.2.1 *General* — A water-closet consists of: (a) the closet proper consisting of the basin and the trap, and (b) the flushing apparatus. The following varieties of water-closets are in common use.

6.4.2.2 *The squatting or the Indian type* — In India people use the closet in a squatting posture and therefore the seat arrangement is modified to have two foot rests on either side of the pan proper, the pan with the trap being placed flush with the floor of the closet appartment. The floor and the foot rests may be made with cement concrete. Separate squatting plates made of vitreous china may be fixed on the floor and finished with cement mortar. The pan and foot rests may be made integral in vitreous china as in the case of 'Orissa' pattern and in the case of 'universal' pattern of closet pans.

The pan may have a flushing rim and connected to a flushing apparatus. In the case of the 'hand pour flushed' type, as in the case of the rural pattern, there is no flushing rim.

Squatting pans shall be made in any one of the following patterns and sizes.

Pattern	*Sizes in mm*
Long pan	580 and 630
Orissa	580 × 440 and 630 × 450
Rural	425
Integrated	500

The squatting pans and traps shall be manufactured separately in two pieces except in the case of the integrated type where the squatting pan and trap are made integrally. Each pan shall have an integral flushing rim of box or open type except the rural pattern which has no flushing rim. The centre of the flushing rim shall be in line with the centre of the outlet. Squatting pans of 680 mm size should be of the box rim type only and adequate number of holes shall be provided to satisfy the prescribed flushing tests. It shall also have an inlet or supply horn for connecting the flush pipe. The flushing rim and inlet shall be of the self-draining type. A weep hole shall be provided at the flushing inlet of the pan. The flushing inlet may be located either at the narrow end or broad end or at both the ends.

The inside of the bottom of the pan shall have sufficient slope from the front towards the inlet to enable easy and quick disposal while flushing. The minimum slope shall be 15° to horizontal for all sizes except for the rural pattern for which the slope is fixed according to the dimensions given, namely 28°. If the pan is of vitreous china, the exterior surface of outlet below the flange shall not be glazed and this surface shall be sufficiently rough or scored or grooved at right angles to the axis of the outlet. Each pan shall be provided with a trap. The trap shall have either P or S outlet with or without an inspection vent. The trap shall be glazed inside.

IS : 2556 (Part 3)-1981 deals with the specific requirements of squatting pans and traps made of vitreous china. IS : 2556 (Part 14)-1974 deals with specific requirements of integrated squatting pans.

6.4.2.3 *Washdown water-closet* — This is also called the European water-closet and is used in a sitting posture over a wooden or plastic seat hinged to the closet structure. Another wooden or plastic cover is also hinged to close the pan from view. The closet is a pedestal fitting with basin and trap in one piece. The pan consists of a short inverted cone, the back of which is almost vertical so that the excreta may fall directly on the water in the trap without fouling the sides. It is always provided with a flushing rim and attached to a flushing apparatus which is usually a low level flushing cistern. It has an efficient water seal, small water content but large water area and is in every sense a self-cleansing fitting.

A washdown fitting, but without the pedestal, designed to be built into and supported from the wall is called a washdown closet with corbel or bracket fitting. Being free of the floor, with the space below visible and accessible for cleaning, this fitting is particularly suitable for institutional and factory use. When not in use, the seat and the cover are folded back and the closet used as a urinal.

Washdown water-closets shall be one of the following patterns:

a) Pattern 1 — Height 390 mm front and rear (*see* Fig. 24).

b) Pattern 2 — Height 390 mm front and rear (*see* Fig. 25).

The figures referred to are as given in IS : 2556 (Part 3)-1981. The dimensions and tolerances of Pattern 1 and Pattern 2 water-closets shall be as given in Table 37 and 38.

Water-closets shall be of one piece construction. Each water-closet shall be provided with two floor fixing holes having a minimum diameter of 6.5 mm and shall have an integral flushing rim of the box or open type. It shall have an inlet or supply horn for connecting the flushing pipe. The flushing rim and the inlet shall be of the self-draining type and a weep hole shall be provided at the flushing inlet of the water-closet. Each water-closet shall have an integral trap with

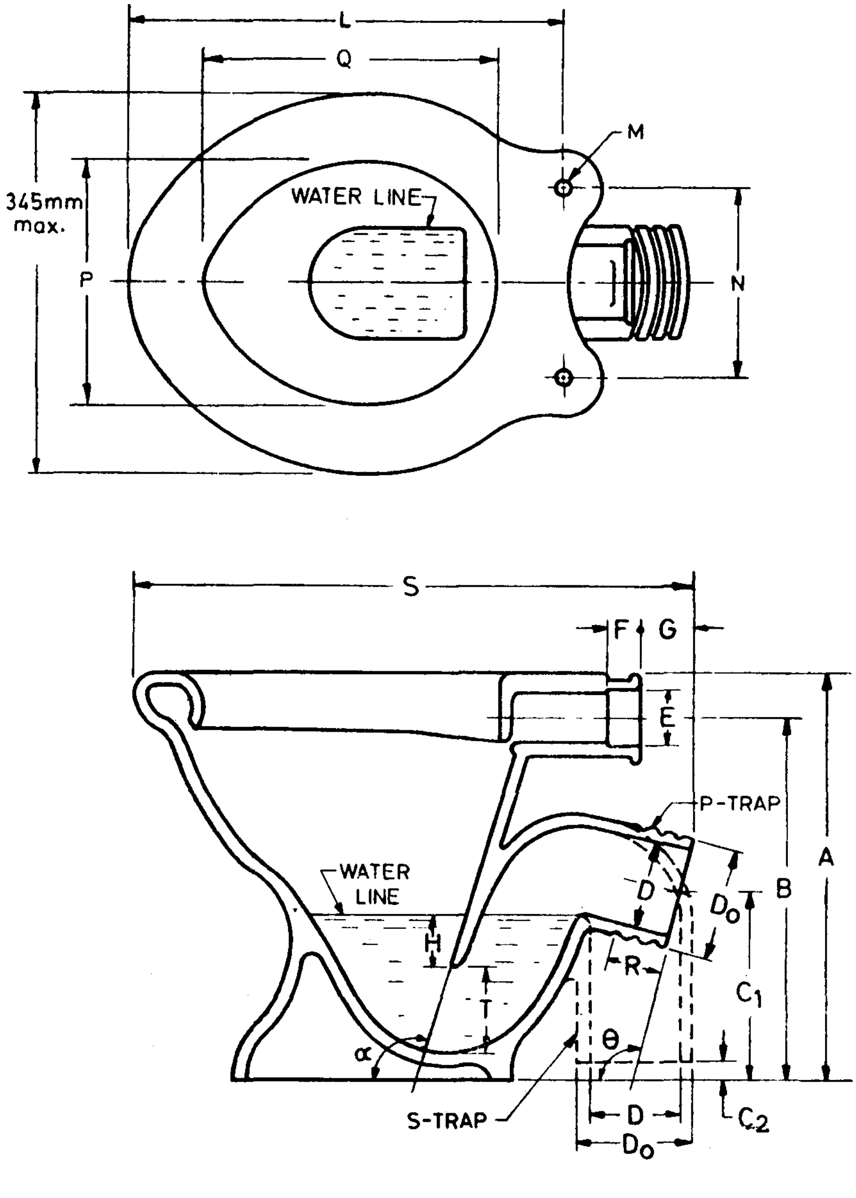
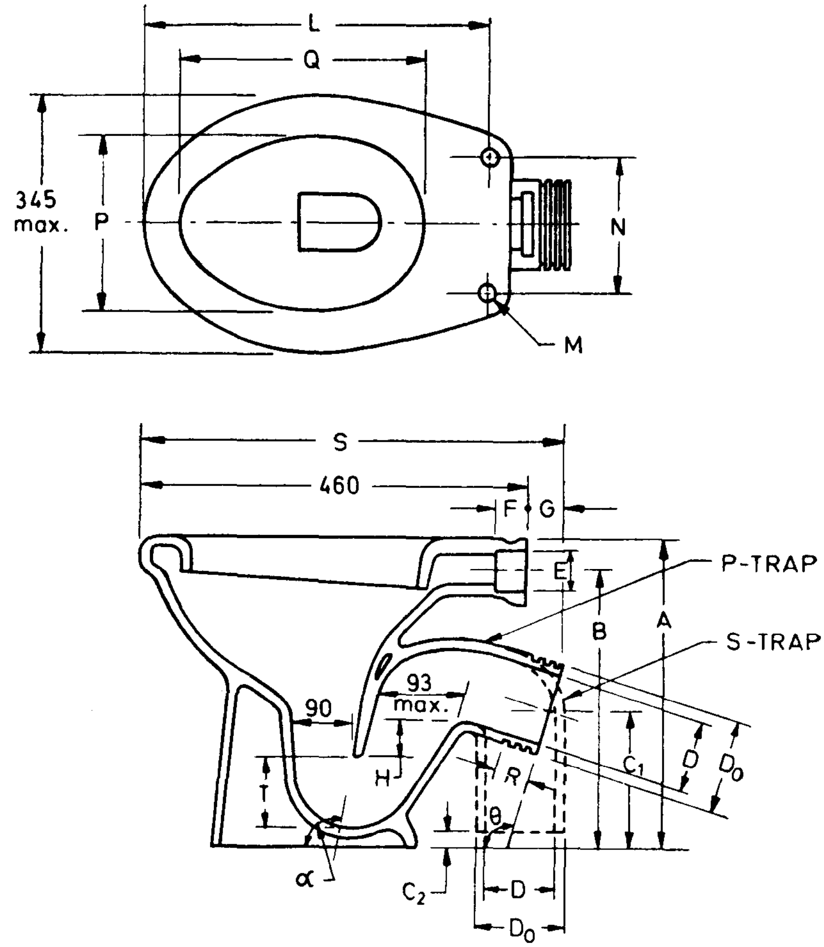


FIG. 24 WATER-CLOSET (PATTERN 1)



All dimensions in millimetres.

FIG. 25. WATER-CLOSET (PATTERN 2)

either P or S outlet conforming to Fig. 24 or Fig. 25. For P trap, the slope of outlet shall be 14°. Where required by the sanitation authority having jurisdiction over the area of installation, each water-closet shall have anti-siphonage vent horn on the outlet side of the trap as per details given in Fig. 26. The water-closets shall satisfy the requirements of the tests given in IS : 2556 (Part 2)-1973.

6.4.2.4 *The siphonic washdown type* — The introduction of this excellent fitting marked a step forward almost as notable as the introduction of the siphonic flushing cisterns, in which the pressure of the atmosphere is utilized to assist the cleaning of sanitary fittings.

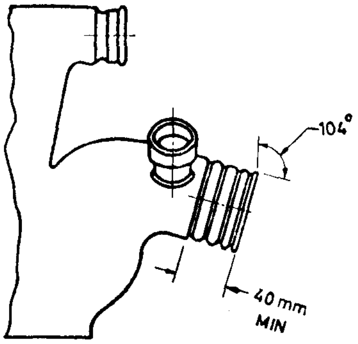
Broadly there are two types of siphonic water-closet. One type is directly dependent upon the actual flushing force of the discharge from the cistern for its siphonic action in the basin. In the other the siphonic action is set up indirectly by means of an injector arranged in the upper portion of the flushing pipe.

There are two patterns, namely, the single trap and the double trap patterns with S or P trap.

In the single trap pattern with S trap, the inlet from the trap is first enlarged and then somewhat suddenly contracted. The effect of this is to cause the discharge from the basin to mix with the air in the outlet and carry some of it away in its flow. Then, while the pressure of the atmosphere remains normal in the inlet, it is subnormal in the outlet and the atmosphere simply pushes the contents of the basin. In the double trap pattern, the first trap being an 'S' one and the second trap being a 'P' one. In this pattern the space between the two traps is closed save for a small pipe which is connected to an injector in the flushing pipe immediately below the cistern. The action is simple and very effective. Immediately the flushing cistern is operated, water passing at a high rate of speed down the flushing pipe acting on the injector rarifies the air contained in the space between the two traps with the result that the full pressure of the atmosphere on the exposed water in the basin is not adequately resisted and movement is inevitable. The action is so efficient that the contents of the basin may actually begin to move out before the first flushing water reaches it. Utilization of the pressure of the atmosphere permits the use of water seals of greater depth in siphonic closets than is practicable in fittings which depend entirely upon the flushing power of water delivered from an ordinary flushing cistern.

IS : 2556 (Part 8)-1973 lays down the specific requirements of siphonic washdown water-closets of vitreous china for the two patterns. The depth of seal for single trap and for each seal in the case of double trap shall not be less than 50 mm.

The flushing cistern shall be of low level type and shall conform to the requirements specified in



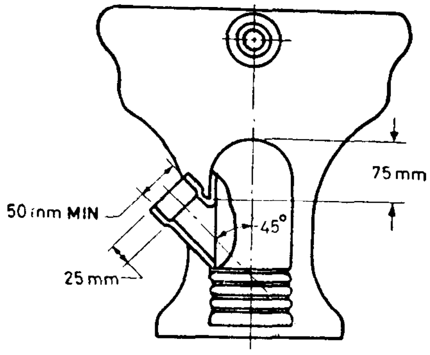


FIG. 26 ANTI-SIPHONAGE VENT HORN DETAIL

TABLE 37 DIMENSIONS AND PERMISSIBLE TOLERANCES OF PATTERN 1 WATER-CLOSETS

(*Clause* 6.4.2.3)

All dimensions in millimetres.

SL No.	DESCRIPTION	REF IN FIG. 23	PATTERN 1 S-Trap	PATTERN 1 P-Trap	TOLERANCE
(1)	(2)	(3)	(4)	(5)	(6)
i)	Height	*A*	390	390	± 20
ii)	Height of centre line of flush inlet	*B*	350	350	± 20
iii)	Height of centre line of outlet for P-trap only	C_1	—	180	± 10
iv)	Distance from end of trap to floor for S-trap only	C_2	20	—	± 5
v)	Internal diameter of outlet, *Min**	*D*	80	80	—
vi)	External diameter of outlet, *Max**	D_0	110	110	—
vii)	Internal diameter of flush inlet socket	*E*	50	50	± 3
viii)	Depth of flush inlet socket	*F*	30	30	± 5
ix)	Distance from and of flush inlet socket to outside of outlet, *Min*	*G*	45	45	—
x)	Depth of water seal	*H*	Not less than 50 mm. Water surface not less than 15 000 mm²		
xi)	Length from seat bolt holes to front rim	*L*	430	430	—
xii)	Diameter of seat bolt holes	*M*	13	13	—
xiii)	Distance between centres of seat bolt holes	*N* (*Min*)	160	160	—
		(*Max*)	175	175	—
xiv)	Width of opening, *Min*	*P*	240	240	—
xv)	Length of opening, *Min*	*Q*	290	290	—
xvi)	Length of serrated part of outlet, *Min*	*R*	40	40	—
xvii)	Overall length	*S*	500 to 575	500 to 575	—
xviii)	Angle of back plate	*α*	90° to 135°	90° to 135°	—
xix)	Angle of outlet	*O*	—	104°	—
xx)	Trap inlet depth, *Min*	*T*	75	75	—

*Ovality permissible within the dimensions for inlet and outlet diameters.

TABLE 38 DIMENSIONS AND PERMISSIBLE TOLERANCES OF PATTERN 2 WATER-CLOSETS

(*Clause* 6.4.2.3)

All dimensions in millimetres.

SL No.	DISCRIPTION	REF IN FIG. 25	DIMENSION	TOLERANCE
(1)	(2)	(3)	(4)	(5)
i)	Height	*A*	390	± 20
ii)	Height of centre line of flush inlet	*B*	350	± 20
iii)	Height of centre line of outlet for P-trap only	C_1	180	± 10
iv)	Distance from end of trap to floor for *S*-trap only	C_2	20	± 5
v)	Internal diameter of outlet, *Min**	*D*	80	—
vi)	External diameter of outlet, *Max**	D_0	110	—
vii)	Internal diameter of flush inlet socket	*E*	50	± 3
viii)	Depth of flush inlet socket	*F*	30	± 3
ix)	Distance from end of flush inlet socket to outside of outlet, *Min*	*G*	45	—
x)	Depth of water seal, *Min*	*H*	50	—
xi)	Water surface area, *Max*	—	7 500 mm²	—
xii)	Length from seat bolt holes to front rim	*L*	430	—
xiii)	Diameter of seat bolt holes	*M*	13	—
xiv)	Distance between centre of seat bolt holes	*N*	*Max* 175	—
			Min 160	—
xv)	Width of opening, *Min*	*P*	240	—
xvi)	Length of opening, *Min*	*Q*	290	—
xvii)	Length of serrated part of outlet	*R*	50	—
xviii)	Overall length, *Max*	*S*	500 to 573	—
xix)	Trap inlet depth	*T*	*Min* 75	—
			Max 90	—
xx)	Angle of back plate	α	90° to 135°	—
xxi)	Angle of outlet	*O*	104°	—

*Ovality permissible within the dimensions for inlet and outlet diameters.

IS : 774-1971 except that there will be no separate flush pipe and the discharge capacity of cistern shall be not less than 10 litres.

6.4.2.5 *Universal or Anglo-Indian type* — This type of closet is suitable both as a squatting pan of the Indian type or as a sitting pan of the European type and hence the name Anglo-Indian type. The top of the pan of the wash-down or European type is flared out to provide for the foot rests when used as the Indian type. For use as the European type, the seat hinged to the closet structure can be turned on to rest over the foot rests. A cover is also hinged to closet structure as in the case of the European type for covering the pan, if so desired.

The universal closets shall be of the following two patterns:

a) 450 mm P or S trap, and

b) 530 mm P or S trap.

P trap universal closet shall be manufactured in one piece. However, S trap universal closet may be made in one or two pieces. Each closet shall be provided with not less than four floor fixing holes and shall have an integral flushing rim. The flushing rim shall be of box type with adequate number of holes. There shall be an inlet or supply horn for connecting the flush pipe. The inlet shall be of the self-draining type and a weep hole shall be provided at the flushing inlet of the closet. When required by the sanitation authority having jurisdiction over the area of installation, each universal closet shall have an anti-siphonage vent horn on the outlet side of the trap and on either right or left hand side at an angle of 45° and with invert of vent horn not below the centre line of the outlet.

IS : 2556(Part 15)-1974 lays down the specific requirements of universal water-closets.

6.4.3 *Slop Sinks* — These are hopper-shaped sinks with a flushing rim and outlet similar to a water-closet pan which is used for the reception and discharge of excreta collected in bed pans of patients. They should be provided with siphonic flushing cisterns or flushing valves in the same way as water-closets and connected to the soil pipe. In hospitals and similar institutions, slop sinks are provided with both hot and cold water supplies. Slop sinks should conform to IS : 771(Part 7)-1981.

6.4.4 *Bidets* — Bidet is a sanitary fitting on which persons sit for washing the excretory organs. It is classed as an ablution fitting and provided with hot and cold water supplies, a properly blended hot and cold water may be supplied to the flushing rim and jet, and a plug outlet designed to be filled with water similarly to a lavatory basin or bath. Sometimes it is provided with a sitz jet or any submerged inlet. The branch supply pipe which is connected to the submerged inlet should join the main supply service not at the level of the fitting itself but at a point not less than 1.6 m above that level. The passage of water by siphonage from the fitting back into the supply service would then require a negative pressure equal to 1.8 m head of water which is unlikely to be obtained. Where this arrangement is not practicable, the fitting of a 'non-return', 'back pressure' or 'reflux' valve in the branch supply pipe, at a point immediately above the fitting, may afford adequate protection.

IS : 2556 (Part 9)-1979 lays down the specific requirements of bidets. Bidets shall be made in vitreousware in three sizes, namely, large size (600 × 350 mm), medium size (530 × 350 mm), and small size (490 × 350 mm). The tolerance on length is ± 10 mm and breadth ± 15 mm. The spray hole dia is 30 mm minimum and 35 mm maximum. The waste hole is 45 mm diameter. The bidet is suitably fixed to the floor.

6.4.5 *Urinals* — The urinals are soil appliances and are connected to a soil pipe after a suitable trap. The urinals shall be of one of the following patterns and sizes:

a) *Bowl* — Flat back (430 mm minimum × 260 mm minimum × 350 mm minimum) and angle back (340 mm × 410 mm minimum × 265 mm).

b) *Slab (single urinal)* — 450 mm × 1000 mm or 600 mm × 1000 mm.

c) *Stall (single urinal)* — 1140 mm × 460 mm × 400 mm.

d) *Squatting plate* — 600 mm × 350 mm and 450 mm × 350 mm.

6.4.5.1 *Bowl urinals* — Bowl urinals shall be of one piece construction with integral flushing box rim with 12 holes (minimum) well distributed in the box rim to ensure satisfactory flushing. At the bottom of the urinal, an outlet horn for connecting to the trap and an outlet pipe shall be provided. The exterior of the outlet horn is not glazed and the surface is provided with grooves at right angles to the axis of outlet to facilitate fixing the outlet pipe with cement. The inside surface of the urinal shall be regular and smooth throughout to ensure efficient flushing. The bottom of pan shall have sufficient slope from the front towards the outlet such that there is efficient drainage of urine and no liquid is left over in the bottom of pan after flushing.

6.4.5.2 *Slab and stall urinals* — shall be manufactured either as a single urinal or as a range of two or more urinals.

6.4.5.3 *Squatting plate* — shall be of one piece construction. Each urinal shall have an integral longitudinal flushing pipe of suitable type which may be connected to the flush pipe. The integral flushing type shall be connected to the sump by three 13 mm dia holes.

IS : 2556 (Part 6/Sections 1 to 6) lays down the specific requirements of urinal as follows:

Section 1 — Bowl type,
Section 2 — Half-stall urinals,
Section 3 — Squatting plates,
Section 4 — Partition slabs,
Section 5 — Waste fittings, and
Section 6 — Water spreaders for half-stall urinals.

6.4.6 *Traps for Sanitary Appliances* — A trap is a device to prevent the passage of air, odours and vermin through it from sewers escaping through a plumbing fixture into the building. The essentials of a good trap are:

a) an efficient 'water seal',

b) to be self-cleansing,

c) should not retard the flow of water unduly, and

d) should retain a minimum amount of water consistent with its purpose.

Every trap should be provided with means of access. The inner surface of the access cap should conform to the internal line and curve of the fitting.

Traps are useless unless they retain their seals at all times. The seals may be broken in the following ways:

a) siphonage,

b) air compression,

c) momentum, and

d) evaporation.

The remedy for (a) and (b) is adequate means of trap ventilation. In the case of (c), an anti-D trap which retards the flow, should be used. In the case of (d), evaporation may occur in fittings left unused for lengthy periods. A film of glycerine poured into the trap is an effective remedy.

The traps of fittings fixed in range are liable to siphonic action and each trap should be ventilated.

Individual trapping of wash basins, when fitted in ranges, is not required in all cases. No trap is proof against siphonage.

The intercepting trap, also called a disconnecting trap, is used to intercept by means of a water seal the passage of air from a sewer or cess pool into a drain. The trap is provided with a rodding arm as means of access to that portion of the drain which lies between the trap and the outfall.

It is now considered unnecessary to provide these traps when proper ventilation is provided.

The traps are of various forms and made of cast iron or glazed stoneware. In P trap, when the inlet leg is vertical, the outlet leg is inclined below the horizontal at a specific angle. In S trap, the outlet leg is parallel with the inlet leg.

'Water seal' in a trap is the depth of water which shall be removed from a fully charged trap before gases at atmospheric pressure may pass from the waste pipe through the trap into a building.

The traps for long pattern and Orissa pattern may be made with either a P or a S outlet, as given in IS : 2556 (Part 13)-1973 which lays down the specific requirements of traps for squatting pans.

The traps for the universal closet shall be the P or S type made integrally with the pan according to IS : 2556 (Part 15)-1974.

The trap for the integrated squatting pan shall be of the P or S type according to IS : 2556 (Part 14)-1974.

The trap for the washdown water-closet shall be of the P or S type according to IS : 2556 (Part 2)-1981.

The water seal in all these cases of soil appliances where the flushing is done with a flushing cistern, either low level or high level, shall be 50 mm (minimum). In case of the rural pattern pan which is hand-pour flushed, the water seal shall be 20 mm.

The slope of the outlet in all P traps except the rural pattern shall be 14° below the horizontal. In the case of the rural pattern it shall be 15°. The internal dia of the outlet in all the traps except for the rural pattern shall be 80 mm minimum. In the case of rural pattern this shall be 70 mm.

IS : 2556 (Part 12)-1973 lays down the specific requirements of floor traps. The floor trap is manufactured without a vent. The length is 310 mm. The inlet end is of 80 mm diameter minimum, the constructed end near the outlet is of 30 mm dia minimum and the outside dia of the outlet shall be 73 mm.

The grating or jelly shall be 95 mm dia with 8 mm dia holes. The minimum depth of water seal shall be 50 mm.

For the traps for wash basins, bath tubs and similar waste appliances, the nominal sizes are 32, 40 and 50 mm. The water seals for the three sizes are either 35 or 75 mm as may be ordered. The rake of outlet in P traps shall be $1\frac{1}{4}°$ minimum and 5° maximum below the horizontal when the access of the inlet is vertical. IS : 5219 (Part 1)-1969 lays down the specification for cast copper alloys traps of P and S types.

The traps provided in drains are the grease and sand traps. The grease trap is a device by means of which the grease content of wastes is cooled and congealed so that it can be skimmed from the surface. This is necessary in the case of liquid wastes from the kitchen or food processing establishments.

The sand trap is a device, often a simple enlargement in cross-sectional area in a conduit, for arresting the sand or silt carried by the liquid wastes through deposition or sedimentation. In Indian houses, where fine silt or ash is also used for cleaning utensils, this separation of the inorganic material is essential to prevent damage to sewers caused by erosion or reduction in capacity.

6.4.7 *Foot Rests for Squatting Pans* — IS : 2556 (Part 10)-1974 gives the specific requirements of foot rests made of vitreous china. The size shall be 250 mm (*Min*) × 125 mm (*Min*) and 15 mm (*Min*). The surface shall be smooth except for serration. The edges shall be suitably rounded or chamfered. In the case of universal water-closet and the Orissa pattern closet, the foot rests are formed integrally with the pan and the length of the foot rests in these cases vary from 260 to 330 mm for different sizes.

6.4.8 *Water-Closet Seats and Covers* — IS : 2548-1980 lays down the specification for plastic water-closet seats and covers. The central opening shall be 250 mm × 215 mm (minimum) and 290 mm × 240 mm (maximum). The thickness of the seat and cover at the thinnest point shall be 3 mm. The seat can be of the closed or open front pattern. The latter shall have an opening of 80 to 100 mm. The seat and cover are hinged to the closet structure at one end. Each seat shall be provided with not less than three rubber or plastic buffers of size 25 × 40 × 10 mm for full round seats and not less than four buffers for open-front seats, securely fixed to the inside of the seat.

Each cover shall be fitted with the same number of buffers as provided for the seat. The buffers below the seat and those in the cover shall be placed vertically over each other. Seats shall be smooth and non-absorptive, and not adversely affected by common solvents or household cleaners.

6.4.9 *Flushing Apparatus of Water-Closets* — The water-closet should be flushed immediately after use and provision should, therefore, be made for the storage and discharge of water. Water is stored in tanks or cisterns which should be separate for each closet, connected with a main tank placed on the top of the house. The cisterns are usually of cast iron, vitreous china or pressed steel or plastic. Wooden bodies, either with or without lead, copper or any other lining, shall not be used. The cistern may be a high level one or a low level one. A high level cistern is a cistern intended to operate with a minimum height of 125 cm between the top of the pan and the underside of the cistern. A low level cistern is intended to operate at a height not exceeding 30 cm between the top of the pan and the underside of the cistern. Water is delivered from the cistern through a flush pipe which shall have a nominal internal diameter of 32 mm for high level cistern and 38 mm for low level cistern. The discharge capacities of cisterns shall be 5, 10 or 12.5 litres with a tolerance of ± 0.5 litre. The discharge capacity of 15 litres with a tolerance of ± 1 litre permitted previously is now obsolete. The average discharge rate is 5 litres in 3 seconds when connected to the appropriate flush pipe. The flush pipe may be of steel tube, seamless or welded or lead pipe or copper alloy pipes or polyethylene pipe (low density or high density) or unplasticized PVC pipe and smooth bore cast iron pipe (for low level flushing cistern). The flushing cisterns are fitted usually with the siphonic apparatus. This is always in the form of an inverted U-tube of which the flushing pipe forms the long arm. Siphonic action must be set up without the operation of any valve through which water could be wasted in case of defect. IS : 774-1984 gives the specification for the flushing cisterns for water-closets and urinals (valveless siphonic type). IS : 7231-1984 lays down the specification for plastic flushing cistern (valveless siphonic type) for water-closets and urinals. In the bell type cistern, when the heavy dome is lifted by the lever and chain and suddenly released, water enclosed within it is thrown over the top of the inner tube and siphonic action is set up.

The flush pipe is securely connected to the cistern outlet by means of coupling nut made of any non-corrosive material, non-ferrous metal or galvanized steel. The nominal internal diameter of the outlet of the cistern shall be the same as the diameter of the flush pipe, namely, 32 and 38 mm for high level and low level cisterns respectively. The ball valves used shall be according to IS : 1703-1977. The chain shall be of galvanized iron, non-ferrous metal or a moulding in any heat resisting and non-absorbent plastic. The overflow pipe is also manufactured from non-ferrous metal or other corrosion resisting material and of 20 mm nominal bore. The cistern is provided with a removable cover. The cistern shall be mosquito proof, that is, there should be no clearance to permit a 1.6 mm wire to pass through the cistern.

6.4.10 *Automatic Flushing Apparatus for Urinals* — Automatic flushing cisterns are generally used for flushing urinals in public places. They are better suited than hand operated flushing cisterns as they do not call for individual attention which would be difficult to achieve in public urinals. Particularly where a battery of urinals is used as in a public lavatory, automatic cisterns are the most convenient arrangement for flushing.

IS : 2326-1970 lays down the specification for automatic flushing cisterns for urinals. This type of cistern is self-acting and flushes intermittently and the number of flushes per day is controlled by the rate of feed through the supply device. The device may consist of an adjustable plug cock or any other suitable device.

The cistern may be of cast iron or glazed earthenware or vitreous china or pressed steel. It is made in nominal sizes of 5, 10 and 15 litres and have a discharge capacity equal to the nominal size with a tolerance of ± 0.5 litre. The nominal size for any urinal cistern is based on a minimum capacity of 2.5 litres per urinal served. The body thickness shall be not less than 5 and 13 mm for cast iron and earthenware respectively and not less than 6 mm in the case of vitreous sanitary appliances. The body of pressed steel shall be of seamless or welded construction of thickness not less than 1.60 mm before coating and shall be porcelain enamelled or otherwise protected against corrosion by an equally efficient coating. The depth of the body cistern shall provide for a clearance of not less than 25 mm between the highest level that can be reached by water before siphonage commences and the spill over level of the top of the cistern.

The siphon of the siphonic apparatus shall be constructed of copper or other equally suitable non-ferrous metal or of cast iron suitably protected both internally and externally against corrosion. The nominal diameter or the outlet of the siphon shall be 25 mm for all sizes of cistern. The cisterns shall be provided with mosquito-proof lids. The outlet of the feeding device shall be so located that it is not less than 3 mm above the highest water level that can be reached by water before siphonage commences.

All siphons shall be capable of delivering not more than 2.5 litres per urinal served at intervals of not less than 10 minutes and not more than 20 minutes.

6.4.11 *Drinking Fountains* — The water supply fitting supplying a drinking fountain has been dealt with under **5.6.6.3** [(c)(8)]. The purpose of a drinking fountain is to supply potable water for drinking that has not been contaminated by the previous user of the water. Hence the jet of the fountain is arranged to issue from a nozzle set at an angle from the vertical so as to prevent the back flow of water in the jet of the orifice. The nozzle is above the edge of the basin so that it may not be flooded in case the fountain drain gets clogged. The waste water is drained to an open drain.

6.4.12 *Wash Basins* — IS : 2556 (Part 4)-1972 lays down the specific requirements of wash basins. The various patterns and sizes are as follows:

Pattern	*Size in* mm
Flat back wash basin (surgeon's basin)	660 × 460
Flat back wash basin with two tap holes	630 × 450 550 × 400
Flat back wash basin with single tap hole	630 × 450 550 × 400 450 × 300
Angle back wash basin, Pattern 1	600 × 480
Angle back wash basin, Pattern 2	400 × 400

Wash basins shall be of one piece including a combined overflow and a soap holder. All internal angles shall be designed so as to facilitate cleaning. All the flat rims shall slope inside towards the bowl. The surgeon's basin to be installed in surgeon's room and operation theatre shall not be provided with soap holder recess and combined overflow. Flat back basins shall be provided with three, two or single tap holes suitable for fixing pillar taps conforming to IS : 1795-1982. Angle back basins shall have one or two tap holes. The tap hole shall be 28 mm square or 30 mm round or 25 mm round (for pep-up hole). A suitable tap hole button shall be supplied if the tap is not required. In installations, 30 mm round hole is suitable only for combination fittings. Each basin shall have circular waste hole through which liquid content of the basins shall drain. The waste hole shall be either rebated or bevelled internally with an overall diameter of 65 mm minimum and a depth of 10 mm to suite a waste fitting having a flange of 64 mm diameter. IS : 2963-1979 lays down the specification for non-ferrous waste fittings for wash basin and sinks. Stud slots shall be provided on the underside of the wash basins. However, alternative arrangements may be made for the support of wash basin in which case special brackets are required. Soap holder recess or recesses shall properly drain into the bowl. A slot type of overflow having an area of not less than 5 cm^2 shall be provided. The overflow channel shall have a minimum cross-sectional area of 4 cm^2. The position of the chain stay hole, if provided, shall not be lower than the overflow slot. The waste plug should conform to IS : 3311-1979.

IS : 8727-1978 lays down the specification for vitreous enamelled steel wash basins.

These wash basins may be of the following patterns and sizes:

Pattern	*Nominal Size in mm (Length × Breadth)*
Flat back (Type 1)	480 × 430 500 × 450
Flat back (Type 2)	500 × 450 600 × 500
Flat rim	480 × 430 500 × 400 510 × 450 530 × 430
Round	450 dia
Oval	450 × 400

The mild steel; sheet should have a thickness of not less than 1 mm. Every basin shall have an integral soap holder recess or recesses which shall drain into the bowl.

The interior of wash basin shall be adequately and evenly coated with vitreous enamel of specified quality. At least one ground or primer coating preferably white or coloured enamel coating shall be applied on the outer surface of the wash basins.

6.4.13 *Sinks* — Kitchen sinks and laboratory sinks are connected to waste pipes and/or waste appliances. Slop sink used in hospitals is a soil appliance and has been dealt with in **6.4.3**.

Sink for laboratory use shall conform to IS : 771 or IS : 2556 (Part 5)-1979.

Vitreous sinks have been restricted to laboratory use only as they are not found suitable for kitchen use.

The sinks suitable for laboratory use shall be in the sizes 400 × 250 × 150 mm, 450 × 300 × 150 mm, 500 × 350 × 150 mm, 600 × 400 × 200 mm and 600 × 450 × 200 mm.

The sinks may be made with or without overflow arrangement. The sinks shall be of one-piece construction including combined overflow, where provided. The sinks shall have a circular waste hole into which the interior of the sinks shall drain. The waste hole shall be either rebated or bevelled with an overall diameter of 65 mm and a depth of 10 mm to suit a waste fitting having a flange of 64 mm diameter. The sink may be provided with a rim. The waste fitting may be of glazed vitreousware, if so desired, or else it should conform to IS : 2963-1979.

IS : 8718-1978 lays down the specification for vitreous enamelled steel kitchen sinks. The sinks suitable for kitchen use shall be of the following pattern:

a) flat rim kitchen sink,

b) flat rim ledge kitchen sink, and

c) flat rim ledge kitchen sink with double compartment.

Mild steel sheets used for the sinks shall be of a thickness not less than 1 mm.

Flat rim sinks have an overall length of 750 to 400 mm; an overall width of 450 to 400 mm and a depth of 150 to 200 mm.

For flat rim ledge sinks, the length shall be 750 or 600 mm with a width of 500 mm and a depth from 150 to 200 mm. Flat rim ledge sink with double compartment shall have an overall length of 1050 or 800 mm, width of 500 mm and a depth of 150 to 200 mm.

The intention of sinks shall be adequately and evenly coated with vitreous enamel of specified quality. At least one ground or primes coating, preferably white or coloured enamel coating, shall be applied on outer surface of sink.

6.4.14 *Waste Fittings for Wash Basins and Sinks* Waste fittings are generally fitted to sanitary appliances, such as wash basins, sinks and urinals to drain away the waste water.

IS : 2963-1979 lays down the specification for non-ferrous waste fittings for wash basins and sinks.

The waste fittings shall be manufactured from brass, leaded tin, bronze or any other suitable corrosion resistant alloy. Waste fittings for wash basins shall be of nominal size 32 mm and for sinks of nominal size 50 mm. The fittings shall be nickel-chromium plated.

6.4.15 *Bath Tubs* — Bath tubs even though they are not commonly used in India are, however, provided in certain hotels and residences for people who prefer to use them. They are also provided to cater for tourists from abroad.

Bath tubs shall be of enamelled steel, gel-coated glass fibre reinforced resin or of any other suitable material. It shall be sanitary, comfortable, easy to get in and out, water tight, easy to instal and maintain. It shall be rectangular or of such a shape which does not have sharp angle or recesses in which dust may collect. It may have panel enclosure or may be round ended for open fixing. The connection for hot and cold water, overflow and waste (with separate traps) shall be of non-ferrous metal or stainless steel. The baths shall be fitted with overflow and waste pipe of nominal diameter not less than 25 mm and inside slope shall be provided at the rate of 1 : 30 towards the outlet. A bath of enclosed type shall have easily removable panel or other means of giving free access to pipe work. Enamalled steel bath tubs shall conform to IS : 3489-1966 and gel-coated glass fibre reinforced polyester resin bath tubs shall conform to IS : 6411-1972.

The capacity of enamelled steel bath tubs should not be greater than 200 litres to the invert of the overflow. The interior of the bath tub is to be adequately and evenly coated with vitreous enamel of thickness not less than 0.2 mm and not greater than 0.5 mm. Layer thickness is measured with an electro-magnetic instrument. Gel-coated glass fibre reinforced polyester resin bath tubs have been successfully used both by the hotel industry and private houses in developed countries and are gradually gaining acceptance by the hotel industry in India also. The gel coat is a resin-rich pigmented protective layer provided on the working surface of the bath tub. During moulding care is taken so that it forms a single homogeneous body with the glass-fibre laminate. It shall be not less than 0.25 mm and not greater than 1.00 mm in thickness. The glass fibre is to be non-alkaline and the proportion of the glass fibre shall be not less than 25 percent of the glass fibre reinforced polyester layer including the gel-coated layer. Thickness of the glass fibre reinforced polyester laminate including the gel-coat shall not be less than the following: apron—2 mm, inner wall and bottom—3 mm and bottom bend—4 mm.

6.4.16 *Cast Iron Brackets and Supports for Wash Basins and Sinks* — IS : 775-1970 lays down the specification for cast iron brackets and suports for wash basins and sinks.

Brackets for building into a wall shall include a lugged portion and shall have flange at the bottom to indicate the wall line. The lugged portion shall be slotted in order to provide a key for the mortar.

Brackets for screwing to a wall shall be provided with a back fixing smooth plate.

Supports which consist of a horizontal strap with a supporting leg or a cast iron bracket. The supporting leg shall be fixed to the wall.

The leg supports shall be either 15 mm nominal bore steel tubes or castings and shall terminate in a flange for fixing to the floor with screws. Supports consisting of strap and leg support for wash basins may also be made with front towel rail.

6.4.17 *Support of Appliances*

a) There are three types of supports:

   1) Wall supports consisting of brackets either built into the wall or screwed to it;

   2) Floor supports consisting of legs, pillars or pedestals of various designs which transmit the weight of the appliance to the floor; and

   3) A combination of (1) and (2).

b) Brackets for building in are provided with lugs, the length of which is related to the thickness of wall and weights to be supported. The relevant brackets and supports should therefore be selected. Brackets for screwing to walls are provided with ear holes for fixing screws which should be screwed into suitable wall plugs. In the case of thin partition walls especially where the appliances are heavy, it is preferable to use some form of floor support. If, however (as in the case of light appliances), wall fittings are used, they should be bolted through the wall using back plates on the remote side. It may sometimes be possible to fix appliances on both sides of a partition by bolting either the appliances or their brackets back-to-back.

6.5 Basic Requirements for Drainage and Sanitation

6.5.1 *General* — IS : 1172-1983 lays down the basic requirements for water supply, drainage and sanitation. The water requirements for residences and buildings other than residences recommended therein have been given in **4.2** and **4.3**. The drainage and sanitation requirements are given below.

6.5.2 *Drainage and Sanitation Requirements for Residences*

6.5.2.1 Dwellings with individual conveniences shall have at least the following fitments;

a) One bath room provided with a tap;

b) One water-closet; and

c) One *nahani* or sink, either in the floor or raised from the floor, with a tap.

Where only one water-closet is provided in a dwelling, the bath and water-closet shall be separately accommodated. Water-closets shall be generally of the Indian squatting type. There shall be at least one water tap and arrangement for drainage in the vicinity of each water-closet or group of water-closets in all buildings.

6.5.2.2 Dwellings without individual conveniences shall have the following fitments:

a) One water tap with draining arrangement in each tenement;

b) One water-closet and one bath for every two tenements; and

c) Water taps in common bath rooms.

6.5.3 *Drainage and Sanitation Requirements in Buildings Other than Residences* — The requirements for fitments for drainage and sanitation in the case of buildings other than residences are given below:

6.5.3.1 *Office buildings* — *See* Table 39.

6.5.3.2 *Factories* — *See* Table 40.

6.5.3.3 *Cinemas, concert halls and theatres* — *See* Table 41.

6.5.3.4 *Art galleries, libraries and museums* — *See* Table 42.

6.5.3.5 *Hospitals, indoor and outdoor patient wards* — *See* Table 43.

6.5.3.6 *Hospitals (administrative buildings, medical staff quarters and nurses' homes)* — *See* Table 44.

6.5.3.7 *Hotels* — *See* Table 45.

6.5.3.8 *Restaurants* — *See* Table 46.

6.5.3.9 *Schools and educational institutions* — *See* Table 47.

6.5.3.10 *Hostels* — *See* Table 48.

6.5.3.11 *Fruit and vegetable markets* — *See* Table 49.

TABLE 39 OFFICE BUILDINGS

(*Clause* 6.5.3.1)

Sl No.	Fitments	For Accommodation Other Than for Principals	
		For Male Personnel	For Female Personnel
(1)	(2)	(3)	(4)
i)	Water-closets*	1 for every 25 persons or part thereof	1 for every 15 persons or part thereof
ii)	Ablution taps	1 in each water-closet	1 in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closet and urinals.	
iii)	Urinals	Nil up to 6 persons 1 for 7 to 20 persons 2 for 21 to 45 persons 3 for 46 to 70 persons 4 for 71 to 100 persons From 101 to 200 persons add at the rate of 3 percent For over 200 persons, add at the rate of 2.5 percent	
iv)	Wash basins	1 for every 25 persons or part thereof	
v)	Drinking water fountains	1 for every 100 persons with a minimum of one on each floor	
vi)	Cleaner's sink	1 per floor, minimum, preferably in or adjacent to sanitary rooms	

*This includes adequate number of European style of water closets, where desired.

TABLE 40 FACTORIES

(Clause 6.5.3.2)

Sl No.	Fitments	For Male Personnel	For Female Personnel
(1)	(2)	(3)	(4)
i)	Water-closets*	1 for 1 to 15 persons 2 for 16 to 35 persons 3 for 36 to 65 persons 4 for 66 to 100 persons From 101 to 200 persons, add at the rate of 3 percent for over 200 persons, add at the rate of 2.5 percent	1 for 1 to 12 persons 2 for 13 to 25 persons 3 for 26 to 40 persons 4 for 41 to 57 persons 5 for 58 to 77 persons 6 for 78 to 100 persons From 101 to 200 persons, add at the rate of 5 percent For over 200 persons, add at the rate of 4 percent
ii)	Ablution taps	1 in each water-closet 1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals.	1 in each water-closet
iii)	Urinals	Nil up to 6 persons 1 for 7 to 20 persons 2 for 21 to 45 persons 3 for 46 to 70 persons 4 for 71 to 100 persons From 101 to 200 persons, add at the rate of 3 percent For over 200 persons, add at the rate of 2.5 percent	
iv)	Washing taps with drainage arrangements	1 for every 25 persons or part thereof	
v)	Drinking water fountains	1 for every 100 persons or part thereof with a minimum of one on each floor	
vi)	Baths (preferably showers)	As required for particular trades or occupations	

NOTE 1 — For many trades of a dirty or dangerous character more extensive provisions are required by law.

NOTE 2 — Creches, where provided, shall be fitted with water closets (one for 10 persons or part thereof) and wash basins (one for 15 persons or part thereof) and drinking water tap with draining arrangements (one for every 50 persons or part thereof)

*Some of the water closets may be of European style, if desired.

TABLE 41 CINEMAS*, CONCERT HALLS AND THEATRES

(Clause 6.5.3.3)

Sl No.	Fitments	For Male Public	For Female Public	For Male Staff	For Female Staff
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water-closets	1 per 100 persons up to 400 persons and for over 400 persons, add at the rate of 1 per 250 persons or part thereof.	3 per 100 persons up to 200 persons and for over 200 persons add at the rate of 2 per 100 persons or part thereof	1 for 1 to 15 persons 2 for 16 to 35 persons	1 for 1 to 12 persons 2 for 13 to 25 persons
ii)	Ablution taps	1 in each water-closet 1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals	1 in each water-closet	1 in each water-closet	1 in each water-closet

(Continued)

TABLE 41 CINEMAS*, CONCERT HALLS AND THEATRES — *Contd*

SL No.	FITMENTS	FOR MALE PUBLIC	FOR FEMALE PUBLIC	FOR MALE STAFF	FOR FEMALE STAFF
(1)	(2)	(3)	(4)	(5)	(6)
iii)	Urinals	1 for 25 persons or part thereof	—	Nil up to 6 persons 1 for 7 to 20 persons 2 for 21 to 45 persons	—
iv)	Wash basins	1 for every 200 persons or part thereof	1 for every 200 persons or part thereof	1 for 1 to 15 persons 2 for 16 to 35 persons	1 for 1 to 12 persons 2 for 13 to 25 persons
v)	Drinking water fountains	← 1 per 100 persons or part thereof →			

NOTE 1 — Some of the water-closets may be of European style, if desired.

NOTE 2 — It may be assumed that two-thirds of the number are males and one-third females.

NOTE 3 — Provisions for water tap may also be made in place of drinking water fountains the scale of which may be 1 per 100 persons of part thereof.

*See also IS : 4878-1976 Byelaws for construction of cinema buildings (*first revision*).

TABLE 42 ART GALLERIES, LIBRARIES AND MUSEUMS

(*Clause* 6.5.3.4)

SL No.	FITMENTS	FOR MALE PUBLIC	FOR FEMALE PUBLIC	FOR MALE STAFF	FOR FEMALE STAFF
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water-closets	1 per 200 persons up to 400 persons; and for over 400 persons add at the rate of 1 per 250 persons or part thereof	1 for 100 persons up to 400 persons; and for over 400 persons, add at the rate of 1 per 150 persons or part thereof	1 for 1 to 15 persons 2 for 16 to 35 persons	1 for 1 to 12 persons 2 for 13 to 25 persons
ii)	Ablution taps	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals.			
iii)	Urinals	1 per 50 persons	—	Nil upto 6 persons 1 for 7 to 20 persons 2 for 21 to 45 persons	—
iv)	Wash basins	1 per every 200 persons or part thereof; and for over 400 persons add at the rate of 1 per 250 persons or part thereof	1 for every 200 persons or part thereof; and for over 200 persons add at the rate of 1 per 150 persons or part thereof	1 for 1 to 15 persons 2 for 16 to 35 persons	1 for 1 to 12 persons 2 for 13 to 25 persons
v)	Cleaner's sinks	← 1 per floor, minimum →			
vi)	Drinking water fountain	← 1 per 100 persons or part thereof →			

NOTE 1 — Some of the water-closets may be of European style, if desired.

NOTE 2 — It may be assumed that two-thirds of number are males and one-third females.

TABLE 43 HOSPITALS, INDOOR AND OUTDOOR PATIENT WARDS

(*Clause* 6.5.3.5)

SL NO.	FITMENTS	REQUIREMENTS	
(1)	(2)	(3)	
		Indoor patient wards (for males and females)	
i)	Water-closets	1 for every 8 beds or part thereof	
ii)	Ablution taps	1 in each water-closet plus one water tap with draining arrangements in the vicinity of water-closets and urinals for every 50 beds or part thereof	
iii)	Wash basins	2 up to 30 beds; add 1 for every additional 30 beds or part thereof	
iv)	Baths	1 bath with shower for every 8 beds or part thereof	
v)	Bed pan washing sinks	1 for each ward	
vi)	Cleaner's sinks	1 for each ward	
vii)	Kitchen sinks and dish washers (where kitchen is provided)	1 for each ward	
		Outdoor patient wards	
		For males	For females
viii)	Water-closets	1 for every 100 persons or part thereof	2 for every 100 persons or part thereof
ix)	Ablution taps	1 in each water closet	1 in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals	
x)	Urinals	1 for every 50 persons or part thereof	—
xi)	Wash basins	1 for every 100 persons or part thereof	1 for every 100 persons or part thereof
xii)	Drinking water fountains	← 1 per 500 persons or part thereof. →	

NOTE 1 — Some of the water-closets may be of European style, if desired.

NOTE 2 — Additional and special fitments for specific needs of hospitals may be provided.

TABLE 44 HOSPITALS (ADMINISTRATIVE BUILDINGS, MEDICAL STAFF QUARTERS AND NURSES' HOMES)

(*Clause* 6.5.3.6)

SL NO.	FITMENTS	FOR ADMINISTRATIVE BUILDINGS		FOR MEDICAL STAFF QUARTERS (HOSTEL TYPE)		FOR NURSES' HOMES (HOSTEL TYPE)
		For male personnel	For female personnel	For male staff	For female staff	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Water-closets*	1 for every 25 persons or part thereof	1 for every 15 persons or part thereof	1 for 4 persons	1 for 4 persons	1 for 4 persons or part thereof
ii)	Ablution taps	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals				
iii)	Urinals	Nil up to 6 persons 1 for 7 to 20 persons 2 for 21 to 45 persons 3 for 46 to 70 persons 4 for 71 to 100 persons	—	—	—	—

*Some of the water-closets may be of European style, if desired.

(*Continued*)

TABLE 44 HOSPITALS (ADMINISTRATIVE BUILDINGS, MEDICAL STAFF QUARTERS AND NURSES' HOMES) — *Contd*

SL NO.	FITMENTS	FOR ADMINISTRATIVE BUILDINGS		FOR MEDICAL STAFF QUARTERS (HOSTEL TYPE)		FOR NURSES' HOMES (HOSTEL TYPE)
		For male personnel	For female personnel	For male staff	For female staff	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		For 101 to 200 persons add at the rate of 3 percent; and for over 200 persons add at the rate of 2.5 percent				
iv)	Wash basins	1 for every 25 persons or part thereof	1 for every 25 persons or part thereof	1 for every 8 persons or part thereof	1 for every 8 persons or part thereof	1 for every 8 persons or part thereof
v)	Baths (with shower)	—	—	1 for 4 persons or part thereof	1 for 4 persons or part thereof	1 for 4 to 6 persons or part thereof
vi)	Drinking water fountains	← 1 per floor, minimum →				
vii)	Cleaness sinks	← 1 per floor minimum →				

TABLE 45 HOTELS

(*Clause* 6.5.3.7)

SL NO.	FITMENTS	FOR RESIDENTIAL PUBLIC AND STAFF	FOR PUBLIC ROOMS		FOR NON-RESIDENTIAL STAFF	
			For Males	For Females	For Males	For Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Water-closets	1 per 8 persons omitting occupants of the room with attached water-closets minimum of 2 if both sexes are lodged	1 per 100 persons up to 400 persons and for over 400, add at the rate for 1 per 250 persons or part thereof	2 per 100 persons up to 200 persons and for over 200, add at the rate of 1 per 100 persons or part thereof	1 for 1 to 15 persons 2 for 16 to 35 persons 3 for 36 to 65 persons 4 for 66 to 100 persons	1 for 1 to 12 persons 2 for 13 to 25 persons 3 for 26 to 40 persons 4 for 41 to 57 persons 5 for 58 to 77 persons 6 for 78 to 100 persons
ii)	Ablution taps	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in in the vicinity of water-closets and urinals				
iii)	Urinals	—	1 per 50 persons or part thereof	—	Nil up to 6 persons 1 for 7 to 20 persons 2 for 21 to 45 persons 3 for 46 to 70 persons 4 for 71 to 100 persons	

(*Continued*)

TABLE 45 HOTELS — *Contd*

SL NO.	FITMENTS	FOR RESIDENTIAL PUBLIC AND STAFF	FOR PUBLIC ROOMS		FOR NON-RESIDENTIAL STAFF	
			For Males	For Females	For Males	For Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)
iv)	Wash basins	1 per 10 persons omiting the wash basins installed in the room suite	1 per water-closet and urinals provided	1 per water-closet provided	1 for 1 to 15 persons 2 for 16 to 35 persons 3 for 36 to 65 persons 4 for 66 to 100 persons	1 for 1 to 12 persons 2 for 13 to 25 persons 3 for 26 to 40 persons 4 for 41 to 57 persons 5 for 58 to 77 persons 6 for 78 to 100 persons
v)	Baths	1 per 10 persons omitting occupants of the room with bath in suite	—	—	—	—
vi)	Slop sinks	1 per 30 bed rooms minimum 1 per floor	—	—	—	—
vii)	Kitchen sinks and dish washers	1 in each kitchen				

NOTE 1 — Some of the water-closets may be of European style, if desired.

NOTE 2 — It may be assumed that two-thirds of the number are males and one-third females.

TABLE 46 RESTAURANTS

(*Clause* 6.5.3.8)

SL NO.	FITMENTS	FOR MALE PUBLIC	FOR FEMALE PUBLIC	FOR MALE STAFF	FOR FEMALE STAFF
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water-closets	1 for 50 seats up to 200 seats; and for over 200 seats, add at the rate of 1 per 100 seats or part thereof	1 for 50 seats upto 200 seats and for over 200 seats, add at the rate of 1 per 100 seats or part thereof	1 for 1 to 15 persons 2 for 16 to 35 persons 3 for 36 to 65 persons 4 for 66 to 100 persons	1 for 1 to 12 persons 2 for 13 to 25 persons 3 for 26 to 40 persons 4 for 41 to 57 persons 5 for 58 to 77 persons 6 for 78 to 100 persons
ii)	Ablution taps	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals			
iii)	Urinals	1 per 50 seats	—	Nil up to 6 persons 1 for 7 to 20 persons 2 for 21 to 45 persons 3 for 46 to 70 persons 4 for 71 to 100 persons	—
iv)	Wash basins	← 1 for every water-closet provided →			
v)	Kitchen sinks and dish washers	← 1 in the restaurant →			
vi)	Slop or service sinks	← 1 in the restaurant →			

NOTE 1 — Some of the water-closets may be of European style, if desired.

NOTE 2 — It may be assumed that two-thirds of the number are males and one-third females.

TABLE 47 SCHOOLS AND EDUCATIONAL INSTITUTIONS

(*Clause* 6.5.3.9)

SL NO.	FITMENTS*	NURSERY SCHOOLS	EDUCATIONAL INSTITUTIONS (Non-Residential)		EDUCATIONAL INSTITUTION (Residential)	
			For Boys	For Girls	For Boys	For Girls
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Water-closets†	1 per 15 pupils or part thereof	1 per 40 pupils or part thereof	1 per 25 pupils or part thereof	1 for every 8 pupils or part thereof	1 for every 6 pupils or part thereof
ii)	Ablution taps	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 pupils or part thereof in the vicinity of water-closets and urinals.				
iii)	Urinals	—	1 per 20 pupils or part thereof	—	1 for every 25 pupils or part thereof	—
iv)	Wash basins	1 per 15 pupils or part thereof	1 per 60, minimum 2	1 per 40, minimum 2	1 for every 8 pupils or part thereof	1 for every 6 pupils or part thereof
v)	Baths	1 bath-sink per 40 pupils or part thereof	—	—	1 for every 8 pupils or part thereof	1 for every 6 pupils or part thereof
vi)	Drinking water fountains or taps	1 for every 50 pupils or part thereof	1 for every 50 pupils or part thereof	1 for every 50 pupils or part thereof	1 for every 50 pupils or part thereof	1 for every 50 pupils or part thereof
vii)	Cleaner's sinks	← 1 per floor, minimum →				

*For teaching staff, schedule of fitments to be provided shall be the same as in the case of office buildings (*See* Table 39).

†Some of the water-closets may be of European style, if desired.

TABLE 48 HOSTELS

(*Clause* 6.5.3.9)

SL NO.	FITMENTS	FOR RESIDENTS AND RESIDENTIAL STAFF		FOR NON-RESIDENTIAL STAFF		ROOMS WHEREIN OUTSIDERS ARE RECEIVED	
		For Males	For Females	For Males	For Females	For Males	For Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
i)	Water-closets*	1 for every 8 persons or part thereof part thereof	1 for every 6 persons or part thereof part thereof	1 for 1 to 15 persons 2 for 16 to 35 persons 3 for 36 to 65 persons 4 for 66 to 100 persons	1 for 1 to 12 persons 2 for 13 to 25 persons 3 for 26 to 40 persons 4 for 41 to 57 persons 5 for 58 to 77 persons 6 for 78 to 100 persons	1 per 100 persons up to 400 persons and for over 400 persons, add at the rate of 1 for 250 persons or part thereof	2 per 100 persons up to 200 persons and for over 200 persons, add at the rate of 1 for 100 persons or part thereof
ii)	Ablution taps	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet
		1 water tap with drinking arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals.					
iii)	Urinals	1 for 25 persons or part thereof		Nil up to 6 persons 1 for 7 to 20 persons		1 per 50 persons or part thereof	

*Some of the water-closets may be of European style, if desired.

(*Continued*)

TABLE 48 HOSTELS — *Contd*

Sl No.	Fitments	For Residents and Residential Staff		For Non-Residential Staff		Rooms Wherein Outsiders are Received	
		For Males	For Females	For Males	For Females	For Males	For Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
				2 for 21 to 45 persons 3 for 46 to 70 persons 4 for 71 to 100 persons			
iv)	Wash basins	1 for 8 persons or part thereof	1 for 6 persons or part thereof	1 for 1 to 15 persons 2 for 16 to 35 persons 3 for 36 to 65 persons 4 for 66 to 100 persons	1 for 1 to 12 persons 2 for 13 to 25 persons 3 for 26 to 40 persons 4 for 41 to 57 persons 5 for 58 to 77 persons 6 for 78 to 100 persons	1 per each water-closet and urinal provided	1 per each water-closet provided
v)	Baths	1 for 8 persons or part thereof	1 for 6 persons or part thereof	—	—	—	—
vi)	Cleaner's sinks	← 1 per floor, minimum →					

TABLE 49 FRUIT AND VEGETABLE MARKETS

(*Clause* 6.5.3.11)

Sl No.	Fitments	Requirements
i)	Urinals	Not less than 2 for every 50 persons
ii)	Water-closets*	2 minimum and an additional one for every 50 persons
iii)	Ablution taps	2 minimum and an additional tap for every 50 persons
iv)	Bathing places	Suitable numbers with bathing platforms

Note 1 — *See also* IS : 1787-1961 'Layout for regulated market yards for fruits and vegetables'.

Note 2 — Separate and adequate provision of water-closets shall be made for females.

Note 3 — Adequate washing places for fruit and vegetables shall be provided.

*Some of water-closets may be of European style, if desired.

6.5.3.12 *Railway platforms, bus station, bus terminals and airports* — The requirements given below include provision for waiting rooms and waiting halls. They do not, however, include requirements for retiring rooms.

The number of persons, for whom the facilities are provided, shall include the average number of passengers handled by the station daily including the staff and vendors.

Adequate arrangements shall be made for satisfactory drainage of all sewage and waste water. Harmful waste waters such as water containing kitchen waste shall be satisfactorily disposed. The drainage shall be so designed as to cause no stagnation at the maximum discharge rate for which the different units are designed.

a) The minimum sanitary conveniences to be provided at any railway station, bus station or bus terminal shall be as given in Table 50.

b) The sanitary conveniences to be provided at airports shall be as given in Table 51.

c) The following additional provisions shall be made:

1) For wash basins at the following rates:

Domestic airports — Minimum of 2, each male and female, with the scale of provisions as for international airports for increase in population.

International airports — 10 for 200 persons, 15 for 400 persons, 20 for 600 persons, and 25 for 1000 persons.

2) Shower stalls with wash basin in the enclosure per stall should be provided at the following locations:

i) four stalls each in the ladies and gents toilets in the transit or departure lounge.

ii) four stalls in the ladies and gents toilets in the main course.

TABLE 50 RAILWAY STATION, BUS STATION OR TERMINAL

(*Clause* 6.5.3.12)

NATURE OF STATION	WC FOR MALES	WC FOR FEMALES	URINALS FOR MALES ONLY
Junction stations and intermediate stations and bus station	3 for first 1000 persons and 1 for every additional 1000 persons or part thereof	4 for first 1000 persons and 1 for every additional 1000 persons	4 for every 1000 persons and 1 for every additional 1000 persons
Terminal stations and bus terminals	4 for first 1000 persons and 1 for every subsequent 1000 persons or part thereof	5 for first 1000 persons and 1 tor every subsequent 2000 persons or part thereof	6 for first 1000 persons and 1 tor every subsequent 1000 persons or part thereof

TABLE 51 AIRPORTS

(*Clause* 6.5.3.12)

TYPE OF AIRPORT	WC FOR MALES	WC FOR FEMALES	URINALS FOR MALES ONLY
Domestic airports (minimum)	2*	4*	2
For 220 persons	5	8	6
For 400 persons	9	15	12
For 600 persons	12	20	16
For 800 persons	16	26	20
For 1000 persons	18	29	22
International airports			
For 200 persons	6	10	8
For 600 persons	12	20	16
For 1000 persons	18	29	22

NOTE — Separate provision shall be made for staff and workers, at these traffic terminal stations.

*Atleast one Indian style water-closet shall be provided in each toilet. Assume 60 male to 40 female in any area.

6.6 Selection, Installation and Maintenance of Sanitary Appliances

6.6.1 *General* — IS : 2064-1973 gives the code of practice for the selection, installation and maintenance of sanitary appliances.

Installation of sanitary appliances in any public or private building is usually governed by the local body bye-laws and rules framed under the Act relating to the local body. These are intended to regulate proper layout of the appliances and their connections so that wastes are suitably disposed off to drains without causing insanitary conditions and nuisance to public. Noting the variations in the bye-laws and rules framed by different authorities in the country, IS : 2064-1973 was issued to ensure fulfilment of minimum requirements.

6.6.2 *Selection of Appliances* — The position of the sanitary compartments, annexes, etc, shall be determined by consultation between the architect and the sanitary engineer while planning in the early stages. The number and kind of appliances to be provided is based on the number and type of occupants who use the building. The water pressure available in the water supply main is to be taken into account when selecting valves and fittings.

6.6.3 *Installation of Appliances*

6.6.3.1 *General* — Grouping of appliances is of importance for economy and efficiency. Care is necessary when selecting positions to ensure sufficient light for the user. Fixing position of appliance shall be established prior to the commencement of building construction. As much work as possible needed in the assembly of appliances shall be prepared and fitted during the progress of the erection of the building before surface finishes are carried out.

Soil waste and ventilating branch connection with supporting brackets shall be fitted before the erection of the appliances is begun. Appliances except those permanently built in shall not be fixed until floor and wall surface are finished ready for decoration. All appliances shall conform to the relevant Indian standards where they exist, otherwise they shall be of the best quality and workmanship which shall be approved by a competent authority. All appliances and sanitary accommodation shall be arranged to facilitate access for cleaning and repairing.

6.6.3.2 *Design considerations*

a) *Water-closet (WC) suites* — The minimum fittings and appliance in a water-closet sink should consist of:

1) A squatting pan with its trap or alternatively a washdown (pedestal type) or a universal closet (pedestal type) provided with seat and cover; and

2) Flushing cistern or flush valve with flush pipe.

b) Where squatting pans with traps are provided, due consideration shall be given to the following:

1) The floor (or slab) may preferably be lower than the general floor level to accommodate the pan,

2) Floor shall be suitably sloped so that the waste water is drained into the pan, and

3) Tap may be provided in a suitable position at a height of 20 to 30 cm above the floor level. Foot rest of suitable dimension shall be provided where it does not form a part of the closet itself as in the case of the 'Orissa' pattern and the universal water-closet.

c) Where washdown water-closets and universal water-closets with seats and covers are provided, the following shall also be provided:

1) A floor trap;

2) A toilet paper holder and

3) An ablution tap, especially in public buildings.

d) *Flushing cisterns* — The following shall be considered:

1) Valveless siphonic type of flushing cisterns;

2) Flushing cisterns of 10 litres capacity discharging at an average rate of 5 litres in 3 seconds;

3) The breadth of low level cistern from front to back shall be such that the cover or seat or both of the water-closet pan shall come to rest in a stable position when raised; and

4) The cistern shall be supported on two cast iron or mild steel brackets or alternatively the cistern shall be fixed to the wall with screws fixed above the overflow level and supplemented by 2 cast iron or mild steel wall supports.

e) *Urinals*

1) The side wall and back of urinals shall be made of hard durable impervious material. The floor under the stall urinals shall also be covered with impervious material. It shall be provided with a drain ending with a trap and provisions for cleaning the floor.

2) Urinal shall be designed to allow a minimum clear width of 60 cm between partitions.

3) Top of the bowl shall be about 60 cm from the floor level.

4) For schools, stall urinals of either slab or curved type are recommended.

5) A drain of sufficient width shall be provided at the bottom of stall urinals so that other places are not fouled in usage. The drain, if open, shall be glazed. Half round urinals may also be considered.

6) Urinals shall be flushed with hand operated cisterns or flush valves discharging through flush pipes and non-ferrous spreaders. However, for public places, use of automatic flushing cisterns or flush valves is recommended.

7) Urinal outlets shall be provided with dome shaped removable grating.

f) *Wash basins*

1) Where the basins are fixed in ranges, it is desirable that they shall be placed at centre-to-centre of at least 75 cm to ensure comfort when basins are in use. The centre line of the last basin shall be kept at least 40 cm from the adjacent wall.

2) Any back skirting shall be true to receive the splash back or the wall tiling.

3) The wash basins may be supported in any one of the ways described in **6.4.16.**

4) Glazed pedestals may be provided for the wash basins, if required. They shall be suitably recessed at the back for the reception of supply, and waste pipes and fittings. They shall be so constructed as to support the basins rigidly and adequately and shall be so designed as to make the height from the floor to top of rim of basin 75 to 80 cm.

5) The flat back wash basin is set against the inside wall. The angle back wash basin is set against a corner of the room. In all cases, the top of the rim of wash basins shall be about 75 to 80 cm above the floor level.

6) Where wash basins are to be provided in the school, the following heights are recommended:

Age Groups	*Height from Floor Level to Rim of the Basin* cm
5 to 7 years	58
7 to 9 years	63
9 to 11 years	68

7) Wherever possible, waste pipe shall be taken through the wall at the back of the fixture rather than extend through the floor beneath it. All pipes shall be completely exposed or easily accessible.

g) *Sinks* — Hot and cold water supplies may be provided, the tap being mounted above the sink.

h) *Bath tubs* — In the case of open fixing, the bath tub shall be placed slightly above the floor level and away from the wall to facilitate cleaning.

j) *Drinking fountains* — Where a drinking fountain is meant for school children, it may be fixed at a height between 45 and 90 cm subject to local conditions.

k) *Showers*

1) A shower may be overhead or at shoulder height or in the case of a foot bath at knee level. Overhead showers may be fixed at a height of 2 metres from floor level.

2) Showers may be arranged singly or in groups to spray water from more than one direction.

3) Hand shower with flexible tube may also be used.

4) Where shower is arranged for cold water supply, each shower shall be controlled by a screw-down stop valve.

5) The shower may be arranged for hot and cold water supplies blended manually by means of a mixing valve [*see* **5.6.6.3** (c)(9)].

Precautions may be taken to ensure equal pressures of both hot and cold water supplies at the mixing valve when in use [*see* **5.7.11.2**(a)].

6) In schools and institutions, the shower may be supplied with hot and cold water already blended by the attendant. This method saves piping and fitting but does not permit user to control the temperature.

6.6.4 *Bath Rooms*

a) Bath rooms of Indian style have a shower and/or a tap.

b) Shower is recommended. Where the tap is considered necessary, it should be fixed at a height of at least 60 cm from floor level. It should be located reasonably away from the outlet and may project about 20 cm from the wall.

c) Bath rooms in which the main fixtures consist of wash basin, bath tub, shower and water-closet, the water-closet is preferably located in a separate compartment.

d) The other accessories in a bath room are soap cup, tooth-brush holder, coat hanger, towel rail, toilet paper holder and mirror.

e) The floor of every bath room shall be constructed of material which does not readily absorb moisture, which can be easily cleaned and is non-slippery. The floor should be sloped away from the door (entrance) towards the outlet with a minimum slope of 1 in 60. The outlet shall be covered by a brass grating to prevent any material which is not to be lost in the drain and to prevent the clogging of the drain by solid waste matter.

f) Every bath room shall be provided with artificial lights so that all parts of the room are easily visible.

g) Ventilation of bath rooms and water-closet compartments is important. Every bath room containing one or more water-closets or urinal shall be ventilated in one of the following ways:

1) Windows having an area of not less than 10 percent of the floor area and located in an exterior wall facing a street, alley, yard or an airshaft. The dimension of the airshaft in the direction perpendicular to the window shall be not less than 1 metre.

2) The ventilation duct shall comply with the requirements laid down in IS : 1256-1967.

3) Skylights in the ceiling should have a glazed surface of at least 0.25 m^2 and arranged so as to provide fixed ventilating openings of at least 0.15 m^2 to the outer air above the roof of the structure or into the courtyard of suitable dimension.

4) Mechanical exhaust ventilation may be permitted under special circumstances. Such system should be of sufficient capacity to exhaust at least 1.15 m^3 of air per minute per water-closet and per

urinal for public toilet room and at least 0.7 m³ per minute per private bath room.

h) It shall not be permissible to use pipe shafts as ventilating shafts:

   1) Bath rooms and water-closet compartments shall not have direct communication with a kitchen or a room used for the preparation of food.

j) The floor level of the water-closet and bath rooms shall be lower than the general floor level.

6.7 Sanitary Pipework Within the Premises

6.7.1 *General* — The soil appliances which collect and discharge excretory matter, discharge through traps into a soil pipe. The waste appliances collect and discharge waste water through traps into a waste pipe. The traps are ventilated by anti-siphonage or ventilating pipes. The ventilating pipe provides a safe outlet into the atmosphere for the foul gases in the drain or sewer. The rain water collected within the premises is carried down the rain water gutters and pipes. The soil pipes discharge into the building (drain) sewer. The waste pipes discharge into a building drain directly or through a trapped gulley. In a partially separate system, where a portion of the rain or storm water is mixed with the sewage, the building sewer (drain) carries rain water also. The vertical main of soil, waste or vent piping is called a stack.

6.7.2 *Systems of Plumbing* — There are four systems of plumbing for building waste water drainage as follows:

a) Two-pipe system,

b) One-pipe system,

c) Single stack system, and

d) Single stack (partially ventilated) system.

See Fig. 27 for system of plumbing. IS : 5329-1983 recommends first three systems only but the fourth system, which is a slight modification of third system, is also much used in practice.

In all these cases, the storm or rain water system is separate.

6.7.2.1 *Two-pipe system* — In this system of plumbing, the soil and the waste pipes are distinct and separate, the soil pipes being connected to the building drain direct and the waste pipes connected to the building drain through a trapped gulley.

All traps of soil appliances are completely ventilated through a separate ventilating pipe. Likewise traps of all waste appliances are also completely ventilated through a separate ventilating pipe. Thus it contains one soil pipe, one waste pipe and two ventilating pipes.

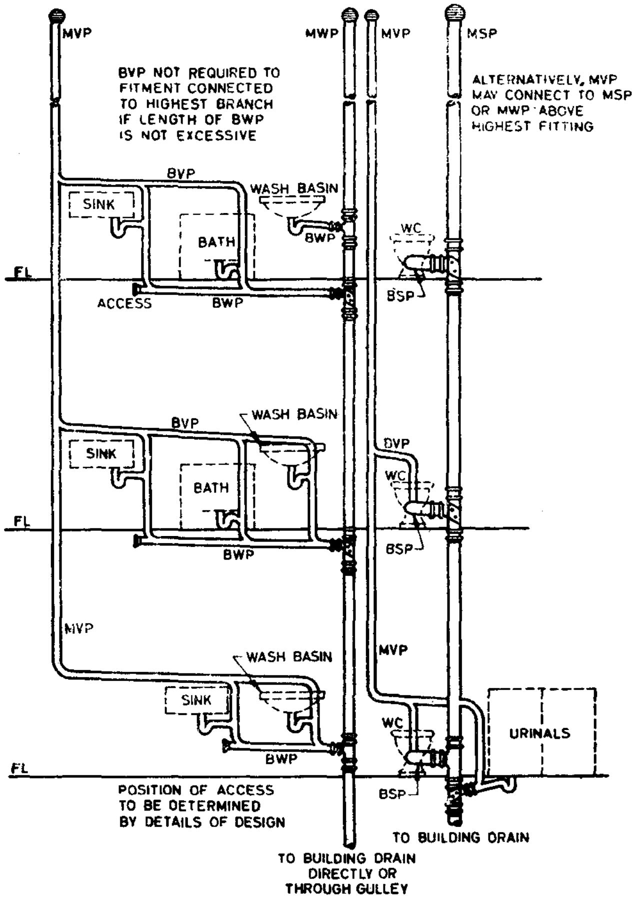


FIG. 27. DIAGRAM OF TWO-PIPE SYSTEM

6.7.2.2 *One-pipe system* — In this system of plumbing, the wastes from all soil appliances are connected to one main pipe which is connected to the building sewer. Gulley traps and waste pipes are completely dispensed with but all the traps of soil and waste appliances are all completely ventilated through a single ventilating pipe. Thus it contains one soil-*cum*-waste pipe and one ventilating pipe for both soil and waste appliances.

6.7.2.3 *Single stack system* — This system of plumbing is the same as one-pipe system but without trap ventilation pipe work. Thus it contains only one soil-*cum*-waste pipe and no ventilating pipe.

6.7.2.4 *Single stack (partially ventilated) system* — This system of plumbing is the same as the one-pipe system but partially ventilated. This is a via-media between the one-pipe system and the single stack system. There is one soil pipe into which all soil and waste appliances discharge and only the traps of soil appliances are ventilated through a single ventilating pipe. Thus it contains soil-*cum*-waste pipe and one ventilating pipe for the soil appliances only.

6.7.3 *Vent Pipe System* — The vent pipe or antisiphonage pipe is installed to provide flow of air to or from a drainage system or to provide circulation of air within such system to protect trap seals from siphonage and back flow. The system consists of one main ventilating pipe (MVP) to which are connected the branch vent pipes (BVP) of each storey. The main ventilating pipe provides a safe outlet of the foul gases in the drain or sewer into the atmosphere.

6.7.4 *Choice of Plumbing System* — The two-pipe system is an age-old and safe system, especially advantageous where the sullage (waste water) from waste appliances can be dealt with separately for use in gardening or any other such purposes. The reasoning behind the two-pipe system in the past has been to segregate what has been regarded as the more objectionable discharges from water-closets and to discharge them to the soil stack, which is, in effect, a direct extension of the building drain. The waste stack is not connected directly to the building drain but to a trapped gulley that discharges to the building drain and forms a barrier to the passage of air from the drain into the waste pipe. Where the two-pipe system is used, the knowledge that the trapped gulley forms a second line of defence against the passage of sewer air into the building via the waste appliances has lead to the use of cheap traps and inadequate water seal. This is a serious defect since the passage of foul air from a waste pipe into a building may be just as objectionable to the occupants as the foul air from a soil pipe. The two-pipe system is a proper system to adopt where conditions are not suitable for the adoption of one of the more modern simplified systems; as for instance where fitments are scattered with water-closets, baths and basins widely separated.

Where the planning of a building provides for a suitable grouping of all soils and waste appliances and where all types of waste waters are taken in a common sewer to the place of disposal or treatment, obviously the one-pipe system is to be preferred. Further, in this system also, the traps of all appliances, soil and waste are fully ventilated. The term one-pipe system is misnomer as there are actually two stacks, one soil-*cum*-waste stack and the other vent stack.

The reasoning behind the one-pipe plumbing system in the past has been based on the fact that there is no second line of defence in the form of a trapped gully against the passage of sewer air into the building at the waste appliances. The trap at the appliance must not fail and to eliminate any risk or failure, every appliance is vented. To make doubly sure deep seal traps were used before. But now it is considered that the 40 mm water seal trap is sufficient for waste appliances and 50 mm water seal for soil appliances. In addition, the following safeguards are to be taken:

a) Each waste pipe shall be connected directly to the common stack above the soil branch at each floor.

b) All traps shall be ventilated by 'loop vents' by means of pipe of not less than 50 mm dia for preserving their seal.

c) Cast iron fittings and branches for waste pipes shall be of the same quality as for soil pipe and all waste pipe joints shall be made gas tight. (IS : 1729-1979 deals with sand cast ventilating, pipes fittings and accessories.)

The modern trend is to go in for a partially ventilated one-pipe or single stack system and the single stack system mainly with a view to economize on the pipe work and taking sufficient safeguards. In the single stack system, the stack itself is made to serve the vent requirements also be restricting the flow in the stack. This system is recommended with 100 mm dia stack up to 4-storey buildings. Not more than two toilet units can discharge to the single stack at each floor level. In high rise buildings, a partially ventilated one-pipe or single stack system is being used where the vent stack is connected to the drainage stack or the soil appliances at each or alternate floors.

The safeguards for the single stack system and the partially ventilated one-pipe or single stack system are as follows:

a) The vertical distance between the waste branch (from floor trap or from the individual appliance) and the soil branch connections when soil pipe is connected to stack above the waste pipe, shall be not less than 20 cm.

b) If appliances like wash basin and the sinks are directly connected to the stack (branch waste pipe less than 75 mm dia), they shall have a 75 mm deep water seal traps. However, if they are connected through the floor trap to the stack, the individual appliances need not have any water seal trap. The floor trap shall have atleast 56 mm water seal. The conventional 50 mm water seal traps in soil appliances are satisfactory. The branches from soil appliances and floor traps shall be of 10 and 7.5 cm dia respectively;

c) The branch pipes from all appliances shall fall gradually and continuously in the direction of flow and shall have a slope of 1 in 10 to 1 in 50.

6.7.5 *Design of the Pipe Layout*

6.7.5.1 *General regarding soil and waste pipe*

a) Pipe work and appliances should be so arranged as to allow close grouping of connections preferably with a water-closet near the main soil pipe. The level of the trap outlet of an appliance shall be studied in relation to the level of the floor and the branch pipe.

b) Pipes should be placed, fixed and jointed so as to avoid risk of damage through variations in temperature. Unless suitable precautions are taken, the jointing of pipes exposed to unduly high temperatures may become unsatisfactory. Small waste pipes are particularly liable to damage caused by the freezing of water from a leaking tap in places where freezing normally occurs.

c) The pipe work in branch connections should always be arranged to allow free drainage of the system. Connections to main or branch pipes should be so arranged as to prevent cross flow from one appliance to another. Connections should be made with an easy sweep in the direction of flow particularly in connections in the single stack system.

d) When the pipes are concealed, inaccessible or laid exposed along with the internal face of the walls, they should preferably be of cast iron. In the ground floor, all the pipes including those laid on the external face of the walls should be of cast iron.

e) Bends should be of long radius where praticable. In the case of bends in the bottommost pipes, they should necessarily be of long radius and should preferably be made of 135° (1/8) bends.

f) Ample provision should be made for access to all pipe work and the embedding of joints in walls should be avoided as far as possible.

g) All pipe work adjacent to living or sleeping quarters should be insulated against sound transmission and steps should be taken to avoid the transmission of noise from one apartment to another by way of pipe system (*see* IS : 1950-1962).

h) Waste fixtures may preferably be connected to the stack directly or through floor traps.

6.7.5.2 *General regarding ventilating pipes*

a) As already mentioned, the main purpose of a trap ventilating or vent pipe is to avoid loss of water in a trap seal caused by siphoning and to prevent admission of foul air to the building caused by back pressure. The air in all branch pipes is constantly renewed by the provision of vent-pipe.

b) One or more building drain ventilating pipes should always be incorporated in a drainage system. Trap-ventilating pipes may be omitted in certain cases.

c) To be effective, a ventilating system should ensure a free circulation of air through the pipes forming the drainage system. The drain ventilating pipe and the main ventilating pipes should be so arranged and of such bore as to meet the requirement under all working conditions.

The sizes of the ventilating pipes have been discussed in **6.7.5.3**.

d) Ventilating pipes should be so installed that water cannot be retained in them. They should be fixed vertically. Wherever possible, horizontal runs should be avoided. The connection of pipe may be done by lead pipe, where necessary.

e) The upper end of the main ventilating pipe may be continued to the open air above roof level as a separate pipe or it may join the main soil pipe (MSP) and/or the main waste pipe (MWP) above the floor level of the highest appliance. Its lower end may be carried down to join the drain at a point where air relief may always be maintained. Four typical method of jointing the main ventilating pipe at the lower end are given in Fig. 28.

f) Branch ventilating pipe should be connected to the top of the branch soil pipe (BSP) and branch waste pipe (BWP) between 75 and 450 mm from the crown of the trap.

g) The ventilating pipe shall always be taken to a point 150 cm above the level of the eaves or flat roof or terrace parapet, whichever is higher, or top of any window within a horizontal distance of 3 m. The least dimension should be taken as a minimum and local conditions should be taken into account.

h) In the case of a window in a gable wall or a dormer window, the ventilating pipes shall be carried up to the ridge of the roof or at least 2 m above the top of the window.

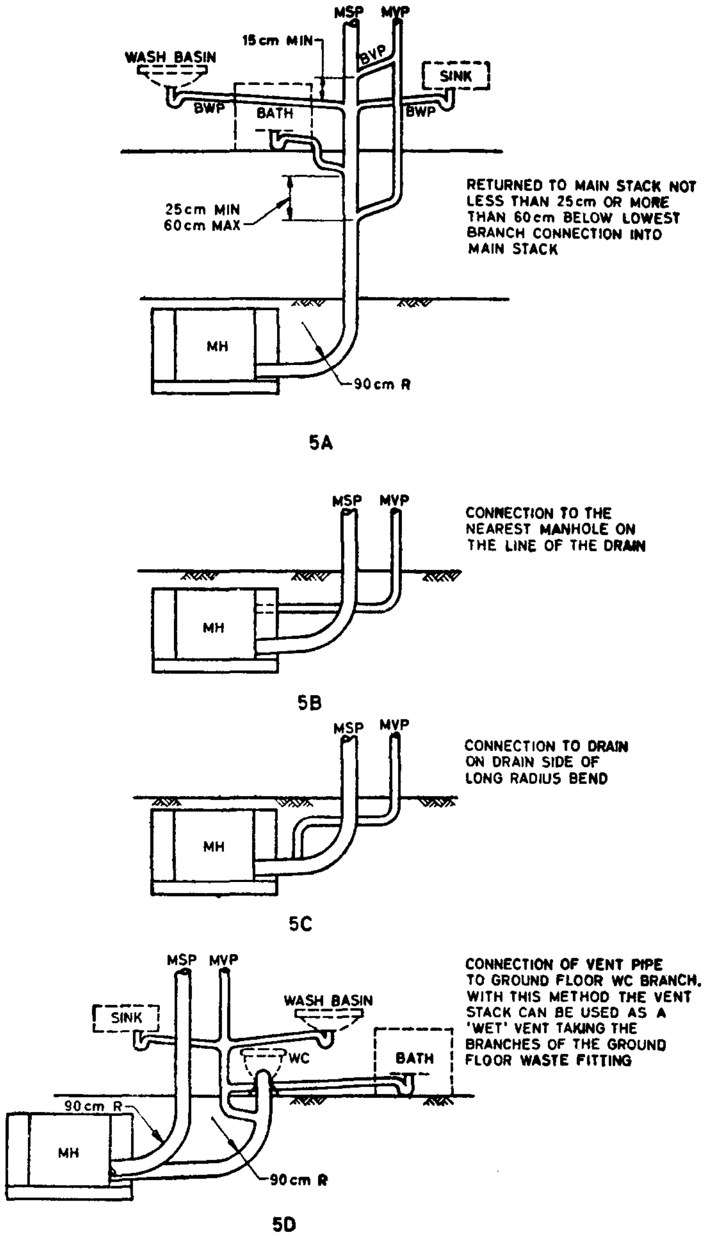


FIG. 28 END CONNECTIONS OF VENT PIPE

j) In the case of a flat roof to which access is provided, it shall be carried up to a height of at least 120 cm above the parapet and not less than 2 m above the head of any window within a horizontal distance of 3 m from the vent pipe and in no case it shall be carried to a height less than 3 m above plinth level.

k) In case the adjoining building is taller, the ventilating pipe shall be carried higher than the roof of the adjacent building.

m) The building drain intended for carrying waste water and sewage from a building shall be provided with at least one ventilating pipe situated as near as practicable to the building and as far away as possible from the point at which the drain empties into the sewer or other carrier.

n) The upper end of every ventilating pipe should be protected by means of a cowl.

6.7.5.3 *Diameter of soil, waste and ventilating pipes* — The diameters of soil and waste pipes should be based on fixture units. The concept of the fixture units is already discussed in **5.6.3.3**. Recommended fixture units for different sanitary appliances or groups of appliances has been given in Table 30.

The fixture units not listed in Table 30 shall be estimated in accordance with Table 31.

The recommended sizes for branches and stacks may then be read off from Table 52.

The recommended pipe sizes for building sewers may be read off from Table 53.

The results should be checked to see that the soil waste and building sewer pipes are not reduced in diameter in the direction of flow. Where appliances are to be added in the fixture, these should be taken into account in assessing the pipe sizes.

Branches and stacks which receive discharges from soil appliances should not be less than 100 mm except where the outlet from the siphonic water-closet is 80 mm, in which case a branch pipe of 80 mm may be used. Outlet of floor traps may be of 75 mm diameter.

The gradient of a horizontal branch should not be flatter than 1 in 50 and not steeper than 1 in 10.

Waste pipes — Every pipe for carrying waste or overflow water from every bath, wash basin or sink to a drain shall be of 32 to 50 mm diameter. Waste stacks shall have a minimum dia of 75 mm.

TABLE 52 RECOMMENDED PIPE SIZES FOR BRANCHES AND STACKS

(*Clause* 6.7.5.3)

Diameter of Pipe mm	Maximum Number of Fixture* Units That May be Connected to			
	Any Horizontal Fixture Branch†	One Stack of 3 Storeys in Height or 3 Intervals	More than 3 Storeys in Height	
			Total for stack	Total at one storey or branch interval
(1)	(2)	(3)	(4)	(5)
30	1	2	2	1
40	3	4	8	2
50	6	10	24	6
65	12	20	42	9
75	20	30	60	16
100	160	240	500	90
125	360	540	1 100	200
150	620	960	1 900	350
200	1 400	2 200	3 600	600
250	2 500	3 800	5 600	1 000
300	3 900	6 000	8 400	1 500
375	7 000	—	—	—

*Depending upon the probability of simulataneous use of appliances considering the frequency of use and peak discharge rate.

†Does not include branches of building sewer.

TABLE 53 MAXIMUM NUMBER OF FIXTURE UNITS THAT CAN BE CONNECTED TO BUILDING DRAINS AND SEWERS

(*Clause* 6.7.5.3)

Diameter of Pipe mm	Gradient			
	1/200	1/100	1/50	1/25
100	—	180	216	250
150	—	700	840	1 000
200	1 400	1 600	1 920	2 300
250	2 500	2 900	3 500	4 200
300	3 900	4 600	5 600	6 700
375	7 000	8 300	10 000	12000

NOTE 1 — Maximum number of fixture units that may be connected to any portion (*see* Note 2) of the building drain or the building sewer is given.

NOTE 2 — Includes branches of the building sewer.

Ventilating pipes

a) The building drain ventilating pipe should be not less than 75 mm in diameter when, however, it is used as main soil pipe or main waste pipe (MSP or MWP). The upper portion, which does not carry discharges, should not be of lesser diameter than the remaining portion.

b) The diameter of the main ventilating pipe should not be less than 50 mm.

c) A branch ventilating pipe on a waste pipe in both one- and two-pipe systems should be of not less than two-thirds the diameter of the branch waste ventilated pipe subject to a minimum of 25 mm.

d) A branch ventilating pipe on a soil pipe should be not less than 32 mm in diameter.

6.7.5.4 *Traps*

a) Traps which are fittings or parts of appliances that retain water so as to prevent the passage of foul air into the building should be properly sited. A trap may be formed as an integral trap with the appliance during manufacture or may be a separate fitting called an attached trap which may be connected to the waste outlet of the appliance.

b) Traps should always be of a self-cleansing pattern. A trap, which is not an integral part of an appliance, should be directly attached to its outlet and the pipe bore should be uniform throughout and have a smooth surface.

c) Traps for use in domestic waste installations and all other traps should be conveniently accessible and provided with cleansing eyes or other means of cleaning.

d) The minimum internal diameter for waste appliances shall be as given in Table 54.

TABLE 54 MINIMUM INTERNAL DIAMETERS FOR WASTE APPLIANCES

Sl No.	Waste Appliances	Minimum Internal Dia in mm
i)	Drinking fountains	25
ii)	Wash basins	30
iii)	Bidets	30
iv)	Domestic sinks and baths	40
v)	Shower bath trays	40
vi)	Domestic bath tubs	50
vii)	Hotel and canteen sinks	50
viii)	Urinals:	
	a) Stall urinals (with not more than 120 cm of channel drainage)	50
	b) Lip urinals	40
ix)	Floor traps (outlet diameter)	65

e) The depth of water seals for different plumbing systems shall be as given in Table 55.

6.7.5.5 *Design of single stack plumbing system*

a) The appliance should be grouped as closely as possible round the main stack so as to keep the branch pipes short and reduce noise.

b) Branch connections should be of large radius along the invert as shown in Fig. 29.

c) Flat gradients reduce self-siphonage and noise; waste pipes should fall at between 1 in 50 and 1 in 10.

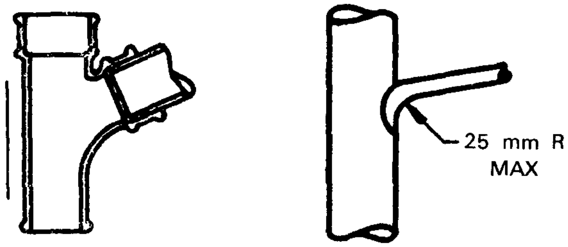
TABLE 55 DEPTH OF SEALS FOR DIFFERENT PLUMBING SYSTEM

(*Clause* 6.7.5.4)

Sl No.	Item	Depth of Water Seal in Plumbing Systems in mm			
		Two-Pipe	One-Pipe	Single Stack	Partially Ventilated One-Pipe or Single Stack
i)	Water-closets	50	50	50	50
ii)	Floor traps	50	50	50	50
iii)	Other fixtures directly connected to the stack				
	a) Where attached to branch waste pipe of dia 75 mm 75 mm or more	40	40	40	40
	b) Where attached to branch waste pipe of less than 75 mm dia	40	40	75	75

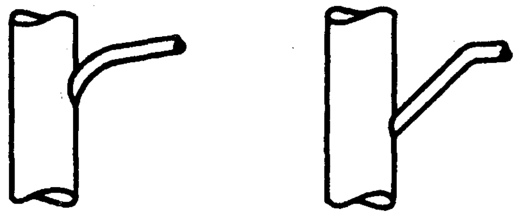
NOTE 1 — In the case of a water closet having the rural pattern, connected to an individual disposal system the water seal shall be 20 mm.

NOTE 2 — Where connection is made through floor trap no separate seals are required for individual fixtures.



29A 29B

SATISFACTORY



29C 29D

UNDESIRABLE ON ACCOUNT
OF SELF SIPHONAGE

FIG. 29 SINGLE STACK SYSTEM—WASTE-PIPE CONNECTIONS

d) A typical method of single stack plumbing is shown in Fig. 30 (A and B).

e) The stack shall be 100 mm in diameter.

f) All apliances directly connected to stack are trapped.

g) Pipes should fall gradually and continuously in the direction of flow.

h) When the basin and bath are at some distance from the stack, it may be cheaper and simpler to combine the waste pipes into one than to run each separately to the stack. Alternatively, a 32 mm dia trap with a short 32 mm tail pipe may be arranged to discharge into 38 or 50 mm waste pipe. Any bends in the waste should be of large radius.

j) The recommendations for the design of several components are given in Table 56.

6.7.5.6 *Storm water drainage pipes* — This has been dealt with in detail in **6.8**.

6.8 Storm Water Drainage

6.8.1 *General*

a) The object of the storm water drainage is to collect and carry, for suitable disposal, the rain water collected within the premises of the building.

b) Rainfall statistics for the areas under consideration shall be studied to arrive at a suitable figure on the basis of which the storm water drains could be designed. Consideration shall be given to the effects of special local condition and to the intensity and duration of rainfall.

c) The impermeability factor, that is, the proportion of the total rainfall discharging to a surface water drain after allowing for soakage, evaporation and other losses varies with the frequency and duration of rainfall. These factors shall be taken into account in design.

The whole of the rainfall on impervious areas shall be assumed to reach the drains, no allowance for evaporation or time of concentration being made in domestic drainage work. The roof area shall be taken as the horizontal projection of the area.

6.8.2 *Rain Water Pipes for Drainage of Roofs*

a) The roofs of a building shall be so constructed or framed as to permit effectual drainage of the rain water therefrom by means of a sufficient number of rain water pipes of adequate size so arranged, jointed and fixed as to ensure that the rain water is carried away from the building without

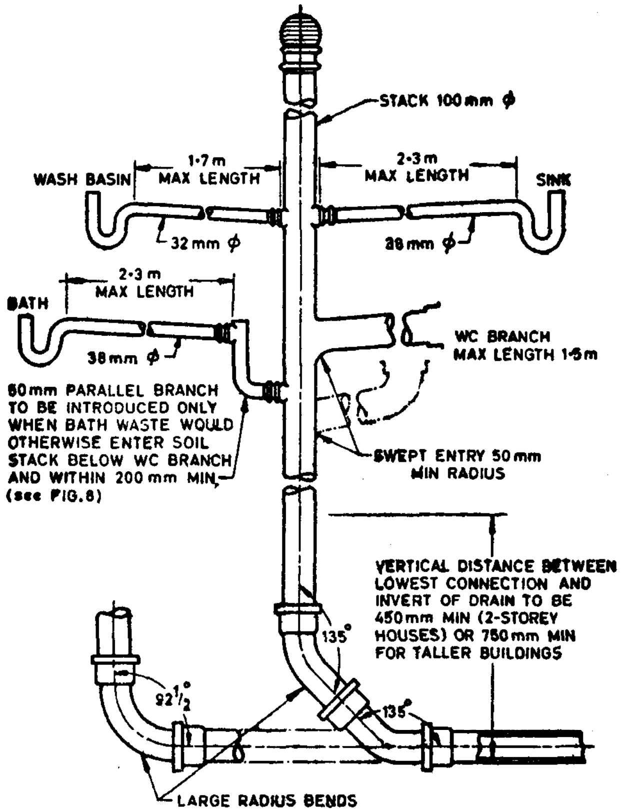


FIG. 30A SINGLE STACK STACK SYSTEM (WESTERN STYLE)

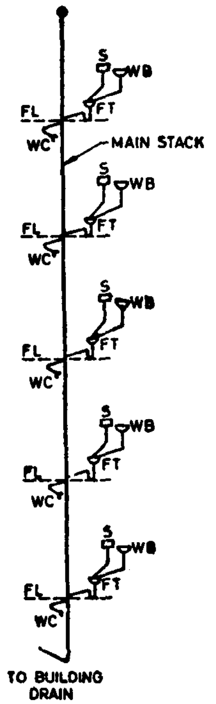


FIG. 30B SINGLE STACK SYSTEM (INDIAN PRACTICE)

FIG. 30 MAIN FEATURES OF DESIGN OF SINGLE STACK SYSTEM

causing dampness in any part of the walls or foundations of the building or those of an adjacent building.

b) The rain water pipes shall be fixed to the outside of the external walls of the building or in recesses or chases cut or framed in such external walls or in such other manner as may be approved by the administrative authority.

c) A rain water pipe conveying rain water shall discharge directly or by means of a channel into or over an inlet to a surface drain or shall discharge freely in a compound, drained to surface drain but in no case shall it discharge directly into any closed drain.

d) Whenever it is not possible to discharge a rain water pipe into or over an inlet to a surface drain or in a compound, drain to a surface drain or in a street drain within 30 m from the boundary of the premises, such rain water pipe shall discharge into a gulley trap which shall be connected with the street drain. Such a gulley trap shall have a screen and a silt catcher incorporated in its design.

e) If such street drain is not available within 30 m of the boundary of the premises, a rain water pipe may discharge directly into the kerb drain and shall be taken through a pipe outlet across the foot path, if any, without obstructing the path.

f) A rain water pipe shall not discharge into or connect with any soil pipe or its ventilating pipe or any waste pipe or its ventilating pipe, nor shall it discharge into a sewer unless specifically permitted to do so by the administrative authority, in which case such discharge into a sewer shall be intercepted by a gulley trap.

g) Rain water pipes shall be constructed of cast iron, asbestos cement, galvanized sheet or other equally suitable material and shall be securely fixed. The latest practice, however, is not to use the pipes made from galvanized sheets for rain water services. Cast iron rain water pipes and fittings shall conform to IS : 1230-1979. Asbestos cement building pipes, and gutters and fittings (spigot and socket type) shall conform to IS : 1626 (Part 1)-1980, IS : 1626 (Part 2)-1980 and IS : 1626 (Part 3)-1981.

h) *Sizing of rain water pipes for roof drainage* — Rain water pipes shall be normally sized on the basis of roof areas according to Table 57.

TABLE 56 RECOMMENDATIONS FOR DESIGN OF SINGLE-STACK SYSTEM

(*Clause* 6.7.5.5)

SL No	COMPONENT	ACTION TO BE GUARDED AGAINST	DESIGN RECOMMENDATIONS
i)	Wash basin waste	Self-siphonage	75 mm seal P-trap to be used. The maximum slope of 40 mm waste pipe to be determined from Fig. 31 according to the length of waste pipe. Any bends to be not less than 75 mm radius to centre line Waste pipes longer than the recommended maximum length of 165 cm should be vented, or a larger diameter waste pipe or approved resealing trap should be used
ii)	Bath and sink wastes 38 mm trap and 38 mm waste pipe	Self-siphonage	75 mm seal traps to be used. Self-siphonage not important. Length and slope of waste branch not critical, but long waste pipes may be troubled by sedimentation and access for cleaning should be provided
		Backing up of discharge from WC branch into bath branch	Position of entry of bath waste into stack to be as in Fig. 39 the bath waste pipe may be connected to the stack at or above the point where the centre line of the WC branch meet the centre line of the stack or atleast 20 cm below it
iii)	Soil branch connection to stack	Induced siphonage lower in the stack when WC is discharged	WC connections should be swept in the direction of flow. Fittings should have a minimum sweep of at least 5 cm radius.
iv)	Bend at foot of stack (*see* Fig. 29)	Back pressure of lowest branch. Build-up of detergent foam.	Bend to be of large radius or two 135° bends to be used. Vertical distance between lowest branch connection and invert of drain to be at least 750 mm (450 mm for 2-storeyed houses with 100 mm stack).
v)	Offsets in stacks	Back pressure above offset	There should be no offsets in stacks below the topmost appliances unless venting is provided to relieve any back pressure. Offsets above the topmost appliances are of no significance
vi)	Floor straps and 75 mm branch pipe	Induced siphonage	50 mm seal trap to be used. Slope of the branch pipe may vary from 1 in 50 to 1 in 10

NOTE — The recommendations apply to systems with swept-inlet WC branches. With straight inlet branches, a 100 mm stack with no vents has been found satisfactory for up to four-storeys, a 150 mm stack with no vents has been found satisfactory for up to 15 storeys.

TABLE 57 SIZING OF RAIN WATER PIPES FOR ROOF DRAINAGE

(*Clause* 6.8.2)

SL No.	DIA OF PIPE mm	AVERAGE RATE OF RAINFALL IN mm/h					
		50	75	100	125	150	200
		Roof area in square metres					
i)	50	13.4	8.9	6.6	5.3	4.4	3.3
ii)	65	24.1	16.0	12.0	9.6	8.0	6.0
iii)	75	40.8	27.0	20.4	16.3	13.6	10.2
iv)	100	85.4	57.0	42.7	34.2	28.5	21.3
v)	125	—	—	80.5	64.3	53.5	40.0
vi)	150	—	—	—	—	83.6	62.7

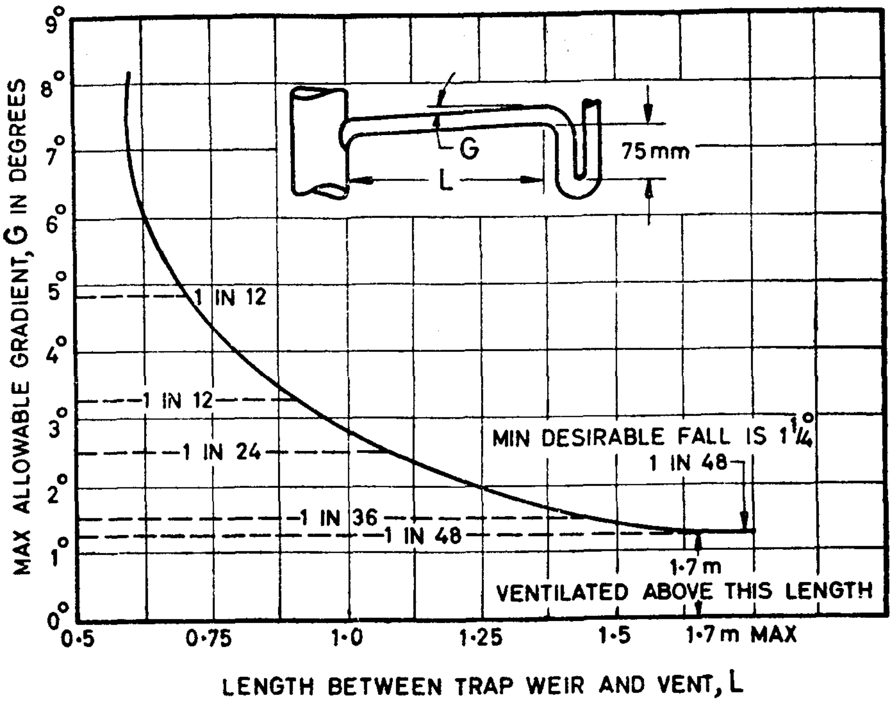


FIG. 31 LENGTH AND FALL OF BASIN WASTE DESIGN CURVE FOR 32 mm WASTE AND 75 mm SEAL P-TRAPS CONNECTED TO SINGLE WASH BASIN

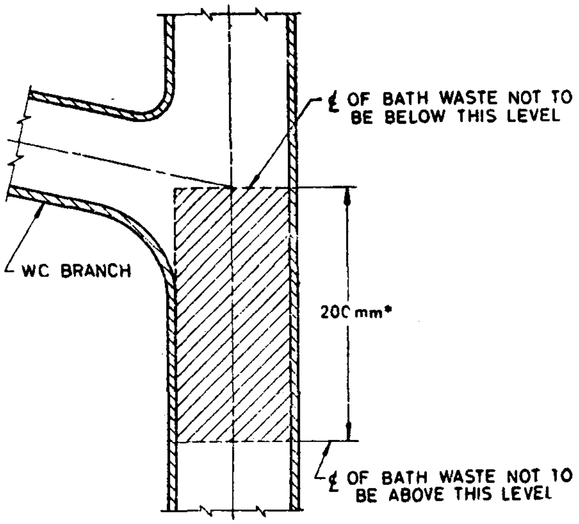


FIG. 32 CONNECTION OF BATH WASTE TO STACK

j) A bell mouth inlet at the roof surface is found to give better drainage effect, provided proper slopes are given to the roof surface.

k) The spacing of pipes depends on the position of the windows and arch openings but 6 m apart is a convenient distance.

m) The strainer fixed to the bell mouth inlet shall have an area $1\frac{1}{2}$ to 2 times the area of pipe which it connects.

n) The storm water shall be let off in a suitable open drain to a water course. The open drain, if not of pucca masonry throughout, shall be so at least where there is either a change in direction or gradient.

p) *Size and gradient of horizontal pipes* — The horizontal pipes shall be so designed as to give a velocity of a flow of not less than 1 m/s when running half full. The maximum velocity shall not exceed 2.5 m/s.

6.8.3 *Disposal of Storm, Rain or Surface Water*

6.8.3.1 Storm, rain or surface water may be disposed off in one or more ways specified below but preferably by the separate system.

6.8.3.2 *Separate system*

a) All courtyards shall be provided with one or more outlets through which rain water may pass to the storm water system. All rain water shall be diverted into the storm water drains and away from any opening connecting with any sewer.

b) Where storm water drains are necessary for the discharge of rain water to a public storm water drain, such drains shall be designed for the intensity of rain based on local conditions but in no case they shall be designed for intensity of rainfall of less than 13 mm/h.

c) Usually each separate plot shall have a separate drain connection made to a covered or open public drain. Such connection to a covered drain shall be made through a pipe at least 3.5 m in length laid at a gradient of not less than that of the connecting drain.

The storm water from the plot should discharge into the storm water drain directly and not through a trap.

6.8.3.3 *Combined or partially separate system* — Where levels do not permit connection to a public storm water drain, storm water from courtyards may be connected to the public sewer, provided it is designed to convey combined discharge. In such cases the surface water shall be admitted to the soil sewer through trapped gulleys in order to prevent the escape of sewer air.

6.8.3.4 *Discharge into a water course* — It may often be convenient to discharge surface water to a nearby stream or a water course. The invert level of the outfall shall be about the same as the normal water level in the water course. The outfall shall be protected against floating debris by a screen.

6.8.3.5 *Discharge to storage tanks* — Water from the roof of a building may be led straight from the down pipes to one or more water-tight storage tanks. Such storage tanks shall be raised to a convenient height above ground and shall always be provided with ventilating cover and have draw-off taps suitably placed so that the rain water may be drained off for domestic washing purposes or for garden water. A large impervious storage tank is sometimes constructed underground, from which rain water is pumped as required to the house. All storage tanks shall be provided with an overflow.

6.8.3.6 *Diversion of the first washings* — An arrangement shall be provided in the rain water leader to divert the first washings from the roof or terrace catchment as they would contain much undesirable material. The mouth of all pipes and openings shall be covered with mosquito proof wire net.

6.8.3.7 *French drains* — May be employed as surface water drains and are useful in the drainage of unpaved surface, such as play fields and certain types of roads. When used for this purpose, in addition to the drain being filled with rubble, it is often advisable to include a field drain in the trench bottoms.

6.9 Subsoil Water Drainage

6.9.1 *General* — Subsoil water is that portion of the rainfall which is absorbed into the ground and the drainage of subsoil water may be necessary for the following reasons:

a) To increase the stability of the surface;

b) To avoid surface flooding;

c) To alleviate or avoid causing dampness in the building, especially in the cellars or underground rooms or vaults;

d) To reduce the humidity in the immediate vicinity of the building; and

e) To increase the workability of the soil.

6.9.2 *Depth of Water Table* — The standing level of the subsoil water will vary with the season, the amount of rainfall and the proximity and level of drainage channels. Information shall be obtained regarding this level by means of boreholes or trial pits, preferably the latter. It is desirable, though not always practicable, to ascertain the level of the standing water over a considerable period so as to enable the seasonal variations to be recorded and in particular the higher water level. The direction of the flow of subsoil water may usually be judged by the general inclination of the land surface and the main lines of the subsoil drains shall follow the natural falls, wherever possible.

6.9.3 *Precautions*

a) Subsoil drains shall be sited so as not to endanger the stability of the buildings or earthwork.

In some portions of the drain, it may be necessary to use non-porous jointed pipe.

b) No field pipe shall be laid in such a manner or position as to communicate directly with any drain constructed or adopted to be used for conveying sewage except where absolutely unavoidable and in that case a suitable efficient trap shall be provided between subsoil drain and such sewer.

6.9.4 *Systems of Subsoil Drainage*

6.9.4.1 *Field drain pipes* — Clay or concrete porous pipes may be used and shall be laid in one of the following ways.

a) *Natural* — The pipes are laid to follow the natural depressions or valleys of the site, branches discharging into the main as tributaries into a river.

b) *Herringbone* — A system consisting of a number of main drains into which discharge from both sides, smaller subsidiary branches parallel to each other at an angle to the mains forming a series of Herringbone pattern.

c) *Grid* — A main or mains near the boundaries of a site into which branches discharge from one side only.

d) *Fan-shaped* — The drains are laid converging to a single outlet at one point on the boundary of a site without use of main or collecting drains.

e) *Moat or cut-off system* — Sometimes drains are laid on one or more sides of a building to intercept the flow of subsoil water and thereby protect the foundations.

6.9.4.2 The choice of one or more of these systems will naturally depend on the local conditions of the site. For building sites, the mains shall be not less than 75 mm in diameter and the branches not less than 65 mm in diameter but normal practice tends towards the use of 100 and 75 mm respecitively. The pipes shall generally be laid at 60 to 90 cm depth or to such a depth to which it is desirable to lower water table and the gradients are determined rather by the fall of the land than by consideration of self-cleansing velocity. The connection of subsidiary drain to main drain is best made by means of a clayware or concrete junction pipe. The outlet of subsoil system may discharge into a soakaway or through a catch pit into the nearest ditch or water course. Where these are not available, the subsoil drains may be connected, with the approval of the administrative authority, through an intercepting trap to the surface water drainage system.

6.10 Public Drainage System

6.10.1 *General* — The human excreta, which has its source in the house, has to be transported, treated and disposed off finally without creating nuisance and endangering life. The transportation of the excreta in the solid state poses problems due to fly breeding, smell and other nuisance. The best sanitary method is the water carriage system in which water is used to flush the closet and transport the solid excreta in an impervious pipeline or sewerage system to the treatment and disposal sites. This system does not pollute the soil and water, and avoids the exposure of the foul material to flies.

6.10.2 *Types of Systems* — If the pipeline or sewers carry only the sanitary sewage, the system is called a separate system. If the sewers carry only the storm water, the system is called a storm sewerage system. If both sanitary sewage and storm water are combined to flow into a single pipeline, the system is called a combined system. In practice, it is not possible to completely isolate storm water from mixing with the sanitary sewage and the result is a partially combined system.

6.10.3 *Design Basis for the Sewerage System*

6.10.3.1 *Estimate of flow* — The sanitary sewage is mostly the spent water of the community with some ground water infiltering into the systyem as well as a portion of the storm water that invariably gets into the system through courtyards of houses, etc. The estimate of flow is, therefore, based upon the contributory population for the design period and the per capita water supply or per capita contribution of the sewage. The following design periods are recommended:

a) For laterals, submains and mains—ultimate phase development after 30 years, and

b) Trunk sewers, outfall sewers and intercepting sewers—Phase I—15 years; Phase II—ultimate development after 30 years.

6.10.3.2 *Population estimate* — There are several methods used for forecasting the population of a community. The most suitable approach is to base the estimation either on anticipated ultimate density of population or on floor space index.

In case the desired information on population is not available in the master plan of the town, the following densities are suggested for adoption.

Size of Town (Population)	*Density of Population per Hectare*
Up to 5 000	75-150
5 000 to 20 000	150-250
20 000 to 50 000	250-300
50 000 to 1 00 000	300-350
Above 1 00 000	350-1 000

6.10.3.3 *Per capita rate* — Although the entire spent water of a community should find its way into the sanitary sewer, it has been observed that a small portion is lost in evaporation, seepage into ground, leakage, etc. The percentage of water reaching the sewer may vary from 40 percent in arid areas to about 90 percent in intensively developed areas. In general, 80 percent figure may be taken for design. The sewers should be designed for a minimum of 150 litres per capita per day.

In cases where industries have their own separate water supply but discharge these wastes into the sanitary sewer, the estimation of such wastes should be made and taken into consideration for the estimation of the flow in the system.

6.10.3.4 *Ground water infiltration* — This depends upon the quality of workmanship in laying of sewers and the height of water table. Suggested estimates for ground water infiltration for sewers laid below ground water table are as follows:

	Minimum	*Maximum*
l pd per hectare	5 000	50 000
l pd/km of sewer/ cm dia	500	5 000
l pd/manhole	250	500

6.10.3.5 *Storm run-off* — Storm run-off is dependent on intensity and duration of precipitation, characteristics of the tributary area and the time required for such flow to reach the sewer. The *rational method* is to be preferred to the empirical formulae. The run-off reaching the sewer is given by the expression:

$$Q = 10CiA$$

where

q = run-off in m^3/h;

C = coefficient of run-off;

i = intensity of rainfall in mm/h; and

A = area of the drainage district in hectares.

The frequency of storm, for which the sewers are to be designed, depends upon the importance of the drainage area. Commercial and industrial areas should be subject to less frequent flooding than the residential areas. The suggested frequency of flooding in the different areas is as follows:

	Frequency
a) Residential Areas	
1) Peripheral areas	twice a year
2) Central and comparatively high priced areas	once a year
b) Commercial and high priced areas	once in 2 years

The intensity of precipitation decreases with duration. An analysis of past records for the area concerned will help to assess the intensity fairly.

Co-efficient of run-off — The portion of rainfall which finds its way into the sewer is dependent upon the imperviousness and the shape of the area apart from the duration of storm.

6.10.3.6 *Peak factors in sewer design* — Sewers, while carrying the waste water discharge for which they are designed, have also to transport suspended solids in such a manner that deposition and odour nuisance therefrom are kept to a minimum. Sewers are designed for flows with free water surface and self-cleansing velocities. Pressure sewers are to be avoided as far as practicable. The sewers are designed for peak flows and the peak factors recommended are given below. The peak factor or the ratio of maximum to average flow depends upon the contributory population.

Population	*Peak Factor*
Up to 20 000	3.5
20 000 to 50 000	2.5
50 000 to 7 50 000	2.25
Above 7 50 000	2.0

6.10.3.7 *Self-cleansing velocity* — It is necessary to ensure a minimum of self-cleansing velocity in a sewer to prevent deposition of suspended solids. A minimum velocity of 0.8 m/s at design peak flow is recommended subject to a minimum velocity of 0.6 m/s for present peak flows. The maximum velocity should not exceed 3 m/s to avoid erosion due to sand and other gritty material carried in the sewer.

Minimum size for street sewer in	
Flat terrains	200 mm
For hilly areas (where slopes are prevelent)	100 mm

6.10.3.8 *Depth of flow* — From consideration of ventilation in waste water flow, sewers should not be designed to run full.

Up to 400 mm dia, sewers may be designed to run at half depth; 400 to 900 mm—at two-thirds depth and larger sewers—at three-fourths depth at ultimate peak flows.

6.10.3.9 *Sewer transitions* are needed for change in size, slope alignment, volume of flow, sewer junctions, etc. Manholes are to be provided at all such transitions.

The hydraulic formulae to be adopted are the Manning's formula for free flow conduits and the Hazen-William's formula for pressure conduits. These are described in **4.12** and **4.11** respectively.

6.10.3.10 *Sewer appurtenances* — These are the necessary devices, in addition to pipes and conduits, for the proper functioning of the sewerage system. This include manholes, lamp holes, gulley traps, intercepting chambers, flushing tanks, ventilating shafts, street inlets, siphons, grease traps, venturi flumes, leaping weirs, etc.

6.10.4 *Materials for Sewer Construction*

6.10.4.1 Brickwork is often used for construction of sewers particularly for larger diameters. The advantage is that they could be constructed in any shape and size. Brick sewers shall have cement concrete or stone for invert and 12.5 mm thick cement plaster with neat finish for the remaining surface. To prevent ground water infiltration, the outside is preferably plastered. Under special conditions, protection against corrosion may be necessary. Sewer bricks should conform to IS : 4885-1968.

6.10.4.2 *Concrete* — Generally RC pipes are only used. Reinforced concrete pipes may be prepared to suit any size and thickness with various percentage of reinforcement. Number of jointing methods are available to suit the pressures and the tightness required. Another factor in favour of these pipes is the rapidity with which the trench may be opened and backfilled. Non-pressure pipes are used for gravity flow and pressure pipes are used for force mains. However, these pipes are subject to corrosion where acid discharges are carried in the sewer or where velocities are not sufficient to prevent septic conditions or where the soil is highly acidic or contain excessive sulphates. Protective liming or coatings are necessary in such cases. Only high alumina cements should be used in such cases (*see also* **5.5.6** to **5.5.8**).

6.10.4.3 *Cast* in-situ *reinforced concrete* — Cast *in-situ* reinforced concrete sewers are constructed where it is more economical or where non-standard sections are required or when a special shape is required. Rectangular sewers having their width in excess or 1½ times their height become uneconomical and have poor hydraulic characteristics. Wide flat culvert bottoms should be provided with a 'Vee' of at least 15 cm depth in the centre. The formwork used should ensure a smooth interior for the sewer. For RC work, a minimum clear cover of 50 mm over reinforcement steel should be used for obtaining a dense concrete structure free of voids. Concrete should conform to IS : 456-1978.

6.10.4.4 *Stoneware or vitrified clay* — Salt glazed stoneware pipes are manufactured in sizes 100 to 600 mm in dia but the maximum size usually used is 380 mm because of economic consideration. The length of vitrified clay pipes are 60, 75 and 90 cm, the preference being for the longer pipes for obvious reasons (*see also* **5.5.11.2**). The resistance of vitrified clay pipes to corrosion from most acids and erosion due to grit and high velocities gives it an advantage over other pipe materials in handling such wastes. The strength of vitrified clay pipes often necessitates special bedding or concrete cradling to improve field supporting strength.

6.10.4.5 *Asbestos cement* — Asbestos cement pipes are usually manufactured in sizes ranging from 80 to 600 mm in dia (*see* IS : 6908-1975). Some of the advantages of AC pipes are:

a) non-corrosiveness to most natural soil conditions;

b) freedom from electrolytic corrosion;

c) lightweight;

d) easy in cutting, drilling, threading and fitting with GI specials;

e) allowance of greater deflection up to about 30 cm with mechanical joints;

f) ease of handling;

g) tight joints; and

h) quick laying and back filling.

Some of the disadvantages are:

a) they cannot stand high superimposed loads and may be broken easily;

b) they are subject to corrosion by acids, highly septic sewage and by highly acidic or high sulphate soils, and need suitable protective measures; and

c) where grit is present, high velocities, such as those encountered in steep grades may cause erosion (*see also* **5.5.9**).

6.10.4.6 *Cast iron* — Cast iron pipes in sizes ranging from 150 to 750 mm in dia with a variety of jointing methods are used for pressure sewers, sewers above ground surface, submerged outfalls piping in sewage treatement plants and occasionally on gravity sewers where absolutely water-tight joints are essential (*see also* **5.5.4**).

The advantages of CI pipes are:

a) long laying lengths with tight joints;

b) ability to withstand high internal pressure and extrernal loads; and

c) corrosion resistance to most natural soils; they are, however, subject to corrosion by acids or highly septic sewage and acid soils.

Wherever it is necessary to deflect pipes from a straight line either in the horizontal or in the vertical plane, the amount of deflection allowed should not normally exceed 2.5° for lead caulked joints and not more than 10° for mechanical joints.

When specifying CI pipes, it is necessary to give the pipe class, the type of joint, the type of lining and the type of exterior coating.

6.10.4.7 *Steel* — Acqueducts, pressure sewer mains, under-water river crossing, necessary connections for pumping stations, self-supporting spans and railway crossing are some of the situations where steel pipes are preferred.

Steel pipes can withstand internal pressures, impact load and vibrations much better than CI pipes. They are more ductile and withstand water hammer better. They are generally preferred for diameters above 750 mm.

The disadvantages are:

a) inability to withstand high external load;

b) likely to collapse when it is subject to negative pressure; and

c) they are susceptible to various types of corrosion.

A thorough soil survey is needed all along the alignment where steel pipes are proposed. Steel pipes should be protected from external corrosion by cathodic protection (*see also* **5.5.5**).

6.10.4.8 *Plastic pipes* — The use of plastic, polyethylene or unplasticized PVC for sewer pipes carrying domestic sewage is not common. But in special cases, where industrial wastes with corrosion problems are to be handled, these pipes may be conveniently used (*see also* **5.5.10**).

6.10.5 *Corrosion Prevention in Sewers*

6.10.5.1 *General* — The main cause of corrosion in sewers is chemical reaction between the constituents of sewage and the material of sewers that come in intimate contact with each other and exposure to gases, particularly hydrogen sulphide emanating from the decomposing sewage in the sewers and which gets oxidized to sulphuric acid.

The more important of the contributing factors are high temperature of sewage, high BOD, low velocity of flow, detention period in force mains and wet wells, degree of turbulance in partially filled conduits and lack of ventilation.

Corrosion control methods can either be the treatment of the sewage or the conveyance system.

6.10.5.2 *Protective barriers* — Commonly used protective barriers for steel, concrete and stoneware pipes are:

a) cement plasters;

b) epoxy resins;

c) PVC sheets;

d) bitumen and coal tar products;

e) fibre glass; and

f) paints.

These linings should be provided under strict supervision and control. Protecting concrete and asbestos cement pipes against acid attack by means of a barrier is difficult.

If any acid gains access to the interior of lining, the damage is done and the effectivness of the lining is destroyed.

6.10.6 *Construction and Maintenance of Sewers*

6.10.6.1 *Construction of sewers* — The planning and construction of sewers are so inter-dependent, the knowledge of one is an essential pre-requisite to the competent performance of the other. The ingenuity of the planner, the supervising engineer and the contractor is continually called for, to reduce the construction cost and to achieve a quality workmanship. The width of trench at and below the top of a sewer should be the minimum necessary for its proper installation with the consideration to its bedding. Excavation for sewer branches for laying sewers shall be in straight lines and to the correct depths and gradients required for the pipes as specified in the drawings. The shoring shall be adequate to prevent caving in the trench walls or subsidence of areas adjacent to the trench. Trenches for sewer construction shall be dewatered for the placement of concrete and the laying of sewer pipe or construction of concrete or brick sewer and kept dewatered until the concrete foundations, pipe joints or brick work and concrete have cured.

Tunnels are employed in sewer systems when it becomes economical, considering the nature of soil to be excavated and surface conditions with reference to the depth at which the sewer is to be laid. Generally in soft soils the minimum depth is about 10 m; in rocks, however, tunnels may be adopted at lesser depths. Shafts are essential in tunnelling to gain access to the depth at which tunnelling is to be done and to remove the excavated material. Shafts are not normally placed at less than 150 m depending on the depth and size of tunnel. All tunnels more 15 m in length should be provided with ventilation arrangement. The tunnelling methods adopted for sewer construction can be classified generally as sugar or boring; jacking of preformed steel or concrete lining; and mining methods.

6.10.6.2 *Maintenance of sewerage systems* — Maintenance of sewers, in general, relates to the work of keeping any installed sewerage facility in a working condition for the benefit of the people for whom it is intended. It may be preventive or routine maintenance which constitutes works executed and precaution taken to prevent any breakdown of sewerage facilities or corrective maintenance which constitutes work of repairs after a breakdown has occurred. Preventive maintenance is more economical and provides for reliability in operation of the sewerage facilities; nevertheless corrective maintenance will also have to be provided for, as breakdowns are possible inspite of the preventive maintenance. Maintenance really begins with the design and construction of the sewerage system. Hence, due consideration shall be given to maintanance requirements at the time of designing sewerage systems.

The factors responsible for the clogging of sewers may be:

a) deposition of grit or other detritus which creates stagnation resulting in the putrefaction of organic matter giving rise to odours and poisonous gases; deposition of grease from hot liquid wastes from kitchens finding entry into the sewers, getting cooled and deposited on the sides which, in course of time, may lead to clogging;

b) penetration of roots from nearby trees through the joints or cracks in the sewers which eventually choke the sewers;

c) growth of fungi which forms a network of tendrils and starts floating, offering an obstruction to the free flow inside the sewers; and

d) stagnation of sewage due to improper working of pumping units leading to settlement of grit and other materials and dumping of solid wastes in the manholes indiscriminately.

The various safety equipments that are normally required in sewer maintenance work are gas masks, oxygen breathing apparatus, portable lighting equipment, non-sparking tools, portable air blowers, safety belts and inhalators. The use of the particular safety equipment is governed by the detection of various gases and oxygen deficiency.

Sewer cleaning work calls for the following equipments and devices like a portable pump set running on either diesel or petrol engine, sectional, sewer rods, flexible sewer rods with thick manila rope for manual cleaning, a ferret used in conjunction with a firehouse, a sewer cleaning bucket machine, a dredger, a rodding machine with flexible sewer rods and cleaning tool attachments, such as augers, corkscrews, hedgehogs and sang cups, scraper, automatic flushing tanks and hydraulically propelled devices, such as flush bags, sewer balls, wooden ball and sewer scooters.

6.11 Pumping of Sewage

6.11.1 *General* — In the design of a sewerage system, it is occasionally necessary to collect the sewage of a low lying area at some convenient point from which it must be lifted by pumps. In the construction of sewers in flat topography, the grade required to cause proper velocities necessitates deep excavations. It is sometimes less expensive to raise sewage by pumping than to continue the construction of sewers in deep excavation. At the treatment plant also, lifting of the sewage may be necessary to provide necessary head for the flow by gravity of the sewage through the several units.

In the construction of large office buildings and business blocks, the sub-basements are frequently constructed below sewer level. The sewage and other drainage from the low portion of the building must, therefore, be removed by pumping.

The nature of the sewage needs special type of pumps. The sewage contains solids and grit, and is liable to become septic if allowed to collect over a period of time. So automatically controlled non-clogging pumps without the necessity of providing food valves are to be used. The following details relate to small pumping stations containing pumps 50 to 150 mm in diameter.

6.11.2 *Location of Pumping Station*

6.11.2.1 *Flooding* — As pumping stations are frequently located in low lying areas, consideration needs to be given to the possibility of flooding and information should be obtained as to the highest recorded flood level in the vicinity. The site should be above flood level or the floor of the supersturcture and, the top of the wet well or the suction chambers should be above the highest recorded flood level. The design should ensure that there is adequate resistance to floatation due to not only flood condition but also to high water table, both of the completed structure and at any stage of its construction.

The pumping station should be located away from the residential locality to avoid complaints of noise and smell.

6.11.2.2 *Overflow* — A site should be selected where, as far as possible, any overflow resulting from mechanical or power failure will cause the least nuisance or damage to property.

6.11.3 *Pumps* — Generally, areas of new development will be drained on the separate system and the sewage flow from individual areas may be too small to suit the output of standard non-clog pump. In these instances the adoption of force or lift and force ejectors, small submersible pumps are to be considered. Generally, the sewage pumps should be capable of dealing with rates of flow up to 6 times the 24-hour average.

Where the sewage flow is sufficient to warrant the installation of vertical spindle, centrifugal pumps should be sited in a dry chamber adjacent to the suction well and should be shaft driven by motors installed at ground level. A duplicate pump should be provided as a standby. Screening should be provided to avoid damage to pumps. Comminutors for masceration of the solids in sewage are not necessary for Indian conditions. Pneumatic ejectors are mostly used for small stations where their use is advantageous in spite of their low efficiency of about 15 percent.

6.11.3.1 *Pheumatic ejector* — A pneumatic ejector consists essentially of a closed chamber into which sewage flows by gravity until it reaches a certain level. The sufficient air under pressure is admitted into the chamber to eject the sewage. The non-return valve on the inlet pipe prevents the sewage from leaving the vessel except through the non-return valve on the outlet. This valve on the outlet prevents backflow into the tank. Thus air under pressure displaces the sewage volumetrically until the low water level fixed by the limiting float travel or other control cuts off the air supply. A standby ejector is usually provided. The volume of air storge tank and the characteristics of the compressor shall be adequate to provide the necessary volume of air at a pressure at least 40 percent higher than that required to raise all the sewage to the maximum computed lift.

The ejectors have, however, the following advantages:

a) No sewer gases can escape except through the vent shafts as sewage is completely enclosed;

b) Operation is fully automatic and the ejector comes into operation only when needed;

c) Only a few parts are in contact with sewage thus necessitating little attention or lubrication;

d) Ejectors are less susceptible to clogging; and

e) Screening is not required as check valves and connecting lines will pass all the solids that enter the ejector compartment.

However, it may be noted that pneumatic ejectors are not manufactured in this country and even those in Bombay city are being progressively replaced by suitable size sewage pumping stations.

6.11.4 *Switch Gear* — Electricity is the only practicable motive power for small pumping stations. Three-phase squirrel cage electric motors are generally preferred. All starters should incorporate in each phase a magnetic overload release controlled by a hydraulic delay dash pot. The electrical gear should be of a pattern that the cycle of operation for each pump will not be less than 5 minutes and maximum retention time in the wet well not exceeding 30 minutes.

The starters should be controlled either by float operated switches or a relay operated by the sewage completing an electrical circuit between low voltage electrodes. The float mechanism requires regular mechanical maintenance and electrodes should be cleaned regularly. When duplicate pumps have been provided, two sets of float operated switches or electrodes should be used with the operating levels arranged so that one starts before the other. They should be connected to the starter through a change-over switch so that the operation of the motors may be changed regularly.

All electrical equipment should be installed above possible floor levels and preferably above ground level.

6.11.5 *Pumping Station Structure* — The form of pumping station structure will depend upon the type of pumping plants to be installed. For larger installation in which vertical spindle centrifugal pumps are commonly used, the structure below ground may consist of a wet well for the reception of the sewage, contiguous with a dry well in which the pumps and valve gears are housed. A superstructre at ground level may contain the electric motors and switch gear. For small installations, submersible pumps may be suspended in a receiving well with sufficient storage capacity below the invert of the incoming drain. Motors and switch gear may be housed in a kiosk at ground level.

The detailed design should provide for easy access for the maintenance of equipment even if this involves some additional capital expenditure. The provision of a steel joint for use in conjunction with lifting tackle will be necessary where items of equipment cannot be conveniently removed by hand.

6.11.6 *Wet Well* — The working capacity of a wet well should be designed in conjunction with the selected pump size to ensure a reasonable frequency of operation and a reasonable pumping period. On a separate system of drainage and with a pump output of six times the 24-hour average, a well capacity of 5 minutes pump output may give a reasonable compromise between frequency of starts and duration of pumping periods. To provide against breakdown, the capacity of the wet well below overflow level and above pump working level should be restricted to the 30 minutes average float.

The sewage authority may wish to limit the rate of discharge from a pumping station which serves mainly large factories, canteens or ablution blocks and this may require the construction of a larger well than normal wet well. In such wells, the pump suction should draw from the bottom of an inverted cone which has a minimum side slope of 45° in order to ensure the removal of settled solids.

Coarse screens conforming to IS : 6280-1971 shall be provided before the wet well with clear opening of 40 to 50 mm between the bars for manually cleaned type and 25 mm for the mechanical type.

6.11.7 *Dry Well* — The dry well needed to house vertical spindle centrifugal pumps, ejectors or other sewage lifting devices should be watertight and should provide ample space for easy maintenance of equipment installed.

Provision should be made for the removal of gland or other leakage and it may be possible to instal a small suction pump in the motor room to lift and discharge this liquid into the wet well.

6.11.8 Pipe Work — The layout of pipe work should provide for separate isolating sluice valves on each side of each pump and for a reflux valve between the pump and the sluice valve on the delivery side. The reflux valve should be fitted in a horizontal run of a pipe between the pump and the rising main to avoid the sedimentation of solids which occurs in the vertical pipe work. A washout should be provided at the lowest point of the vertical pipe work to enable accumulated solids to be discharged into the wet well.

The reflux valve should be provided with an external hand level so that it may be used in conjunction with the sluice valve to permit back flushing of a blocked pump. All the pipe joints in the pump house should necessarily be flanged ones which will facilitate easy removal of the pipe in case any work is required to be done on the pipeline.

Where the outlet of a centrifugal pump is between the top of the casing, an air release pipe from the top of the casing may be necessary to ensure that the pump will prime. this pipe should discharge into the wet well above the liquid level and should be treated to inhibit corrosion.

6.11.9 *Ventilation* — In order to avoid dangerous accumulation of sewer gas, all wet wells should be open at the top. If this is impracticable, ventilation should be provided by means of a low level inlet and a high level outlet, both of adequate area.

The motor room and any building containing electrical equipment needs to be adequately ventilated to avoid any danger from accumulation of sewer gas and to avoid condensation of moisture. Precautions may be necessary to prevent dust and grit being blown into pump or motor bearings and to prevent an undue fall in temperature during cold weather.

6.11.10 *Pumping Mains* — The diameter of a pumping main is usually determined in conjunction with the selection of a pumping rate so as to ensure a velocity between 0.6 and 1.2 m/s in the main. Velocities below 0.6 m/s are likely to permit the accumulation of solids in the main. Whereas velocities over 1.2 m/s are generally considered to be uneconomic due to the high friction head and possibly increased surge problems.

Where small quantities of sewage are to be pumped, it is necessary to consider the volume of the pumping main in relation to the daily volume of sewage as an unduly long period by retention in the rising main is likely to result in the sewage becoming septic and consequently in the creation of corrosion and smell problems.

To avoid maceration of sewage, the minimum dia of the main should be 100 mm. The pipes and joints used for a pumping main should be capable of withstanding the maximum surge pressure produced.

6.12 Treatment and Disposal of Sewage

6.12.1 *General* — Sewage is the waste water containing human wastes especially the faecal matter. The other main constituent is wastes from kitchen and washings. Water is used to flush the faeces from the water-closet into the sewer and transport it to the treatment site. At the treatment site, the offensive and dangerous organic matter is treated and the less offensive water is mostly separated for disposal on land, sea or any water course.

In the course of its travel in the sewer, the organic wastes get thoroughly mixed with the water and the inorganic wastes are mechanically carried.

Physically sewage contains matter in suspension and in solution. Of the suspended solids, some will settle when the transporting power of water is decreased by a reduction in its velocity and some will remain in suspension even during protracted periods of quiescence.

Chemically sewage contains substances of animal, vegetable and mineral origin. The animal and vegetable substances, collectively called organic matter, are mostly offensive in character. They constitute about 50 percent of the sewage solids and are made up of complex chemical substances which are readily broken down by biological and to a lesser degree chemical action into other usually simpler compounds.

Biologically sewage contains vast number of living organisms among which the bacteria predominate. Most of these organisms are harmless to man and are largely engaged in the beneficient activity of converting the complex organic constituents of sewage into simpler and more stable organic and mineral compounds. Sewage may, however, contain bacteria or other pathogenic organisms that have come with the faeces from persons sick with typhoid fever, dysentry or other water-borne or fly-borne diseases. This constitutes the real danger to public health.

6.12.2 *Principles of Sewage Treatement* — The coarser suspended solids, such as rags, paper and shells are removed by screening. The mineral matter such as sand or grit, called detritus, is removed by sedimentation in grit chambers. The finer settleable solids are removed by sedimentation in primary sedimentation tanks. The colloidal solids settle after chemical treatment. The settled sewage solids constitute the sewage sludge. The non-settleable and dissolved solids can be acted upon by the micro-organisms such as bacteria and are reduced to simpler substances. The design of the biological treatment units aim at providing an environment favourable for the growth and activity of the bacteria. The main feature of the units is the provision of enough oxygen for the organisms. Depending upon the type and manner in which the oxygen is supplied, the units derive their names. Air, which contains nearly 20 percent oxygen, is the main source for aeration units. Water in contact with air absorbs the air, the extent of which is measured by the dissolved oxygen content of water. This dissolved oxygen sustains the organisms in water. When water contains green plants such as algae, the supplying of oxygen may also be by photosynthesis. This principle is utilized in oxidation or stabilization ponds.

Air may be forced or bubbled through sewage as in difusion processes or sewage may be sprayed or cascaded as in the several activated sludge processes or sewge may be filtered through aerated beds as in trickling filters and contact beds. Where there is no aeration, another class of bacteria, called anaerobic bacteria, attack the organic solids and take the oxygen from the molecules of the organic substances, thereby collapsing the chemical structure of the organic materials and produce sludge gas containing methane, etc. This kind of bacteria are grown in septic tanks and sludge digestion tanks. After treatment in biological units, the sewage is settled again in secondary sedimentation tanks and the effluent, which is now mostly freed from the offensive matter, is disposed of on land for irrigation as in sewage farms or diluted in sea or other stream courses.

Generally, for dealing with sewage from small installations or colonies, either septic tank treatment and soil absorption systems as well as oxidation or stabilization ponds are usually employed which are only discussed in this handbook. However, small sophisticated treatment units may also be employed.

6.12.3 *Degree of Treatment* — The degree of treatment will mostly be decided by the regulatory agencies and the extent to which the final products of treatment are to be utilized. These regulatory bodies might have laid down standards for the effluent or might specify the conditions under which the effluent could be discharged into a natural stream, sea or disposed on land. These regulatory bodies may be the local body or a State Water Pollution Prevention and Control Board. The method of treatment adopted should not only meet the requirements of these regulatory agencies but also result in the maximum use of end products consistent with economy.

6.13 Drainage into Individual Disposal System

6.13.1 *General* — Where there is no public sewerge system, and where the houses are located in isolated places and which cannot be connected to a sewerage system economically, the benefit of the water-closet can still be had and the wastes conveyed to one of the following individual disposal systems:

a) leaching cess pool;

b) collecting well cleared periodically by a vaccum car and wastes taken to a central treatment and disposal site; and

c) septic tank and the tank effluent discharged into:

1) a soak pit, or

2) a subsurface absorption system, or

3) a secondary treatment unit such as sand filters or trickling filters and final effluent used for gardening, or

4) a collecting well and periodically cleared by a vacuum car or a cess pool cart and taken to a central place for mixing with refuse for making compost.

6.13.2 *Leaching Systems*

6.13.2.1 *General* — A leaching system is one in which the sewage effluent from a primary treatment unit or a secondary treatment unit or the storm water is allowed to soak into the soil for absorption or for re-charging the acquifers. In the case of sewage wells, the sludge after digestion collects at the bottom of the pit and is cleared periodically.

The design of leaching system is based on the ability of the soil to absorb water or liquid effluent. Soils may be classified into gravel, sand, silt and clay, and depending upon which is predominent as sandy loam, gravelly loam, silty loam, clay loam or clay. Loam is a mixture of gravel, sand, silt and clay containing decayed plant and animal matter or humus which is called top soil. The top soil may be about one metre in depth. Soil bacteria and other micro-organisms thrive in the top soil as it is well aerated.

A lump of soil with good structure will break apart with little pressure along definite cleavage planes. If the colour of the soil is yellow, brown or red, it would indicate that air is there and therefore water passes through. Whereas, if the soil is of greyish colour, it would indicate lack of aeration and therefore a tight soil, that is, probably unsuitable for subsurface absorption.

A greyish soil may be suitable, if drained. Magnesium and calcium tend to keep the soil loose whereas sodium and potassium have the opposite effect. Sodium hydroxide, a common constituent of the so-called septic tank cleaners, would cause a breakdown of the soil structure which results in smaller pore space and reduced soil permeability. Aerobic bacteria are found in the zone of aertion which extends through the top soil and into upper portion of the subsoil depending upon the soil structure, earthworm population, root penetration and other factors. The top soil supports vegetative organisms, such as bacteria, fungi and mould as well as animal organisms such as protozoa, nematodes, insects and larger animals. These organisms have the capability of reducing complex organic matter to simpler forms through their life processes. The effluent from a primary treatment unit such as a septic tank contains material in solution in colloidal state and in suspension. When this is discharged into the top soil or close to it, it will be acted upon by these organisms and will be reduced to soil as well as liquids and gases. This is accomplished provided the effluent is not discharged at too rapid a rate or in too great a strength into the earth in the zone of aeration. A water-logged soil tends to destory the organisms and preserve the organic matter in septic tank effluent thereby delaying decompFosition and increasing mechanical clogging of the soil with the organic matter. Subsurface tiled fields are laid usually at a depth of about half a metre. The gravel around the open joint tile or perforated pipe should extend into the zone of aeration usually within about half a metre of the ground surface. The design of the leaching system must take into account the soil structure and its absorption capacity, direction and depth of ground water flow and the relative location of wells and springs with respect to their possible pollution.

The design of leaching pits and cess pools is based on the ability of the soil, found at a depth between one and three metres, to absorb water. Sometimes pits are made 6 to 8 metres or more in depth using prefabricated sections in order to reach permeable soil or aquifer which should consist predominently of coarse sand or gravel to be satisfactory.

Leaching cess pools and pits should be prohibited in shale and limestone area or where ground water is high and avoided when shallow wells or springs are in the vicinity, unless adequate protecting distances and soils can be assured. Where the soil is relatively impermeable at shallow and deep depths, then an artificial sand filter which requires an outlet to a ditch or water course or other treatment or disposal devices is needed in place of a conventional leaching system. The leaching system should conform to IS : 2470 (Part 1)-1985.

It is desitable to have at least one metre of suitable soil over clay or rock or ground water.

With a suitable soil, the disposal of the sewage effluent can be simple, economical and inoffensive but careful maintenance is essential for continued satisfactory operation. Where rock or ground water is close to the surface or the soil is tight clay, the soil is not suitable for a leaching system.

6.13.2.2 *Soil absorptive capacity*

a) *General* — There is a measure of soil permeability at any depth at which it is intended to dispose off the effluent. It is determined by a soil percolation test.

b) *Percolation test* — A square or a circular hole with side width or diameter of 10 to 30 cm and vertical sides shall be dug or bored to the depth of the proposed absorption trench. The bottom and sides of the holes shall be carefully scratched in order to remove any smeared soil surface and to provide a natural soil interface into which water may percolate. All the loose material shall be removed from the hole and coarse sand or fine gravel shall be added a depth of about 5 cm to protect the bottom from scouring and sediment.

Water shall then be poured up to a minimum depth of 30 cm over the gravel. In order to ensure that the soil is given ample opportunity to swell and to approach the condition it will be in the wettest season of the year, the percolation shall be determined 24 hours after the water is added. If the water remains in the test hole after the overnight swelling period, the depth shall be adjusted to 15 cm over the gravel. Then, from a fixed reference point, the drop in water level shall be noted over a 30 minute period. This drop shall be used to calculate the percolation rate.

If no water remains in the hole, water shall be added to bring the depth of the water in the hole till it is 15 cm over the gravel, From a fixed reference point, the drop in water level shall be measured at 30 minutes intervals for 4 hours, refilling 15 cm over the gravel, as necessary. The drop that occurs during the final 30 minutes period shall be used to calculate the percolation rate. The drops during prior periods provide information for possible modification of the procedure to suit local circumstances.

In sandy soils or other porous soils in which the first 15 cm of water seeps away in less than 30 minutes after the overnight swelling period, the time interval between measurement shall be taken as 10 minutes and the test run for one hour. The drop that occurs during the final 10 minutes shall be used to calculate the percolation rate.

Based on the final drop, the percolation rate, that is, the time in minutes required for water to fall 25 mm shall be calculated.

6.13.2.3 *Design of the soil absorption system* — the allowable rate of application of effluent per unit area of dispersion trench or seepage pit is limited by the percolation rate of the soil determined as indicated above. The allowable rate of effluent application for certain selected values of percolation rates are given in Table 58 based on the equation:

$$Q = \frac{204}{\sqrt{t}}$$

where

Q = maximum rate of effluent application for the standard percolation rate, and

t = standard percolation time in minutes.

6.13.2.4 *Construction of the soil absorption system*

a) *General* — The various soil absorption system are discussed below:

1) *Shallow seepage pit with filling* — These are suitable for location near trees. The seepage pit

TABLE 58 ALLOWABLE RATE OF EFFLUENT APPLICATIONS TO SOIL ABSORPTION SYSTEM

(*Clause* 6.13.2.3)

PERCOLATION RATE min	MAXIMUM RATE OF EFFLUENT APPLICATION $l/m^2/day$
1 or less	204
2	143
3	118
4	102
5	90
10	65
15	52
30	37
45	33
60	26

NOTE 1 — The absorption area for a dispersion trench is the trench bottom area.

NOTE 2 — The absorption area for seepage pits is the effective side wall area, effective depth being measured from 15 cm below invert level of inlet pipe to the bottom of the pit.

NOTE 3 — If the percolation rate exceeds 30 minutes, the soil is unsuitable for soakways. If the percolation rate exceeds 60 minutes, the soil is unsuitable for any soil absorption system.

may be of any suitable shape with the least cross-sectional dimension of 90 cm but less than 100 cm in depth below the invert level of the inlet pipe. No masonry lining is used except for the top 90 cm at which level the inlet pipe is taken as an anti-mosquito measure. The top lining may be with brick, stone or concrete block with mortar joint. The top of the masonry ring may be kept above ground level to prevent damage by flooding of the pit by surface run off. The filling may be with stone or brick aggregate. The top lining may be made to rest on 30 cm thick outer casing with coarse sand. The inlet pipe may end in a bend discharging into a brick chamber with open joints as shown in Fig. 33. The entire pit should be filled with loose stones or brick aggregates.

2) *Shallow seepage pit without filling but with lining* — The seepage pit may be of any suitable shape with the least cross-sectional dimension of 90 cm but not less than 100 cm in depth below the invert level of the inlet pipe. The pit may be lined with stone, brick or concrete blocks with open joints which should be backed with at least 7.5 cm of clear coarse aggregate. The lining above the inlet level should be finished with mortar. In the case of pits with large dimension, the top portion may be narrowed to reduce the size of the RCC cover slab. The slab may be removable precast RCC slab with an opening at the centre for ventilation. The inlet pipe may be taken down to a depth of 90 cm from the top as an anti-mosquito measure.

3) *Leach pit for pour flush water seal latrine* — Where the pour flush water seal latrine of the household is directly connected to a leach pit, suitable approved designs should be adopted. The latrine is connected to a twin leaching pit. The capacity of each pit will be such that it may last for 4 to 5 years for a family of 5 persons. When one pit is filled with sludge, it will be disconnected from the P trap and the second pit will be put into use. The sludge from the first pit can be removed after 2 years when it becomes free of pathogens and can be safely handled.

The leaching pits should be located in the case of compact soils, at least 8 metres away from an open well or tube well from which water is drawn for domestic use and also away from trees whose roots may damage the pits.

Approximately 2 litres of water is required for each flush. This type of latrine should not be provided with a flushing cistern or taps for flushing purposes as they are likely to damage the pits and might make them structurally unsafe in some cases.

These pits may be located within the premises or outside the premises in streets or public property with permission.

The pits are 1000 mm in dia and 1300 mm deep. The sides of the pit are with honeycomb brick work in cement mortar 1 : 6 and 115 thick. The pits inside the premises are covered with a 75 mm RCC slab and those located outside the permises are covered with a 50 mm RCC dome.

4) *Deep pits with prefabricated sections* — These are used in special cases to recharge acquifers. The sizes and location of perforation depend on the nature of acquifer pierced through. Usually storm water is used for this purpose

5) *Dispersion trenches* — Dispersion trenches shall be 50 to 100 cm deep and 30 to 100 cm wide, excavated to a slight gradient and shall be provided with 15 to 25 cm of washed gravel or crushed stones. Open jointed pipes placed inside the trench shall be made of unglazed earthenware clay or concrete and shall have minimum internal dia of 75 to 100 mm. Each dispersion trench shall not be longer than 30 m and trenches should not be placed closer than 1.8 m.

The covering for the pipes on the top should be with coarse aggregate of uniform size to a depth of nearly 15 cm. The aggregate above this level may be graded with aggregate 12 to 15 mm to prevent ingress of top soil while the free flow of water is in no way retarded. The trench may be covered with about 30 cm of ordinary soil to form a mound and turfed over. Dispersion trenches are not recommended in areas where fibrous roots of trees or vegetation are likely to penetrate the system and cause blockages. The finished top surface may be kept atleast 15 cm above ground

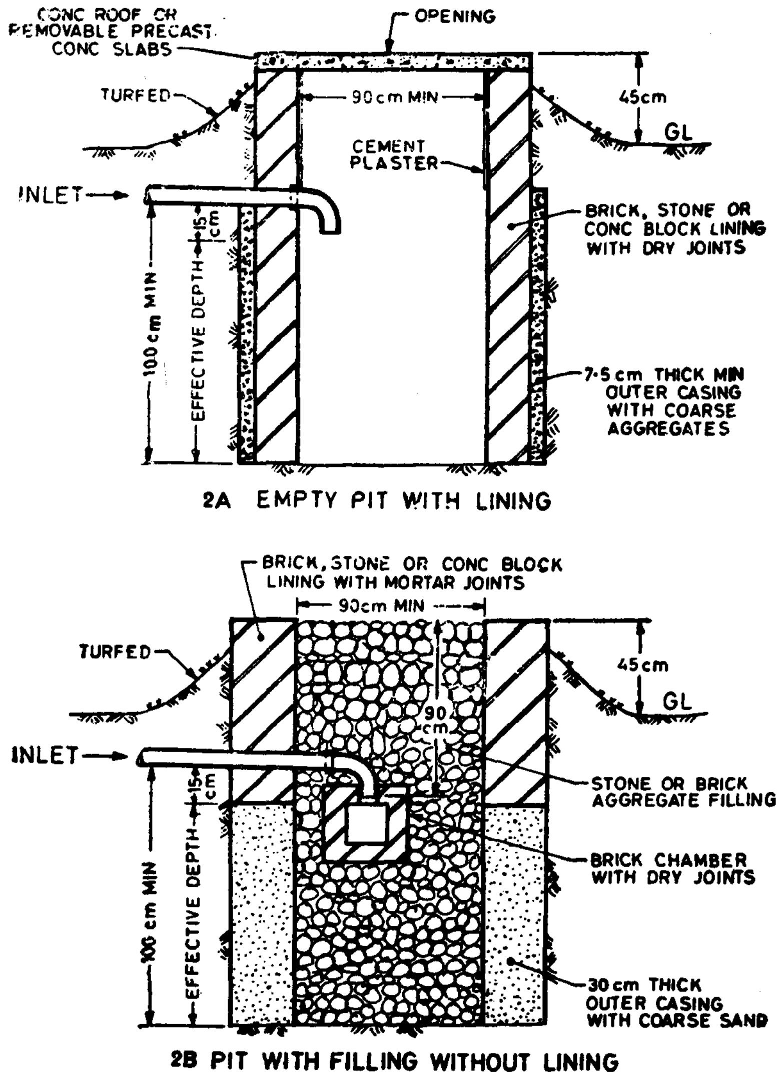


FIG. 33. TYPICAL ILLUSTRATIONS OF SEEPAGE PITS

level to prevent direct flooding of the trench during rains. Illustration of a typical soil absorption system through dispersion trench is given in Fig. 34.

6.13.2.5 *Location of subsurface absorption systems* — A subsoil dispersion system shall not be closer than 18 m from any source of drinking water such as well to mitigate the possibility of bacterial pollution of water supply. It shall also be as far removed from the nearest habitable building as economically feasible but not closer than 6 m to avoid damage to the structures. The actual distance, however, shall be based on the soil conditions in relation to both percolation and bearing capacity. Care should be taken that the ground below the adjacent building is not likely to be affected by the effluent seeping into the soil. In limestone or crevice rock formations, the soil absorption system is not recommended as these may be channels in the formation which may carry contamination over a long distance. In such cases and generally where suitable conditions do not exist for adoption of soil absorption systems, the effluent where feasible should be treated in a trickling filter or chlorinated and the effluent discharged into a natural drainage course or used for gardening.

6.13.3 *Septic Tank*

6.13.3.1 *General* — A septic tank is a water-tight tank which is designed to slow down the movement of raw sewage and wastes passing through so that solids can separate or settle and be broken down by liquefaction and anaerobic bacterial action. There is an appreciable reduction in volume of sludge and release of gases like methane, carbon dioxide and hydrogen sulphide. It does not purify the sewage, eliminate odours or destroy all solid matter. It conditions the sewage so that it can be disposed off to a surface leaching

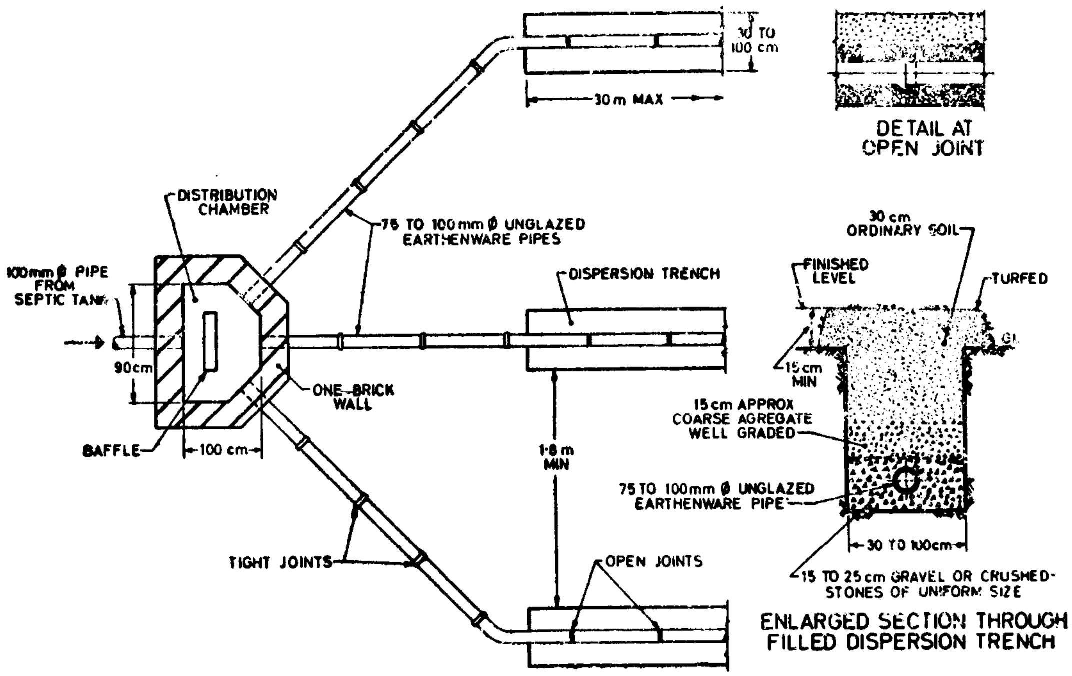


FIG. 34. TYPICAL SOIL ABSORPTION SYSTEM WITH DISPERSION TRENCHES

system or to an artificial sand filter without prematurely clogging the system. The effluent, although clarified to some extent, will still contain considerable amount of dissolved and suspended putrescible organic solids and viable pathogens, and therefore the disposal of the effluent merits careful consideration. Because of the unsatisfactory quality of the effluent and also difficulty of providing a proper disposal system for the effluent, septic tanks are recommended only for small communities and institutions whose contributory population does not exceed 300. For larger communities, provision of septic tanks should be avoided as far as possible. For the septic tanks to function satisfactorily, a fairly adequate water supply is a pre-requisite. Wastes containing detergents and disinfectants are not suited for treatment in septic tanks as they adversely affect the anaerobic decomposition.

6.13.3.2 *Design criteria* — Rational design of a septic tank should be based upon the function it is expected to perform, namely:

a) Sedimentation to remove the maximum possible amounts of suspended solids from sewage;

b) Digestion of the settled sludge resulting in a much reduced volume of dense and digested sludge; and

c) Storage of sludge and scum accumulating in between successive cleanings thereby preventing their escape.

Thus the tank should have an effective capacity large enough to provide for the above three requirements.

a) *Sewage flow* — The maximum flow to the tank is based on the number of plumbing fixtures discharging simultaneously rather than the number of users and per capita waste water flow expected to reach the tank. The various sanitation facilities and their fixture units have already been dealt with in **5.6.3.3** and **6.7.5.3**.

b) *Tank dimensions*

1) *Sedimentation* — Both surface area and detention or depth are important factors in the settling of flocculant particles such as sewage solids. For average Indian conditions at a temperature fo 25°C, the surface area required will be 0.92 m^2 for every 10 lpm peak flow rate. This is based on 75 percent removal of sewage particles of size 0.05 mm and above with a specific gravity of 1.2. A minimum depth of sedimentation of 25-30 cm is necessary. The length is maintained at 2 to 4 times the breadth. Having determined the surface area and the depth as assumed, the volume is calculated.

2) *Sludge digestion* — The fresh sludge must stay in the tank long enough to undergo satisfactory anaerobic digestion so that as much of the organic matter as possible may be destroyed and the sludge may become innocuous and suitable for dewatering or drying. The time required for digestion is dependent on temperature and the detention time in a septic tank can be computed on the basis of annual average temperature.

The per capita suspended solids entering the septic tank may be taken as 70 g/day. Assuming that 60 percent of the solids is removed along with fresh sludge of which 70 percent is volatile with a solids content of 5 percent or moisture content of 95 percent, the volume of fresh sludge works out to 0.000 83 m^3/capita/day. Considering that 2/3 of the volatile matter is destoryed of which 1/4 is mineralized during digestion and the solid contents of 13 percent in the digested sludge, the volume of digested sludge works out to 0.000 2 m^3/capita/day. The digestion zone contains both fresh and digesting sludge, and hence digestion space should provide for the average volume of the mixtures of the fresh and digested sludge which works out to 0.000 515 m^3/capita/day. Based on the period of digestion, the capacity needed for the digestion zone could be determined. For temperture of 25° C, the capacity required for sludge digestion works out to

$$63 \times 0.000\,515 = 0.032 \text{ m}^3/\text{capita.}$$

It may, however, be mentioned that Prof Arceivala and Prof Inahabal have arrived at a figure of 45 g per capita based on the experiments carried out by them at the housing colony in Bandra (East). It is left to the designer, however, to adopt a figure based on the merits of the particular case.

c) *Sludge and scum storage* — Adequate provision should be made for the storage of digested sludge and scum in the tank as otherwise their accumulation interferes with the efficiency of the tank by encroaching upon the space provided for sedimentation and digestion. A sludge storage capacity of $0.000\,2 \times 365 \times 100 = 7.3$ m^3/100 persons for an interval of cleaning of one year is provided below the sedimentation zone. This figure should be increased by 10 percent to provide for seed sludge which will be left behind in the tank during cleaning.

The tank should also provide for a free board of not less than 30 cm, which should be sufficient to include the depth of scum above the liquid surface.

d) Total capacity is the sum of the several capacities worked out as above for sedimentation, sludge digestion, and sludge and scum storage.

e) *Minimum dimensions* — Septic tanks shall have a minimum width of 75 cm, minimum depth of 1 m below water level and a minimum liquid capacity of 1 m^3. The length of the tanks shall be 2 to 4 times the width. The design should be based on the rational method mentioned above and not on detention period.

6.13.3.3 *Construction details* — The location of the inlet, outlet and baffles, ventilating pipes and bottom slopes, and the desludging arrangements should preferably be of Type 2 given in IS : 2470 (Part 1)-1985 for small installations and as per the design given in IS : 2470 (Part 2)-1985 for large installations.

6.13.3.4 *Secondary treatment and disposal of effluent* — Although sewage undergoes treatment in a septic tank, the effluent may still contain pathogenic organisms and hence septic tank effluents cannot be considered safe. Further the effluents will be malodorous and more objectionable than the incoming sewage. The primary function of the septic tank is to condition the sewage so that it will cause less closing of the dispersal field or make it more amenable to other treatment. Final purification of the effluent, and the removal and death of pathogens is effected by percolation through the soil or other media. Normally the disposal of effluent in a soak pit or dispersion trenches is practised. The details about leaching systems have been discussed in **6.13.2.**

6.13.3.5 Typical design of a septic tank is illustrated in Appendix E.

6.14 Stabilization Ponds

6.14.1 *General* — Stabilization ponds are open, flow-through earthen basins specially designed and constructed to treat sewage and biodegradable industrial wastes. These ponds provide comparatively long detention periods from a few to seweral days when the putrescible organic matter in the wastes gets stabilized by the action of natural forces.

These ponds may be aerobic, anaerobic or facultative depending upon the mechanism of waste purification. The aerobic pond functions aerobically throughout its depth with all the oxygen needs being met by algal photosynthesis. The pond is kept shallow with depths less than 0.5 m and the contents are stirred occasionally to prevent anaerobic conditions in the settled sludge. In the anaerobic pond, the purification results mainly from methane fermentation owing to the large depth employed. The process is somewhat attended by septic odours and the effluent will only be partially purified. Pond depths usually range from 2.5 to 4 m. This type of pond finds use mainly in the treatment of strong industrial wastes and has limited application for the treatment of sewage. The facultative pond functions aerobically at the surface while anaerobic conditions prevail at the bottom. The aerobic layer acts as a good check against odour evolution from the pond. The treatment effected by this type of pond is comparable to that of conventional secondary treatment processes. The facultative pond is hence best suited and most commonly used for treatment of sewage.

6.14.2 *Mechanism of Purification in a Facultative Pond* — In a facultative pond, the influent organic matter is stabilized partly by methane fermentation in the bottom layers and partly by bacterial oxidation in the top layers. When the sewage enters the pond, the suspended organic matter in the influent as well as the bioflocculated colloidal organic matter settle to the bottom of the pond. In the absence of dissolved oxygen at the pond bottom, the settled sludge undergoes anaerobic fermentation with the liberation of methane which represents a B.O.D.

removal from the system. In the liquid layers of the pond, algae begins to grow under favourable conditions. The algae utilizes the carbon dioxide in the sewage for photosynthesis during day light hours liberating oxygen, which maintains aerobic conditions in the upper layers of the pond. These conditions promote the oxidation of organic waste matter by the aerobic bacteria. Thus it is seen that there is an interdependence between algae and bacteria with the algae supplying oxygen required by the bacteria and the bacteria making available the carbon dioxide required by the algae. This inter-relationship is termed as algae-bacteria symbiosis.

6.14.3 *Design Consideration*

6.14.3.1 *Surface area* — The amount of oxygen that can be produced by photosynthesis and the B.O.D. that can be satisfied per unit area of a facultative pond depends mainly on the quantum of sunlight falling on the pond surface which, in turn, depends on the lattitude of the pond site, its elevation above MSL, time of the year and sky clearance. Recommended B.O.D. loadings (*see* IS : 5611-1970) for different latitudes are given in Table 59.

TABLE 59 PERMISSIBLE AREA B.O.D. LOADING AT DIFFERENT LATITUDES

Latitude	Aerial B.O.D. Loading
°N	kg/ha/d
36	150
32	175
28	200
24	225
20	250
16	275
12	300
8	325

The recommended B.O.D. loadings are for municipal sewage and are inclusive of the B.O.D. of the settleable solids in the waste. The values are applicable at sea levels and where the sky is clear for nearly 75 percent of the days in a year. The loadings should be modified due to the elevation of the plant to be located.

6.14.3.2 *Pond depth* — It will be found that, for pond designs for domestic sewage in most parts of India, the adoption of depth of 1 to 1.5 m and surface area based on the organic loading given in Table 59, will give sufficient detention time (minimum 6 days) for the removal of 80-90 percent B.O.D. (based on filtered effluent B.O.D.) at the averge winter temperature usually encountered.

However, in the case of ponds located in very cold temperatures at high altitudes, detention periods may have to be increased taking into account the decrease in the rate of biological activity at the lower temperatures. The detention period may be increased either by an increase in depth (up to 1.5 m) or by increasing the surface area of ponds. Where prolonged periods of sky cloudiness are experienced, the surface area has to be suitably increased.

6.14.3.3 *Sludge accumulation* — The reported rate of sludge accumulation in ponds treating municipal sewage ranges from 0.05 to 0.10 m^3/capita/year. A design value of 0.07 m^3/capita/year may be adopted for design. Facultative ponds require periodical desludging at intervals ranging from 6 to 12 years.

6.14.3.4 *Number of units* — Ponds smaller than 0.5 ha may be single unit. Larger ponds may be in multiple units working in parallel or in series. This facilitiates maintenance.

Ponds in series have functioned more satisfactorily and are recommended for larger installations. To avoid anaerobic conditions in the primary pond, its area may be 65 to 70 percent of the total area.

6.14.3.5 *Pond shape* — It is not necessary that it should be of any particular type. It may be anything depending on the site conditions. The corners should be rounded to avoid accumulation of floating materials and creation of dead pockets. There should be no islands or raised pockets inside the pond.

6.14.3.6 *Location* — No pond should be located within 200 m from residential colonies and the local prevailing winds should be in the direction of uninhabited areas. The longest dimension of the pond should be at right angles to the local prevailing wind to avoid short-circuiting of the flow. There should be no trees within a distance of 30 m from the water edge. The surface run-off should be drained away from the pond. The elevation of the site should permit flow by gravity of the effluent at MWL. There should be no drinking water well within a distance of at least 15 m from the pond. (50 m is preferable, in homogeneous soils.) In areas of fissured rock formation, ground water pollution studies should be undertaken before locating the pond.

6.14.4 *Constructional Details* — These are given in IS : 5611-1970.

6.14.5 *Commissioning, Operation and Maintenance of Ponds* — Soils generally harbour the spores of various algae and a spontaneous growth of algae is likely to take place within a week or two after the sewage is admitted to the pond. Hence, artificial addition of algae culture is not necessary. Raw sewage may be admitted to the pond gradually so that anaerobic conditions do not set in and proper growth of algae is obtained.

Though the operation does not call for a highly technical skill, it is necessary to have a regular checking of the pond, periodical testing of the pond contents such as B.O.D. and pH. Microscopic examination of algae and depths for mosquito larvae should be carried out regularly. Excessive sludge build-up should be avoided.

The surface of the pond should be kept free from floating material. The inside slope of the pond should be free from weeds and marginal vegetations to avoid mosquito nuisance. Larvicidal measures should be carefully carried out avoiding the ill-effects on pond algae.

6.14.6 *Disposal of Effluent* — The treated effluent may be disposed of as irrigation water or for fish culture or discharged into a local stream subject to local regulations.

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SECTION 7

MEASUREMENT OF WATER SUPPLY, DRAINAGE AND SANITARY WORKS

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SECTION 7 MEASUREMENT OF WATER SUPPLY, DRAINAGE AND SANITARY WORKS

7.1 General — The methods followed for the measurement of works are not uniform and considerable differences exist between the practice followed by one construction agency and another, and also between various central and state government departments. While it is recognized that each system of measurement has to be specifically related to the administrative and financial organization within the department responsible for the work, a unification of the various systems at the technical level has been accepted as very desirable specially as it permits a wider circle of operation for civil engineering contractors, and eliminates ambiguities and misundertaking arising out of inadequate understanding of the various systems followed.

IS : 1200 published in several parts describes the method of measurement of building and civil engineering works. The two parts specially relevant to plumbing are:

a) Part 16 — Laying of water and sewer lines including appurtenant works.

b) Part 19 — Water supply, plumbing and drains.

The essentials are extracted for general reference.

7.2 Measurements

7.2.1 *General* — All work shall be measured in the decimal system as fixed in its place subject to the following, unless otherwise stated.

7.2.2 *Booking Dimensions* — In booking dimensions, the order shall be consistent and generally in the sequence of length, width or breadth and height or depth or thickness. Dimensions shall be measured to the nearest 0.01 m, areas shall be worked to the nearest 0.01 m^2, and volumes shall be worked to the nearest 0.01 m^3.

7.2.3 *Classification of Items* — Works executed in different conditions such as the following shall be measured separately:

a) work in or under water;

b) work in liquid mud;

c) work in or under foul positions;

d) work interrupted by tides; and

e) where springs requiring pumping are likely to be encountered, the work shall be measured against a separate specific provision made for the purpose.

7.2.4 *Measurement in Stages* — Works above or below ground shall be measured separately under convenient stages stating the height or depth. The ground level shall be specified in each case.

7.2.5 *Description of Items* — The description of each item shall, unless otherwise stated, be held to include where necessary supply, conveyance and delivery, handling, loading and unloading, storing, fabrication, hoisting, all labour needed for finishing to required shape and size, setting, fitting and fixing in position, straight cutting and wastes, etc, and also testing.

7.3 Measurement of Water Lines

7.3.1 *Pipes* — Pipes shall be described by their internal nominal diameter and length as laid or fixed, unless otherwise stated, and measured in running metres, the measurement being taken along the centre line of pipes and fittings or specials. Fittings and specials shall be enumerated extra over pipes. Alternatively, the measurement shall be taken along the centre line of pipes in between the fittings. The joints, specials and fitting shall be fully described and enumerated. The former method is preferable as it expedites measurement of the pipeline.

7.3.2 *Excavations* — Method of measurement for excavation for trenches for laying pipelines and other allied works and refilling the trenches, etc, shall be as given in IS : 1200 (Part 1)-1974.

7.3.3 Miscellaneous works, such as valve chambers or cisterns, public fountain platforms, fire hydrants, meters, masonry supports, and hangers shall be described in detail and enumerated independently.

7.3.4 *House Service Connections* — These shall be described according to size and tested in position.

7.4 Measurement of Sewer Lines

7.4.1 *Sewer Lines* — Sewer lines shall be described by their internal diameter and length, unless otherwise stated, and measured in running metres inclusive of joints, the measurement being taken along the centre line of pipes and fittings. Fittings and specials, and manholes shall be enumerated extra over pipe. Alternately, the measurement shall be taken along the centre line of pipes in between the fittings and specials, and manholes. The joints, specials and fittings shall be fully described and enumerated. The former method is preferable as it expedites measurement of the sewer line.

7.4.2 *Manholes and Inspection Chambers* — Manholes and inspection chambers shall be fully described and enumerated. They shall be classified into different groups depending upon the depth, such as up to half metre depth, half to one, one to two, two to three and so on. The depth of manhole shall be the distance between the top of the manhole cover and the invert level of the main drain or alternately the manholes and inspection chambers shall be measured in detail under the various parts of the standard. The former method is preferable as it expedites the enumeration, the data for each category having been previously determined.

Where sewer lines are to be laid in areas which are yet to be developed or in valley crossings, the sewer lines shall be measured with respect to the actual ground level while the manholes which have to be constructed to the full height up to the new formation level, the portion of the manhole below the existing ground level and the portion above the existing ground level shall be measured or enumerated separately.

7.4.3 *Appurtenant Items* — Ventilating shafts, flushing manholes or cisterns and other appurtenant items of work shall be enumerated separately. The items of the work shall be described in detail and the designs given or alternatively these items shall be measured under various parts of IS : 1200. The former is preferable.

7.4.4 The house service connections shall be described and enumerated.

7.5 Measurement of Plumbing Works in Buildings

7.5.1 *Sanitary Fittings*

7.5.1.1 *General* — All sanitary fittings shall be described and enumerated according to size. The joints and fixing shall also be described and included in the item as also testing.

7.5.1.2 *Connections* — The connection with the water main shall be described and enumerated.

The water supply pipelines shall be measured up to the point of connection to wheel valve or stopcock.

a) *Wash basin* — The item shall include the supply, delivery, handling, fixing in position with supporting brackets or pedestal or other arrangements, waste outlet pipe with necessary fixings, plug with chain, etc, but shall not include the pillar taps and their connections. The pillar taps, flexible connections, wheel valve or stopcock shall all be enumerated separately and described to include supply, delivery, fixing in position with necessary accessories and connections to the water supply pipe. The pipeline shall be measured up to the point of connection to the wheel valve or stopcock.

b) *Water-closet* — The item shall be described and enumerated according to type and include supply, delivery, fixing in position and connection to the bend containing the cleaning eye. The foot rests, wooden seats and cover, where necessary, shall all be included in the description. The flushing pipe and its connection to the water-closet shall not be included in the description of this item as it will come under the flushing cistern item.

c) *Flushing cistern* — The flushing cistern shall be described and enumerated to include the flushing pipe and its connection to the flushing cistern at one end and to the water-closet at the other end. The items such as float valve, the chain with handle shall all be included under the description. The flexible connection, the wheel valve or stopcock shall all be enumerted separately and include supply, fixing in position with the necessary accessories.

d) *Miscellaneous* — All other terminal fittings shall be described and enumerated according to size and tested in position.

7.5.2 *Soil Waste and Vent Pipes*

7.5.2.1 *Pipes* — The length of the pipes shall be taken along the centre line of the pipes, fittings or specials, bends, branches, swan necks, enlarged sockets, etc, and shall be enumerated as extra.

7.5.2.2 Wire quards and ventilating cowls over tops of pipes shall be described, enumerated and measured separately according to the bore of the pipe.

7.5.2.3 Stack clamps shall be described and enumerated stating the length of stay and the method of fixing to wall or roof.

7.5.2.4 Lead pipes shall be classified according to their size and weight per running metre and shall be measured in running metres. The method of fixing shall be described and wiped soldered joints shall be included with the item excepting those not in the running length of the pipe.

7.5.2.5 *Traps* — All traps shall be described and enumerated according to size.

7.5.3 *Drain*

7.5.3.1 The drain pipes shall be described and each type measured separately. The length shall be measured in running metres as laid or fixed and measured along all bends, specials, etc. All fittings, specials, etc, shall be described and enumerated as extra over the corresponding lengths.

7.5.3.2 Concrete beds, haunchings and coverings including any formwork required shall be described and measured in running metres stating the size of the pipe, dimensions and mix of concrete.

7.5.3.3 Fresh air inlets shall be described and enumerated.

7.5.3.4 Effluent open drains shall be described and measured in running metres according to size.

7.5.3.5 Gulleys, siphons, intercepting traps, cleaning eyes and similar items, together with their setting concrete bedding and connections to drains, shall be described and enumerated.

APPENDIX A

(*Clause* 3.5.7)

PROCEDURE ADOPTED BY THE MADRAS METROPOLITAN WATER SUPPLY AND SEWERAGE BOARD FOR GRANT OF WATER CONNECTIONS FOR DOMESTIC CONSUMPTION AND USE

A-1. The authorized authority shall, on the application by the owner or occupier of any building or premises, arrange to supply water thereto for domestic consumption and use, if

a) such building or premises has an annual value of more than three hundred rupees as assessed under Section 35;

b) the building or premises is within thirty metres of a main of the Board from which water can be supplied; and

c) the cost of all works necessary for that purpose shall be borne by the applicant.

Provided that the authorized authority may arrange for supply even if the building or premises is beyond thirty metres as aforesaid if the applicant agrees to bear all costs and expenses and if the supply is otherwise practicable.

A-2. Whenever it appears to the authorized authority that any building assessed to an annual value of not less than three hundred rupees is without a proper supply of water for domestic consumption and use and that such a supply can be furnished from a main not more than thirty metres distant from any part of such building, the authorized authority may, by notice, require the owner to obtain such supply and to execute all such works as may be necessary for that purpose at the cost of the owner.

A-3. It shall not be lawful for the owner of any dwelling house, assessed at an annual value of not less than three hundred rupees, to occupy it or cause or permit it to be occupied until he has obtained a certificate from the authority that there is provision within or within a reasonable distance of the house for supply of wholesome water for domestic consumption and use of the inmates of the house.

A-4. Where on any land there are two or more superstructures, the annual value of each of which is less than three hundred rupees and the owner of the land is not the owner of all the superstructures, the authorized authority may, if it appears to it that the superstructures are without a proper supply of water for domestic consumption and use and that a supply can be furnished from a main not more than thirty metres distant from any part of any such superstructure, by notice, require the owner of the land to obtain such supply.

A-5. In any other case, where any premises are without supply of water for domestic consumption and use, the authorized authority may arrange for such supply on the application of the owner and at the owner's cost or he may by written notice require the owner to obtain such supply from the Board's main, and may for that purpose provide at the owner's cost such pipes, hydrants, standpipes or posts and other fittings.

A-6. The Board may, subject to such conditions as it may impose, supply water for any purpose other than irrigation or domestic consumption or use, on receiving a written application specifying the purpose for which such supply is required and the quantity likely to be consumed.

Explanation — For the purpose of this Chapter

a) Supply of water for domestic consumption and use shall be deemed to include a supply:

   1) for flushing latrines or house-sewers;

   2) for all baths other than swimming baths or public baths;

   3) for the consumption and use of inmates of hotels, boarding houses and residential clubs and for baths used by such inmates, or

   4) for the consumption and use of persons resorting to theatres and cinemas; and

b) Supply of water for non-domestic consumption and use shall be deemed to include a supply

   1) for any trade, manufacture or business;

   2) for garden;

   3) for building purposes;

   4) for fountains, swimming baths, public baths or tanks or for any ornamental or mechanical purpose

   5) for animals, when they are kept for sale or hire; or

   6) for washing vehicles where they are kept for sale or hire.

APPENDIX B

(*Clause* 3.5.7)

PROCEDURE ADOPTED BY THE MADRAS METROPOLITAN WATER SUPPLY AND SEWERAGE BOARD FOR THE GRANT OF SEWER CONNECTIONS

B-1. The authorized authority shall, on the application of the owner or occupier of any premises or the owner of a private street, arrange for the applicant's house sewer or other sewer in the private street to empty into a sewer of the Board, if

a) the premises or the property in which the private street is situated is assessed to an annual value of not less than three hundred rupees as assessed under Section 35;

b) there is a sewer of the Board within thirty metres of the nearest point from such premises or property;

c) the owner or occupier agrees to bear all cost and expenses of the work and materials necessary for that purpose; and

d) the owner or occupier complies with such conditions and requirements as may be prescribed.

B-2. If there is a public sewer or other place set apart by the Board for the discharge of the sewage within a distance not exceeding thirty metres of the nearest point on any premises, or if within such distance, a Board's sewer or other place for the discharge of sewage is about to be provided or is in the process of construction, the authorized authority may:

a) by notice direct the owner of the said premises to construct a sewer leading therefrom to such sewer or place and to execute all such works as may be necessary at owner's expense, or

b) cause to be constructed a sewer leading from the said premises to such Board's sewer or place and cause to be executed all such works as may be necessary;

Provided that

1) not less than fifteen days before constructing any sewer or executing any work under **B-2** (b), the authorized authority shall give notice to the owner of the nature of the intended work and the estimated expenses recoverable from the owner; and

2) the expenses incurred by the authorized authority in constructing any sewer or executing any work under **B-2** (b) shall be recoverable from the owner in such instalments as the Board may deem fit and recoverable in the same manner as tax under this Act.

B-3. If any premises is, in the opinion of the authorized authority, without sufficient means of effectual sewerage, but no part thereof is situated within thirty metres of a Board's sewer or other place set apart by the Board for the discharge of sewage, the authorized authority may, by notice, direct the owner of the said premises to construct a closed cess pool (or other sewage disposal plant) of such material, dimensions and description in such position and at such level as the authorized authority thinks necessary and to construct a sewer or sewers emptying into such cess pool and to execute all such works as may be necessary.

B-4. It shall not be lawful for the owner of any building to occupy it or cause or permit it to be occupied until he has obtained a certificate from the authorized authority that the said building is provided with such means of sewerage as appear to the authorized authority, to be sufficient.

APPENDIX C

(*Clause* 3.5.8)

RULES REGARDING GRANT OF LICENCE AND SERVICE CONDITIONS OF PLUMBERS FOLLOWED BY THE MADRAS METROPOLITAN WATER SUPPLY AND SEWERAGE BOARD

C-1. These rules may be called the Plumbers' Licence Rules. These will govern the issue of plumbing licences to qualified persons and also the renewal of such licences.

RULES

1. A person may be granted a plumber's licence provided he satisfies the following conditions:

a) He must be a citizen of India,

b) He should be atleast 21 years of age,

c) He must hold a degree or diploma in civil engineering or an equivalent qualification as approved by the All India Council of Technical Education, or must have passed the trade test in plumbing under the Craftsmen Training Scheme, Government of India.

d) He must have a minimum of 3 years experience in plumbing work which can be waived in the case of graduates in engineering,

e) He will also be given a written and oral test on the water supply by-laws, regulations and plumbers' rules if the Water Works Engineer considers it necessary.

Plumbers already licensed in the Water Works Department who do not satisfy these conditions will have to acquire the necessary qualifications within 1 year from the date of which these rules come into effect.

2. Plumbers whose applications for licence are approved shall deposit a sum of Rs. 200 (or such sum as may be fixed by the Commissioner from time to time) as security deposit for the due and proper fulfilment of the plumbers' duties. In the case of Executive Engineers of the P.W.D. holding plumber's licence, no security deposit need be paid, but plumber's licence has to be obtained or renewed every year.

3. Plumbers intending to obtain new licence or renew their existing licences, shall apply to the Water Works Engineer in writing giving full particulars of their general and technical qualifications as well as experience in this line supported by copies of testimonials, before the 31 of March of each year failing which, their applications are liable to be rejected.

4. The licence will be issued annually and year by year and the licence issued to any new applicant during the course of the year will hold good for the remaining part of that official year within which the deposit and the licencing fees were paid.

5. Licences will be issued only in the name of individuals, except in the case of reputed firms. In such cases the Commissioner may, at his discretion, grant licence in the name of the company or firm, but the plumber's estimates will have to be signed each time by an official holding Power of Attorney and also competent to hold plumber's licence to sign on behalf of the company or firm.

6. A list of Licenced Plumbers shall be kept at the Office of the Water Works Engineer for the information of the public.

7. The plumbers are empowered to carry out all house service connections inside private premises including new service connections, extension, alterations, renewals, etc, in conformity with M.C.M.C. Act, the water supply bye-laws and the corporation's 'Rules regarding grant of licence and service conditions of plumbers' and subject to any reasonable orders given by the Water Works Engineer, after submitting necessary estimates and obtaining sanction and after remitting the municipal charges.

8. The plumber shall present at the office of the Water Works Engineer an estimate of the work to be done in the prescribed form with a neat sketch showing the porposals clearly and a site plan showing the nearest important street and the north point, all in triplicate, together with an application in the prescribed form duly filled in, with One Rupee Court Fee Stamp affixed to it.

9. All the three copies of the estimates and the plans should be signed by the plumber and the owner or occupier of the premises legibly with full signature. The plumber's signature shall be over a rubber stamp showing his name and address. No fascimile stamps or similar impressions will be accepted in the place of full signatures.

10. The sanctioned copy of the estimate will be sent to the plumber for payment and the plumber should immediately remit the municipal charges. If for any reason the municipal charges could not be paid and the work executed within two months

on receipt of the sanctioned estimate the plumber should apply in writing for extension of time which may be granted at the discretion of the Water Works Engineer. If the work could not be carried out within six months of receipt of the sanctioned estimate, the sanction will lapse and the plumber should submit fresh plans and proposals for sanction.

11. After paying the municipal charges and after the inside works are completed, the plumber should furnish completion certificate in the prescribed form and only thereafter the road portion of the service will be completed and supply turned on provided the work is carried out by the plumber to the satisfaction of the Water Works Engineer.

12. Whenever a plumber requires water to be shut off from or let on to any premises before or after laying, altering, repairing or renewing private house service pipes, he should notify the Division Supervisor/Overseer of the division in the prescribed form. No plumber shall interfere with any street stop-cock, valve, etc, as all such fittings are under the control of the corporation.

13. In the case of serious leaks in the inside service the plumber may with the prior permission of the concerned Assistant Engineer and the Divisional Supervisor/Overseer carry out repair works in anticipation of sanction of the estimate. But he shall not meddle with the existing alignment of the service in any manner or use bigger size pipes. If the length of the service to be renewed is more than 2 metres, and if the size of the service is more than 25 mm without a metre, the new pipe to be used should be only 20 mm and not more.

14. All materials used or to be used and all works done shall be subject to the supervision, approval or rejection by officers of the corporation duly authorized for such purposes.

15. All cocks, taps, pipes, fittings, etc, shall be in accordance with the specifications given in the Water Supply Bye-laws.

16. Plumbers shall employ only competent, honest and well-behaved workmen to do their works and anyone under the service of any Licensed Plumbing company or firm, who, in the opinion of the Water Works Engineer, is dishonest, incompetent or disorderly, shall forthwith be removed from the service of such a plumber, plumbing company or firm when ordered by the Water Works Engineer in writing.

Plumbers are specially warned against:

a) unsatisfactory work,

b) submitting incorect or misleading plans and estimates or bad workmanship, and

c) making exorbitant charges, or taking advances from the public under false pretences, for which adequate service has not been rendered.

17. The Commissioner may at any time, suspend, or cancel with or without forfeiture of security, the licence granted to any plumber or plumbing company or firm found guilty of breaking or evading any bye-law, any regulations or any of the foregoing rules or who shall be guilty of any breach of the City Municipal Act or who fails to comply with any reasonable order given to him by a duly authorized officer of the Corporation or whose work, in the opinion of the Commissioner, is not satisfactory.

18. All the inside work within the private premises shall be carried out under the personal supervision of the Licensed Plumber who will be held responsible for all works carried out inside the premises.

19. The Licensed Plumbers should take only a reasonable amount as advance from the public and carry out the work in a satisfactory manner without giving room for any complaint.

20. Every Licensed Plumber shall maintain a register in which shall be entered the estimate number, the date of submission, the date of receipt of the sanctioned copy, the date of remittance of the municipal charges, and the date of execution of the work and the details of the work done by them. The diary should be produced whenever required by the Water Works Engineer or his Assistants. Failure to maintain a diary will be considered as gross neglect and may be taken as sufficient reason for cancelling the Plumber's Licence.

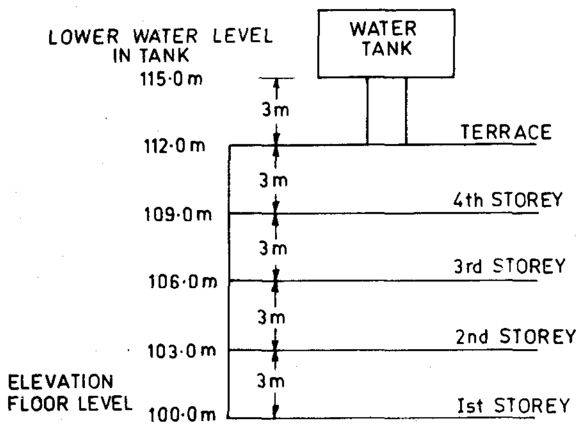
21. Every Licensed Plumber of the Water Works Department must be well conversant with and must be in possession of a copy of the 'Rules regarding grant of licence and service conditions of plumbers' which can be obtained from the Corporation's Enquiry Office, on payment of cost.

APPENDIX D

[*Clause* 5.6.2.2 (b)]

DESIGN OF A WATER SUPPLY SYSTEM IN THE BUILDING OF A FOUR STOREYED BLOCK OF TWIN APARTMENTS WITH WATER SUPPLY FROM AN OVERHEAD TANK ON THE BUILDING (SUPPLY TO EACH FLOOR TO BE METERED SEPARATELY)

D-1. GENERAL



The sanitary fixtures in each apartment consist of the following:

a) 1 sink and 1 tap in the kitchen;

b) 1 overhead flushing tank for water-closet and an ablution tap in the water-closet room;

c) 1 shower, a tap and 1 wash basin; and

d) 1 mini geyser in the bath room.

The fixture units are as follows:

Fixtures	*Fixture Units*
Kitchen	
Kitchen sink	2
Kitchen tap	2
Water-closet Room	
Ablution tap	1
Supply to overhead flushing tank,	1.0
Bath Room	
Shower	2
Tap	2
Wash basin	1
Supply to mini geyser	2
Total	13 units

For two apartments in one floor

Total number of units $= 2 \times 13 = 26$

For 26 fixture units, the effective fixture units (From Table 32).

$$= 2.0 + \frac{6}{20} \times (3.3 - 2.0)$$

$$= 2.0 + \frac{7.8}{20} = 2.0 + 0.39 \text{ or } 2.4$$

One unit rate of flow = 28.32 litres/min

Water supply demand $= 2.4 \times 28.32$ l/min
= 67.968 or 68 l/min

or $\frac{68 \times 60 \times 24}{1000}$ kld = 97.92 or 98 kld.

or 68×60 l/h = 4080 l/h

From Fig. 5, for a discharge of 4080 litres per hour in an inferential type of domestic meter, the loss in a 25 mm size meter is 4.5 m.

D-2. SUPPLY TO FIRST STOREY (GROUND FLOOR)

Elevation of L.W.L. in overhead tank	= 115.0 m
Elevation of first storey floor level	= 100.0 m
Elevation of the highest fixture, namely, supply to overhead flushing tank for water-closet in first storey	= 100 + 1.95
	= 101.95 m
Difference in elevation	= 115 − 101.95
	= 13.05 m
Loss in 25 mm meter	= 4.5 m
Available head	= 8.55 m

Maximum developed length of water pipe from the overhead tank to the common distribution pipeline laid near the ceiling level of:

first storey = 12 m + 2 m for loss in fittings
= 14 m

The available head of 8.55 m is to be lost in 14 m or

$\frac{8.55}{14}$ or 0.61 m/metre

or 61 m/100 metre

The size of pipe with a slope of 61 m/100 m for a discharge of 98 kld is found from Fig. 3 to be less than 25 mm.

A size of 25 mm will be adopted. The actual loss in this size is found to be 48 m/100 m and the velocity to be 2.4 m/s.

For the subsidiary distribution, pipeline supplying to each of the apartments in the first storey, the minimum size of 20 mm will be adopted.

The branches taking off from this subsidiary distribution main to the several sanitary fixtures will be 15 mm, the minimum size to be adopted.

D-3. SUPPLY TO SECOND STOREY

Elevation of LWL in O.H. tank = 115.0 m

Elevation of second storey floor = 103.0 m

Elevation of the highest fixture (namely) supply to the O.H. flush tank for W.C. in second storey = 103.0 + 1.95 m = 104.95 m

Difference in elevation = 115 − 104.95 = 10.05 m

Loss in 25 mm meter = 4.5 m

Available head = 5.55 m

Maximum developed length of water pipe from the O.H. tank to the common distribution pipeline laid near the ceiling level of second storey = 9 + 1.5 m (loss in fittings) = 10.5 m

The available head of 5.55 m is to be lost in 10.5 m or $\frac{5.55}{10.5}$ or 0.526 m/m or 52.6 m/100 m

The size of pipe with a slope of 52.6 m/100 m for a discharge of 98 kld is found from Fig. 3 to be slightly less than 25 mm. This size will be adopted. The other details will be as for first storey pipe system.

D-4. SUPPLY TO THIRD STOREY

Elevation of LWL in O.H. Tank = 115.0 m

Elevation of Third storey floor = 106.0 m

Elevtion of the highest fixture (namely) the supply point to O.H. Flush tank for the W.C. in Third storey = 106 + 1.95 = 107.95 m

Difference in elevation = 115 − 107.95 = 7.05 m

Loss in 25 mm meter = 4.5 m

Available head = 2.55 mm

Maximum developed length of water pipe from the over-head tank to the common distribution pipeline laid near the ceiling level of the third storey

= 6 + 1 (for loss in fittings) = 7 m.

The available head of 2.55 m is to be lost in 7 m of pipeline

or $\frac{2.55}{7}$ or 0.37 m/metre

or 37 m/100 m.

The size of pipe with a slope of 37 m/100 m for a discharge of 98 kld is found from Fig. 3 to be greater than 25 mm but less than 33 mm. Adopt a 33 mm size. Actual velocity in 33 mm for 98 kld discharge

= 1.45 m/s

Loss/100 m = 14 m

Loss in 7 m of pipe = 7 × 0.14 = 0.98 m against 2.55 m available.

The subsidiary distribution pipeline to each of the two apartments in the third storey will be of 20 mm size, the minimum which gives a velocity of 1.9 m/s. The branches taking off from this distribution pipe to each of the sanitary fixtures will be of 15 mm, the minimum size to be adopted.

D-5. SUPPLY TO THE FOURTH STOREY

Elevation of LWL in O.H. tank = 115.0 m

Elevation of the fourth storey floor = 109 m

Elevation of the highest fixture (namely) the supply point to the O.H. flush tank of W.C. in fourth storey = 109 + 1.95 = 110.95 m

Difference in elevation = 115 − 110.95 m = 4.05 m

Loss in a 25 mm meter = 4.5

As this loss in the meter is greater than the difference in elevation, there will be no satisfactory supply in the fourth storey if a meter was to be installed. Either the installation of a meter is to be avoided or the elevation of the O.H tank has to be raised, which is not desirable. So the metering of the supply to the fourth storey will be avoided. The charges for this supply may be based on similar supply to the other floors.

In that case the available lead = 4.05 m

Maximum developed length of water pipe from the O H tank to the common distribution pipeline laid near the ceiling level of fourth storey = 3 + 0.5 m (for loss in fittings)

= 3.5 m

4.05 m is to be lost in 3.5 m of pipeline or

$$\frac{4.05}{3.5} \text{ or } 1.14 \text{ m/m or } 114 \text{ m/100 m.}$$

The size of pipe with a slope of 114 m/100 m for a discharge of 98 kld is found from Fig. 3 to be about 20 mm. However, a size of 25 mm will be adopted. The subsidiary distribution pipeline to each of the two apartments will be minimum of 20 mm size.

The branches taking off from this distribution pipe to each of the sanitary fixture will be 15 mm, the minimum size to be adopted.

D-6. DESIGN OF THE STORAGE TANKS

D-6.1 Ground Level Tank Receiving the Supply from the Corporation or Municipal Main — Total daily supply for the population in the 8 apartments in the 4 storeys at 5 persons family in an apartment at the rate of 135 l c d = 8 × 5 × 135 = 5400 litres/day. Assuming that water supply is available in the street main all through 24 hours, average rate of supply = 5400 litres/day, that is, inflow into the ground level storage tank = 5400 litres/day.

Assuming 8 hours pumping into the overhead storage tank, rate of pumping

$$= \frac{5400}{8} = 675 \text{ litres/h.}$$

Assuming that the pattern of pumping is from 6 to 10 am and 2 to 6 pm

Let a be the average hourly demand

$$a = \frac{\text{Total daily demand}}{24} = \frac{5400}{24} \text{ l/h}$$

$$= 225 \text{ l/h.}$$

The total daily supply is pumped in 8 hours.

$$\text{that is, rate of pumping} = \frac{5400}{8} = 675 \text{ l/h}$$

$$\text{hourly rate of pumping} = \frac{675}{225} = 3\ a.$$

Based only on these two rates, a and $3a$ and the pattern of pumping, that is, for 4 hours from 6 to 10 am and for 4 hours from 2 to 6 pm, the capacity of the ground level storage tank is calculated as given in Table 60.

The storage needed for ground level tank = Maximum storage + Maximum deficit = 12 a = 12 times average supply or half-a-day's supply. The tank will be full at 6 am, that is, when the pumping starts for the day. The tank will become empty at 6 pm that is, when the pumping stops at 6 pm for the day. Storage needed in ground level reservoir = $\frac{5400}{2}$ = 2700 litres. The minimum storage in a ground level reservoir is also 50 percent of the storage in an overhead reservoir. The actual storage to be

TABLE 60 CAPACITY OF GROUND LEVEL STORAGE TANK

(*Clause* D-6.1)

Time in Hours: From	Time in Hours: To	Hourly Demand	Cumulative Demand	Hourly Pumping	Cumulative Pumping	Cumulative Deficit (−) or Surplus (+)	Storage in Reservoir
24	6	a	$6a$	0	0	$6a$	$12a$
6	7	a	$7a$	$3a$	$3a$	$4a$	$10a$
7	8	a	$8a$	$3a$	$6a$	$2a$	$8a$
8	9	a	$9a$	$3a$	$9a$	0	$6a$
9	10	a	$10a$	$3a$	$12a$	$-2a$	$4a$
10	11	a	$11a$	0	$12a$	$-a$	$5a$
11	12	a	$12a$	0	$12a$	0	$6a$
12	13	a	$13a$	0	$12a$	a	$7a$
13	14	a	$14a$	0	$12a$	$2a$	$8a$
14	15	a	$15a$	$3a$	$15a$	0	$6a$
15	16	a	$16a$	$3a$	$18a$	$-2a$	$4a$
16	17	a	$17a$	$3a$	$21a$	$-4a$	$2a$
17	18	a	$18a$	$3a$	$24a$	$-6a$	0
18	24	a	$24a$	—	$24a$	0	$6a$

provided in this case will be decided after the storage capacity of the overhead reservoir is decided.

D-6.2 Capacity of the Overhead Reservoir — The capacity can be calculated based on the rates and hours of pumping into the overhead tank and the rate of withdrawal from the tank, which is based on the demand of the sanitary fixtures in the building (*see* Table 61).

As the rate of withdrawal from the tank or the rate of demand of the sanitary fixtures depends on the habits of the people of the building, an hourly pattern of demand is assumed to work out the theoretical capacity of the overhead storage tank.

Storage = maximum deficit + maximum surplus

$= 3.85\ a + 3.8a$

$= 7.65\ a$

Maximum storage in O.H. reservoir = 7.65 average supply

$= 7.65 \times 225$ litres

$= 1721.25$ litres (1)

The storage capacity as per the norms given in Table 16 based on the population in the residential building

= No. of population × 70 litres

No. of population in the four storeyed block of twin apartments

$= 4 \times 2 \times 5 = 40$

Storage needed for the overhead reservoir

$= 40 \times 70 = 2800$ litres (2)

No. of water-closets in the building

$= 4 \times 2 \times 1 = 8$

Storage needed for flushing W.C. as in Table 17.

$= 270 \times 8 = 2160$ litres. (3)

The minimum storage as in **5.4.2.3** = 1/2 day

supply $= \frac{5400}{2}$ litres = 2700 litres (4)

The various figures for the storage, as calculated in (1) to (4), are 1721.25 litres, 2800 litres, 2160 litres, and 2700 litres.

The storage needed in this case shall be as in (2), that is, 2800 litres.

The storage needed for the ground level reservoir shall be a minimum of 50 percent of 2800 litres or 1400 litres which is less than that was calculated earlier, that is, 2700 litres. However, a day's supply may be provided in the ground level reservoir, that is, 5400 litres to be on the safe side.

D-6.3 Size of the Overhead Tank

Capacity = 2800 litres

Assuming a total depth of 1.0 metre and effective depth = 0.85 m

Area of section $= \frac{2800 \times 1000}{85} = 32\,941\ \text{cm}^2$

TABLE 61 CAPACITY OF OVERHEAD RESERVOIR

(*Clause* D-6.2)

Time in Hours From	Time in Hours To	Hourly Demand	Cumulative Demand	Hourly Pumping	Cumulative Pumping	Cumulative Deficit (−) or Surplus (+)	Storage in Reservoir
24	4	0.2a	0.8a	0	0	−0.8a	3.05a
4	5	0.4a	1.2a	0	0	−1.2a	2.65a
5	6	0.8a	2.0a	0	0	−2.0a	1.85a
6	7	2.25a	4.25a	3a	3a	−1.25a	2.6a
7	8	2.25a	6.5a	3a	6a	−0.5a	3.35a
8	9	2.25a	8.75a	3a	9a	+0.25a	4.1a
9	10	2.25a	11a	3a	12a	+a	4.85a
10	11	a	12a	0	12a	0	3.85a
11	12	a	13a	0	12a	−a	2.85a
12	13	0.6a	13.6a	0	12a	−1.6a	2.25a
13	14	2.25a	15.85a	0	12a	−3.85a	0
14	15	0.7a	16.55a	3a	15a	−1.55a	2.30a
15	16	0.7a	17.25a	3a	18a	+0.75a	4.60a
16	17	0.7a	17.95a	3a	21a	+3.05a	6.9a
17	18	2.25a	20.20a	3a	24a	+3.8a	7.65a
18	20	0.9a	22.0a	0	24a	+2a	5.85a
20	22	0.7a	23.4a	0	24a	+0.6a	4.45a
22	23	0.4a	23.8a	0	24a	+0.2a	4.05a
23	24	0.2a	24a	0	24a	0	3.85a

Assume a square section

$b^2 = 32\,941$

$b = \sqrt{32\,941}$

$= 181.5$ cm or 1.9 metres (say)

The size will be 1.9 m $\times$ 1.9 m $\times$ 1.0 m

D-6.4 Ground Level Tank

Capacity = 5400 litres

Assume a total depth of 1.2 m and effective depth = 1.05 m

$$\text{Area of section} = \frac{5400 \times 1000}{105} = 51\,428 \text{ cm}^2$$

Assuming a square section

$b^2 = 51428$ or $b = \sqrt{51428} = 226.7$ or 230 cm $= 2.3$ m

The size will be, say 2.3 m $\times$ 2.3 m $\times$ 1.2 m

APPENDIX E

(*Clause* 6.13.3.5)

TYPICAL DESIGN OF A SEPTIC TANK INSTALLATION WITH SOIL ABSORPTION SYSTEM FOR THE FOUR STOREYED BLOCK OF TWIN APARTMENTS

E-1. *General* — The sanitary fixtures are as detailed in example in Appendix A.

The fixture units for each apartment serving 5 persons = 13 units. Total fixture units in the four storeyed block = 4 $\times$ 2 $\times$ 13 = 104 units (for 40 persons). Estimated peak discharge is assured to be the same as the probable demand on the water pipes based on fixture units (*see* Table 32 and Fig. 15, system is supposed to be with flush tanks).

For 104 units, peak discharge from 40 persons at 5.84 units rate of flow = 5.84 $\times$ 28.316 = 165.4 lpm [**6.13.3.2**(b)] (*see* Table 32).

E-2. Tank Capacity

For Sedimentation — Surface area of tank at 0.92 m²/10 lpm peak flow rate

$$= 0.92 \times \frac{165.4}{10} = 15.2 \text{ m}^2.$$

Assuming 0.3 m depth,
volume = $15.2 \times 0.3 = 4.56$ m^3

For Sludge Digestion (for Average Temperature of 25°C) — Capacity required for sludge digestion at 0.032 m^3 per capita
$= 0.032 \times 40 = 1.28$ m^3

For Sludge Storage — Assuming cleaning once in 2 years, volume required for digested sludge at 0.0002 m^3/cap/day
$= 0.0002 \times 365 \times 40 \times 2 = 5.84$ m^3

For Seed Sludge — Increase the volume by 10 percent to provide for seed sludge, that is, 0.584 m^3.

Free Board — Assuming a free board of 30 cm, volume = $15.2 \times 0.3 = 4.56$ m^3

Total Capacity and Dimension — Total capacity of tank = 4.56 + 1.28 + 5.84 + 0.584 + 4.56 = 16.284 m^3

Area of tank = 15.2 m^2

$$\text{Total depth of tank} = \frac{16.824}{15.2} = 1.11 \text{ m}$$

Adopting a length to breadth ratio of 2.5 : 1

$2.5\, b^2 = 15.2$ m^2

or $b^2 = \dfrac{15.2}{2.5} = 6.08$

or $b = \sqrt{6.08} = 2.5$ m

$l = 2.5b = 2.5 \times 2.5 = 6.25$ m

Tank dimensions are 6.25 m $\times$ 2.5 m $\times$ 1.1 m

E-3. Miscellaneous Details — Typical details of inlet and outlet arrangements baffles desludging arrangements, etc. are to be according to septic tank Type 2 of IS : 2470 (Part 1)-1985.

E-4. Soil Absorption System — Assuming the percolation rate, that is, time in minutes for a fall of 25 mm in water level as 5 minutes, the maximum rate of effluent application as in **6.13.2.3** is 90 l/m²/day. As the rate of water supply is 135 lpcd,

Total flow per day = 40 $\times$ 135
= 5400 litres

$$\text{Total area of trench required} = \frac{5400}{90} = 60 \text{ m}^2$$

Assuming a trench width of 1 m, total length of trench needed is 60 m. Assuming three rows of trench, length of each trench is 20 m. The trenches may be in one plot with a separation distance between trenches of 2 m, and the details may be generally as in Fig. 6 of IS : 2470 (Part 1)-1985.

APPENDIX F

LIST OF INDIAN STANDARDS RELATING TO WATER SUPPLY, DRAINAGE AND SANITATION

General

SP : 7-1983 National Building Code of India: Part IX Plumbing services

IS : 456-1978 Code of practice for plain and reinforced concrete (*third revision*)

IS : 962-1967 Code of practice for architectural and building drawings (*first revision*)

IS : 1256-1967 Code of practice for bulding bye-laws (*first revision*)

IS : 1343-1980 Code of practice for pre-stressed concrete (*first revision*)

IS : 2332-1972 Nomenclature of floors and storeys (*first revision*)

IS : 7973-1976 Code of practice for architectural and building working drawings

IS : 7022 (Part 1)-1973 Glossary of terms relating to water, sewage and industrial effluents: Part 1

IS : 786-1967 Conversion factors and conversion tables (*first revision*)

IS : 1020-1963 Conversion tables for ordinary use (*revised*)

IS : 787-1956 Guide for inter-conversion of values from one system of units to another

IS : 1172-1983 Code of basic requirements for water supply, drainage and sanitation (*third revision*)

IS : 2065-1983 Code of practice for water supply in buildings (*second revision*)

IS : 6295-1971 Code of practice for water supply and drainage in high altitudes and/or subzero temperature regions

IS : 7558-1974 Code of practice for domestic hot water installations

IS : 1742-1983 Code of practice for building drainage (*second revision*)

IS : 2470 Code of practice for installation of septic tanks:

- IS : 2470 (Part 1)-1985 Design criteria and construction (*second revision*)
- IS : 2470 (Part 2)-1985 Secondary treatment and disposal of septic tank effluents (*second revision*)

IS : 5611-1970 Code of practice for waste stabilization ponds (facultative type)

IS : 5329-1983 Code of practice for sanitary pipe work above ground for buildings (*first revision*)

IS : 2064-1973 Code of practice for selection, installation and maintenance of sanitary appliances (*first revision*)

IS : 8835-1978 Guidelines for planning and design of surface drains

IS : 6924-1973 Code of practice for the construction of refuse chutes in multistoreyed buildings

IS : 1200 Method of measurement of building and civil engineering works:

- IS : 1200 (Part 1)-1974 Earthwork (*third revision*)
- IS : 1200 (Part 16)—1979 Laying of water and sewer lines including appurtenant items (*third revision*)
- IS : 1200 (Part 19)-1981 Water supply, plumbing and drains (*third revision*)

IS : 10446-1983 Glossary of terms relating to water supply and sanitation.

Pipes, Specials, Fittings and Laying

IS : 1536-1976 Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage (*second revision*)

IS : 6163-1978 Specification for centrifugally cast (spun) iron low pressure pipes for water, gas and sewage (*first revision*)

IS : 8329-1977 Specification for centrifugally cast (spun) ductile iron pressure pipes for water, gas and sewage

IS : 1537-1976 Specification for vertically cast iron pressure pipes for water, gas and sewage (*first revision*)

IS : 7181-1974 Specification for horizontally cast iron double flanged pipes for water, gas and sewage

IS : 1729-1979 Specification for sand cast iron spigot and socket soil, waste and ventilating pipes, fittings and accessories (*first revision*)

IS : 3486-1966 Specification for cast iron spigot and socket drain pipes

IS : 3989-1984 Specification for centrifugally-cast (spun) iron spigot and socket soil, waste and ventilating pipes, fittings and accessories (*second revision*)

IS : 1879 (Parts 1 to 10)-1975 Specification for malleable cast iron pipe fittings (*first revision*)

IS : 1538 (Parts 1 to 23)-1976 Specification for cast iron fittings for pressure pipes for water, gas and sewage (*second revision*)

IS : 1230-1979 Specification for cast iron pipes and fittings (*second revision*)

IS : 6418-1971 Specification for cast iron and malleable cast iron flanges for general engineering purposes

IS : 3114-1985 Code of practice for laying of cast iron pipes (*first revision*)

IS : 782-1978 Specification for caulking lead (*third revision*)

IS : 3589-1981 Specification for electrically welded steel pipes for water, gas and sewage (200 mm to 2000 mm nominal diameter) (*first revision*)

IS : 1239 Specification for mild steel tubes, tubulars and other wrought steel fittings:

IS : 1239 (Part 1)-1979 Mild steel tubes (*fourth revision*)

IS : 1239 (Part 2)-1982 Mild steel tubulars and other wrought steel pipe fittings (*third revision*)

IS : 6631-1972 Specification for steel pipes for hydraulic purposes

IS : 6392-1971 Specification for steel pipe flanges

IS : 2379-1963 Specification for colour code for the identification of pipe lines

IS : 4270-1983 Specification for steel tubes used for water wells (*first revision*)

IS : 806-1968 Code of practice for use of steel tubes in general building construction (*first revision*)

IS : 5822-1970 Code of practice for laying of welded steel pipes for water supply

IS : 2800 Code of practice for construction and testing of tube wells:

IS : 2800 (Part 1)-1979 Construction (*first revision*)

IS : 2800 (Part 2)-1979 Testing (*first revision*)

IS : 8110-1985 Requirements for well screens and slotted pipes (*first revision*)

IS : 6935-1973 Method of determination of water level in a bore hole

IS : 4097-1967 Specification for gravel for use as pack in tube wells

IS : 6908-1975 Specification for asbestos cement pipes and fittings for sewerage and drainage

IS : 1592-1980 Specification for asbestos cement pressure pipes (*second revision*)

IS : 1626 (Part 1)-1980 Specification for asbestos cement building pipes and pipe fittings, gutter and gutter fittings, and roof fittings: Part 1 Pipes and pipe fittings (*first revision*)

IS : 8794-1978 Specification for cast iron detachable joints for use with asbestos cement pressure pipes

IS : 5531 (Parts 1 to 3)-1977 Specification for cast iron specials for asbestos cement pressure pipes for water, gas and sewage (*first revision*)

IS : 6530-1972 Code of practice for laying of asbestos cement pressure pipes

IS : 1916-1963 Specification for steel cylinder reinforced concrete pipes

IS : 7322-1983 Specification for specials for steel cylinder reinforced concrete pipes (*first revision*)

IS : 458-1971 Specification for concrete pipes (with and without reinforcement) (*second revision*)

IS : 4350-1967 Specification for concrete porous pipes for under-drainage

IS : 3597-1985 Method of test for concrete pipes (*first revision*)

IS : 784-1978 Specification for prestressed concrete pipes (including fittings) (*first revision*)

IS : 7319-1974 Specification for perforated concrete pipes

IS : 783-1959 Code of practice for laying of concrete pipes

IS : 7634 Code of practice for plastics pipe work for potable water suplies:

IS : 7634 (Part 1)-1975 Choice of materials and general recommendations

IS : 7634 (Part 2)-1975 Laying and jointing of polyethylene (PE) pipes

IS : 7634 (Part 3)-1975 Laying and jointing of unplasticised PVC pipes

IS : 4984-1978 Specification for high density polyethylene pipes for potable water supplies, sewage and industrial effluents (*second revision*)

IS : 8008 Specification for injection moulded high density polyethylene (HDPE) fittings for potable water supplies:

IS : 8008 (Part 1)-1976 General requirements

IS : 8008 (Part 2)-1976 Specific requirements for 90° bends

IS : 8008 (Part 3)-1976 Specific requirements for 90° tees.

IS : 8008 (Part 4)-1976 Specific requirements for reducers.

IS : 8008 (Part 5)-1976 Specific requirements for ferrule

IS : 8008 (Part 6)-1976 Specific requirements for pipe ends.

IS : 8008 (Part 7)-1976 Specific requirements for sandwich flanges

IS : 3076-1985 Specification for low density polyethylene pipes for potable water supplies (*second revision*)

IS : 4985-1981 Specification for unplasticized PVC pipes for potable water supplies (*first revision*)

IS : 7834 Specification for injection moulded PVC socket fittings with solvent cement joints for water supplies:

IS : 7834 (Part 1)-1975 General requirements

IS : 7834 (Part 2)-1975 Specific requirements for 45° elbows

IS : 7834 (Part 3)-1975 Specific requirements for 90° elbows

IS : 7834 (Part 4)-1975 Specific requirements for 90° tees.

IS : 7834 (Part 5)-1975 Specific requirements for 45° tees

IS : 7834 (Part 6)-1975 Specific requirements for sockets.

IS : 7834 (Part 7)-1975 Specific requirements for unions

IS : 7834 (Part 8)-1975 Specific requirements for caps.

IS : 2501-1985 Specification for copper tubes for general engineering purposes (*second revision*)

IS : 404 Specification for lead pipes:

IS : 404 (Part 1)-1977 For other than chemical purposes (*second revision*)

IS : 404 (Part 2)-1979 For chemical purposes (*second revision*)

IS : 651-1980 Specification for salt-glazed stoneware pipes and fittings (*fourth revision*)

IS : 3006-1979 Specification for chemically resistant glazed stoneware pipes and fittings (*first revision*)

IS : 4127-1983 Code of practice for laying of glazed stoneware pipes (*first revision*)

IS : 2527-1984 Code of practice for fixing rain water gutters and downpipes for roof drainage (*first revision*)

IS : 7740-1975 Code of practice for road gullies

Sluice Valves, Sluice Gates, Ball Valves, Foot Valves, Mixing Valves and Landing Valves

IS : 780-1984 Specification for sluice valves for water works purposes (50 to 300 mm size) (*sixth revision*)

IS : 2906-1984 Specification for sluice valves for water works purposes (350 to 1200 mm size) (*third revision*)

IS : 2685-1971 Code of practice for selection, installation and maintenance of sluice valves (*first revision*)

IS : 3042-1965 Specification for single faced, sluice gates (200 to 1200 mm size)

IS : 5312 (Part 1)-1969 Specification for swing check type reflux (non-return) valves for water purposes : Part 1 Single door pattern (*first revision*)

IS : 1703-1977 Specification for ball valves (horizontal plunger type) including floats for water supply purposes (*second revision*)

IS : 5290-1983 Specification for landing valves (*second revision*)

IS : 4038-1979 Specification for foot valves for water works purposes (*first revision*)

IS : 1701-1960 Specification for mixing valves for ablutionary and domestic purposes

IS : 778-1984 Specification for copper alloy gate, globe and check valves for water works purposes (*fourth revision*)

IS : 3950-1979 Specification for surface boxes for sluice valves (*first revision*)

Meters

IS : 779-1978 Specification for water meters (domestic type) (*fifth revision*)

IS : 2373-1981 Specification for water meters (bulk type) (*third revision*)

IS : 2104-1981 Specification for water meter boxes (domestic type) (*first revision*)

IS : 6784-1984 Method for performance testing of water meters (domestic type) (*first revision*)

IS : 2401-1973 Code of practice for selection, installation and maintenance of domestic water meters (*first revision*)

Sanitary Fittings

IS : 8931-1978 Specification for cast copper alloy fancy bib taps and stop valves for water services

IS : 8934-1978 Specification for cast copper alloy fancy filler taps for water services

IS : 781-1984 Specification for cast copper alloy screw down bib taps and stop valves for water services (*third revision*)

IS : 5219 (Part 1)-1969 Specification for cast copper alloys traps: Part 1 'P' and 'S' traps

IS : 1700-1973 Specification for drinking fountains (*first revision*)

IS : 772-1973 Specification for general requirements for enamelled cast iron sanitary appliances (*second revision*)

IS : 3489-1985 Specification for enamelled steel bath tubs (*first revision*)

IS : 2692-1978 Specification for ferrules for water services (*first revision*)

IS : 6249-1971 Specification for flush valves and fittings for marine purposes

IS : 2326-1970 Specification for automatic flushing cistern for urinals (*first revision*)

IS : 774-1984 Specification for flushing cisterns for water-closets and urinals (other than plastic cisterns) (*fourth revision*)

IS : 6411-1985 Specification for gel-coated glass fibre reinforced polyester resin bath tubs (*first revision*)

IS : 771 Specification for glazed fire-clay sanitary appliances:

IS : 771 (Part 1)-1979 General requirements (*second revision*)

IS : 771 (Part 2)-1985 Specific requirements of kitchen and laboratory sinks (*third revision*)

IS : 771 (Part 3) Specific requirements of urinals:

IS : 771 (Part 3/Sec 1)-1979 Slab urinals (*second revision*)

IS : 771 (Part 3/Sec 2)-1985 Stall urinals (*third revision*).

IS : 771 (Part 4)-1979 Specific requirements of postmortem slabs (*second revision*)

IS : 771 (Part 5)-1979 Specific requirements of shower trays (*second revision*)

IS : 771 (Part 6)-1979 Specific requirements of bed pan sinks (*second revision*)

IS : 5961-1970 Specification for cast iron gratings for drainage purposes

IS : 5869-1970 Specification for pillar taps for marine use

IS : 7231-1974 Specification for plastic flushing cisterns for water-closets and urinals (*first revision*)

IS : 2548 Specification for plastic seats and covers for water-closets:

IS : 2548 (Part 1)-1983 Thermoset seats and covers (*fourth revision*)

IS : 2548 (Part 2)-1983 Thermoplastic seats and covers (*fourth revision*)

IS : 3004-1979 Specification for plug cocks for water supply purposes (*first revision*)

IS : 1711-1984 Specification for self-closing taps for water supply (*second revision*)

IS : 6251-1971 Specification for shower and shower fittings for marine use

IS : 4346-1982 Specification for washers for use with fittings for water services (*first revision*)

IS : 2963-1979 Specification for copper alloys waste-fittings for wash-basins and sinks (*first revision*)

IS : 3311-1979 Specification for waste plug and its accessories for sinks and wash-basins (*first revision*)

IS : 773-1964 Specification for enamelled cast iron water-closets, railway coaching stock type (*second revision*)

IS : 1795-1982 Specification for pillar taps for water supply purposes (*second revision*)

IS : 805-1968 Code of practice for use of steel in gravity water tanks

IS : 3468-1975 Specification for pipe nuts (*first revision*)

IS : 5369-1975 General requirements for plain washers and lock washers (*first revision*).

Vitreous Ware

IS : 8718-1978 Specification for vitreous enamelled steel kitchen sinks

IS : 8727-1978 Specification for vitreous enamelled steel wash basin

IS : 9076-1979 Specification for vitreous integrated squatting pan for marine use

IS : 9140-1985 Methods of sampling of vitreous and fire clay sanitary appliances (*first revision*)

IS : 2556 Specification for vitreous sanitary appliances (vitreous china):

IS : 2556 (Part 1)-1974 General requirements (*second revision*)

IS : 2556 (Part 2)-1981 Specific requirements of wash-down water-closets (*third revision*)

IS : 2556 (Part 3)-1981 Specific requirements of squatting pans (*third revision*)

IS : 2556 (Part 4)-1972 Specific requirements of wash-basins (*second revision*)

IS : 2556 (Part 5)-1979 Specific requirements of laboratory sinks (*second revision*)

IS : 2556 (Part 6) Specific requirements of urinals:

IS : 2556 (Part 6/Sec 1)-1979 Bowl type (*third revision*)

IS : 2556 (Part 6/Sec 2)-1974 Half stall urinals (*second revision*)

IS : 2556 (Part 6/Sec 3)-1974 Squatting plates (*second revision*)

IS : 2556 (Part 6/Sec 4)-1974 Partition slabs (*second revision*)

IS : 2556 (Part 6/Sec 5)-1974 Waste fittings (*second revision*)

IS : 2556 (Part 6/Sec 6)-1974 Water spreaders for half stall urinals (*second revision*)

IS : 2556 (Part 7)-1973 Specific requirements of half round channel (*second revision*)

IS : 2556 (Part 8)-1985 Specific requirements of siphonic wash-down water-closets (*third revision*).

IS : 2556 (Part 9)-1979 Specific requirements of bidets (*third revision*)

IS : 2556 (Part 10)-1974 Specific requirements of foot rest (*second revision*)

IS : 2556 (Part 11)-1979 Specific requirements for shower rose (*first revision*)

IS : 2556 (Part 12)-1973 Specific requirements for floor traps

IS : 2556 (Part 13)-1973 Specific requirements of traps for squatting pans

IS : 2556 (Part 14)-1974 Specific requirements of integrated squatting pans

IS : 2556 (Part 15)-1974 Specific requirements of universal water-closet

IS : 8719-1978 Specification for vitreous siphonic wash-down water-closets for marine use

IS : 5917-1970 Specification for vitreous (vitreous china) wash basins for marine purposes

IS : 775-1970 Specification for cast iron brackets and supports for lavatory basins and sinks (*second revision*)

IS : 7402-1986 Specification for filters for drinking water purposes (*first revision*)

Fire Fighting

IS : 2871-1983 Specification for branch pipe, universal, for fire fighting purposes (*first revision*)

IS : 906-1972 Specification for branch with revolving head for fire fighting purposes (*second revision*)

IS : 910-1980 Specification for combined key for hydrant, hydrant cover and lower valve (*second revision*)

IS : 901-1975 Specification for couplings, double male and double female, instantaneous pattern for fire fighting (*second revision*)

IS : 903-1984 Specification for fire hose delivery couplings, branch pipe, nozzles and nozzle spanner (*third revision*)

IS : 908-1975 Specification for fire hydrant, stand post type (*second revision*)

IS : 952-1969 Specification for fog-nozzle for fire brigade use

IS : 2546-1974 Specification for galvanized mild steel fire bucket (*first revision*)

IS : 5714-1981 Specification for hydrant, standpipe for fire fighting (*first revision*)

IS : 5132-1969 Specification for hose reel tubing for fire fighting

IS : 909-1975 Specification for underground fire hydrant, sluice-valve type (*second revision*)

IS : 3844-1966 Code of practice for installation of internal fire hydrants in multistorey buildings

IS : 9668-1980 Code of practice for provision and maintenance of water supplies for fire fighting

Ancillary Structures in Sewerage System

IS : 4111 Code of practice for ancillary structure system:

IS : 4111 (Part 1)-1986 Manholes (*first revision*)

IS : 4111 (Part 2)-1985 Flushing tanks (*first revision*)

IS : 4111 (Part 3)-1985 Inverted syphon (*first revision*)

IS : 4111 (Part 4)-1968 Pumping stations and pumping mains (rising mains)

IS : 1726 Specification for cast iron manhole covers and frames:

IS : 1726 (Part 1)-1974 General requirements (*second revision*)

IS : 1726 (Part 2)-1974 Specific requirements of HD circular type (*second revision*)

IS : 1726 (Part 3)-1974 Specific requirements for HD double triangular type (*second revision*)

IS : 1726 (Part 4)-1974 Specific requirements for MD circular type (*second revision*)

IS : 1726 (Part 5)-1974 Specific requirements for MD rectangular type (*second revision*)

IS : 1726 (Part 6/Sec 1)-1974 Specific requirements for LD rectangular type, Section 1 Single seal (*second revision*)

IS : 1726 (Part 6/Sec 2)-1974 Specific requirements for LD rectangular type, Section 2 Double seal (*second revision*)

IS : 1726 (Part 7/Sec 1)-1974 Specific requirements for LD square type, Section 1 Single seal (*second revision*)

IS : 1726 (Part 7/Sec 2)-1974 Specific requirements for LD square type, Section 2 Double seal (*second revision*)

IS : 5455-1969 Specification for cast iron steps for manholes

Public Health Engineering Equipment

IS : 8403-1977 Code of practice for consturction of clarifier digester for treatment of sewage

IS : 6279-1971 Specification for equipment for grit removal devices

IS : 7208-1974 Guidelines for flocculator devices

IS : 7090-1985 Guidelines for rapid mixing devices (*first revision*)

IS : 9110-1979 Specification for hand operated augers for cleaning water-closet pipes and sewers

IS : 9222 (Part 1)-1979 Recommendation for handling and dosing devices for chemicals for water treatment: Part 1 Coagulants

IS : 7232-1974 Method for Imhoff cone test

IS : 8413 (Part 1)-1977 Requirements for biological tretment equipment: Part 1 Trickling filters

IS : 8419 (Part 1)-1977 Requirements for rapid sand gravity filtration equipment: Part 1 Filtration media—Sand and gravel

IS : 6280-1971 Specification for sewage screens

Pumps

IS : 1520-1980 Specification for horizontal centrifugal pumps for clear cold fresh water (*second revision*)

IS : 8418-1977 Specification for horizontal centrifugal self-priming pumps

IS : 8472-1977 Specification for regenerative self-priming pumps for clear, cold, fresh water

IS : 5600-1970 Specification for sewage and drainage pumps

IS : 8034-1976 Specification for submersible pump sets for clear, cold, fresh water

IS : 1710-1972 Specification for vertical turbine pumps for clear, cold, fresh water (*first revision*)

IS : 8035-1976 Specification for shallow well hand pumps

Fluid Flow Measurement

IS : 2951 Recommendation for estimation of flow of liquids in closed conduits:

IS : 2951 (Part 1)-1965 Head loss in straight pipes due to frictional resistance

IS : 2951 (Part 2)-1965 Head loss in valves and fittings

IS : 9119-1979 Method of flow estimation by jet characteristics (approximate method)

IS : 4477 (Part 1)-1967 Methods of measurement of fluid flow by means of venturi meters: Part 1 Liquids

IS : 1191-1971 Glossary of terms and symbols used in connection with the measurement of liquid flow with a free surface (*first revision*)

IS : 9108-1979 Liquid flow measurement in open channels using thin plate weirs

IS : 6063-1971 Method of measurement of flow of water in open channels using standing wave flume

IS : 2952 Recommendation for methods of measurement of fluid flow by means of orifice plates and nozzles:

IS : 2952 (Part 1)-1964 Incompressible fluids

IS : 2952 (Part 2)-1975 Compressible fluids

IS : 9118-1979 Method of measurement of pressure by means of manometers

Quality Tolerances

IS : 3328-1965 Specification for quality tolerances for water for swimming pools

IS : 8914-1978 Specification for quality tolerances for water for vitreous enamel industry

IS : 4733-1972 Methods of sampling and test for sewage effluents (*first revision*)

IS : 2296-1982 Tolerance limits for inland surface waters subject to pollution (*second revision*)

IS : 4764-1973 Tolerance limits for sewage effluents discharged into inland surface waters (*first revision*)

IS : 6582-1971 Specification for bio-assay methods for evaluating acute toxicity of industrial effluents and waste waters

Chemicals

IS : 1065-1971 Specification for bleaching powder, stable (*first revision*)

IS : 646-1986 Specification for liquid chlorine, technical (*second revision*)

IS : 261-1982 Specification for copper sulphate (*second revision*)

IS : 711-1970 Specification for ferric chloride, technical (*first revision*)

IS : 262-1982 Specification for ferrous sulphate, heptahydrate (*second revision*)

IS : 258-1967 Specification for potash alum (*first revision*)

IS : 4955-1982 Specification for household laundry detergent powders (*second revision*)

IS : 7983-1976 Specification for cleaning solution, porcelain

IS : 5481-1969 Specification for floor polish, liquid

IS : 8541-1977 Specification for floor polish, paste

IS : 8540-1986 Specification for glass cleaner, liquid (*first revision*)

IS : 5487-1969 Specification for metal polish, liquid

IS : 7932-1982 Specification for boiler water treatment compounds (*first revision*)

Hand Tools

IS : 4123-1982 Specification for chain pipe wrenches (*first revision*)

IS : 6389-1972 Specification for combination wrenches

IS : 3650-1981 Specification for combination side cutting pliers (*first revision*)

IS : 5169-1969 Specification for hacksaw frames

IS : 841-1983 Specification for steel hammers (*second revision*)

IS : 7958-1976 Specification for hand vices

IS : 5995-1971 Specification for pipe grip pliers

IS : 5684-1970 Specification for pipe vices (chain type)

IS : 2587-1975 Specification for pipe vices (open side type and fixed side type) (*first revision*)

IS : 6007-1971 Specification for pipe vices (hinged type)

IS : 4003 Specification for pipe wrenches:

IS : 4003 (Part 1)-1978 General purpose (*first revision*)

IS : 4003 (Part 2)-1978 Heavy duty

IS : 2029-1981 Specification for ring wrenches (spanners) (*second revision*)

IS : 844 Specification for screw drivers:

IS : 844 (Part 1)-1979 Technical supply conditions (*second revision*)

IS : 844 (Part 2)-1979 Dimensions (*second revision*)

IS : 844 (Part 3)-1979 Dimensions for screw drivers for recessed head screws (*second revision*)

IS : 6379-1971 Specification for single ended ring wrenches (spanners)

IS : 6843-1984 Technical supply conditions for pipe cutters (*first revision*)

IS : 7145-1973 Technical supply conditions for torque wrenches.

APPENDIX G
SOLVED EXAMPLES

Example 1

System of Pipes in Series

20 m   5 m
A ____________|____________|____________ D
50 mm × 20 m   B   32 mm × 40 m   C   25 mm × 30 m

Let the three pipes in series be:

a) AB of 50 mm dia × 20 m long,

b) BC of 32 mm dia × 40 m long, and

c) CD of 25 mm dia × 30 m long.

To find the flow through the system for a loss of head of 15 m between A and D.

Solution—To solve this problem, an equivalent pipeline to the given system has to be found out first and for the given loss of head of 15 m the flow through that equivalent pipeline determined which will be the flow through the given system.

To determine the equivalent pipeline — Assume a flow of 100 kld through the system and find out the total loss of head between A and D. An equivalent pipeline will give the same total loss of head for the same flow of 100 kld.

Loss of head in AB
(that is, 50 mm dia pipe × 20 m long)

Loss of head in 50 mm dia pipe for 100 kld = 1.69 m/100 mm length (*see* Fig. 3).

$$\text{Loss of head in 20 m length} = \frac{1.69}{100} \times 20 = 0.338 \text{ m}$$

Loss of head in 32 m dia pipe for 100 kld = 14.7 m/100 m length

$$\text{Loss of head in 40 m length} = \frac{14.7}{100} \times 40 = 5.88 \text{ m}$$

Loss of head in 25 mm dia pipe for 100 kld = 51.5 m/100 m length

$$\text{Loss of head in 30 m length} = \frac{51.5}{100} \times 30 = 15.45 \text{ m}$$

$$\text{Total loss of head in A to D} = 0.338 + 5.88 + 15.45 = 21.668 \text{ m}$$

The equivalent pipeline is one which gives a loss of head of 21.668 m for a flow of 100 kld. Assume a pipe dia of 32 mm and calculate the length for this flow and loss of head.

Loss of head per 100 m in 32 mm dia pipe for a flow of 100 kld is 14.7 m.

Length of 32 mm dia pipe to give a loss of head of 21.668 m

$$= \frac{21.668}{14.7} \times 100 = 147.4 \text{ m}$$

The equivalent length of 32 mm dia pipe is 147.4 m.

The total loss in the system = 15 m.

For this loss in 147.4 m long of 32 mm dia pipe, the flow is found using the chart which is the flow through the system.

Loss in 147.4 m length = 15 m

$$\text{Loss in 100 m length} = \frac{15}{147.4} \times 100 = 10.18 \text{ m}$$

Flow in 32 mm dia pipe for this loss of head of 10.18 m per 100 m is found from Fig. 3 to be 83 kld. The flow through the pipe system for a total loss of 15 m is 83 kld.

Check — For a flow of 83 kld through the system, the loss in the three pipe lengths must sum up to 15 m.

Loss in AB — For a flow of 83 kld, the loss in 50 mm dia pipe = 1.17 m/100 m

$$\text{Loss in 20 m length} = \frac{1.17}{100} \times 20 = 0.234 \text{ m}$$

Loss in BC — For a flow of 83 kld, the loss in 32 mm dia pipe = 10.3 m/100 m

$$\text{Loss in 40 m length} = \frac{10.3}{100} \times 40 = 4.12 \text{ m}$$

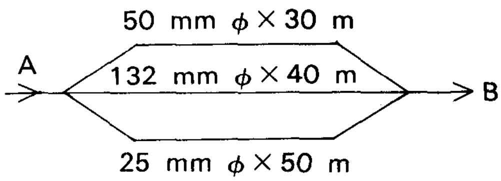
Loss in CD — For a flow of 83 kld, the loss in 25 mm dia pipe = 35.5 m

$$\text{Loss in 30 m length} = \frac{35.5}{100} \times 30 = 10.65 \text{ m}$$

Total Loss in AD = Loss in AB + Loss in BC + loss in CD = 0.234 + 4.12 + 10.65 = 15.004 or 15 m.

Example 2

System of pipes in Parallel — Consider a system of pipes consisting of three pipes



a) 50 mm dia $\times$ 30 m long,

b) 32 mm dia $\times$ 40 m long, and

c) 25 mm dia $\times$ 50 m long all connected at points A and B.

To find the flow through the system for a loss of head of 15 m between A and B.

Solution — Any flow entering the system at A gets divided into three flows and again joins at B. The loss of head for the flow obtaining in each pipeline between A and B is same as the pipes are in parallel.

For a given loss of head between A and B, the flow in each pipeline is calculated and total flow is the sum of the flows in the three pipelines.

Flow in (a) — 15 m is to be lost in 30 m length (that is, loss in 100 m) $= \frac{15}{30} \times 100 = 50$ m

For a loss of 50 m in 100 m in 50 mm dia pipe, the flow is found from the chart to be 630 kld (*see* Fig. 3).

Flow in (b) — 15 m is to be lost in 40 m length (that is, loss in 100 m) $= \frac{15}{40} \times 100 = 37.5$ m.

For this loss of 37.5 m/100 m, the flow in 32 mm dia pipe is found from the chart to be 170 kld

Flow in (c) — 15 m is to be lost in 50 m length (that is, loss in 100 m) $= \frac{15}{50} \times 100 = 30$ m.

For this loss of 30 m/100 m, the flow in 25 mm dia pipe is found from the chart to be 76 kld.

The total flow entering at A = Flow through (a) + flow through (b) + flow through (c) = 630 + 170 + 76 kld = 876 kld.

Check — The same system can be checked in another way. For a given flow of 876 kld, the loss of head between A and B may be calculated. To solve this problem we have to find an equivalent pipe to replace the given system of pipes and then calcutate the loss of head in that equivalent pipe for a flow of 876 kld, which is the loss of head between A and B.

To determine the equivalent pipeline — Assume a head loss of 20 m between A and B and calculate the flows in each pipe.

Flow in (a) — 20 m is to be lost in 30 m length (that is, loss in 100 m) $= \frac{20}{30} \times 100 = 66.7$ m.

For this loss of 66.7 m/100 m, the flow in 50 mm dia pipe is found from Fig. 3 to be 735 kld.

Flow in (b) — 20 m is to be lost in 40 m length (that is, loss in 100 m) $= \frac{20}{40} \times 100 = 50$ m.

For this loss of 50 m/100 m, the flow in 32 mm dia pipe is found from the Fig. 3 to be 88 kld.

Flow in (c) — 20 m is to be lost in 50 m length (that is, loss in 100 m) $= \frac{20}{50} \times 100 = 40$ m.

For this loss of 40 m/100 m, the flow in 25 mm dia pipe is found from Fig. 3 to be 88 kld.

Total flow entering at A = 735 + 195 + 88 = 1 018 kld.

An equivalent pipe is one which gives a loss of head of 20 m for this flow of 1 018 kld. Assume a pipe of 50 mm dia. The loss per 100 m in this pipe for a flow of 1 018 kld = 123 m.

For a total loss of 20 m, the length is $\frac{100}{123} \times 20$ or 16.26 m.

The equivalent pipe is, therefore, a 50 mm dia pipe 16.26 m long.

To calculate the loss of head in the equivalent pipe for a flow of 876 kld.

The loss in 50 mm dia for 100 m for a flow of 876 kld is found from Fig. 3 to be 92 m.

Loss for 16.26 m length $= \frac{92}{100} \times 16.26 = 14.96$ or 15 m.

This is the loss of head in the given system of pipes between A and B.

Example 3

An example is worked out below to compute the storage needed for an impounding reservoir for a constant draft of 23 million litres/sq km/month of 30.4 days with the following recorded mean monthly run-off values:

Order of the month	1	2	3	4	5
Observed monthly mean run-off, million litres per sq km	94	122	45	5	5
Order of the month	6	7	8	9	10
Observed monthly mean run-off, million litres per sq km	2	0	2	16	7
Order of the month	11	12	13	14	15
Observed monthly mean run-off, million litres per sq km	72	92	21	55	33

Solution — The mass diagram is obtained by plotting the time interval (order of months) as abscissa and the cumulative run off and cumulative draft up to the corresponding time intervals as calculated in Table 14 as ordinates.

Example 4

To find out the capacity of storage reservoir for the following conditions:

Data given

1. Design population—24 000
2. Per capita water supply—90 lpd
3. Peak factor—2.25
4. Peak hours — 0600 to 1000 h
   1300 to 1400 h
   1700 to 1800 h
5. Hourly demand for other than peak hours are as follows:

a) 2300 to 0400 h — 20 percent of the average hourly demand

b) 0400 to 0500 h — and 2200 to 2300 h 40 percent of the average hourly demand

c) 1200 to 1300 h — 60 percent of the average hourly demand

d) 1400 to 1700 h — and 2000 to 2200 h 70 percent of the average hourly demand

e) 0500 to 0600 h — 80 percent of the average hourly demand

f) 1800 to 2000 h — 90 percent of the average hourly demand

g) 1000 to 1200 h — 100 percent of the average hourly demand

6. Water supply is continuous
7. Pumping hours—16 (from 2200 to 0600 h and 1000 to 1800 h).

Solution :

1. Total demand—24000 × 90 lpd
   = 2.16 million litres/day
2. Average hourly demand
   $$a = \frac{2.16}{24} = 0.09 \text{ million litres}$$
3. Peak demand = 2.25 × average hourly demand
   = 2.25 a.

Example 5

Cold water—25°C
Storage temperature—60°C
Temperature of hot bath—43°C
(as run for use at 41°C)

Solution

Let percentage of hot water to total volume = x

$$\frac{x}{100} \times 60 + \frac{(100 - x)}{100} \times 25 = 1 \times 43$$

$$0.6x + 25 - 0.25x = 43$$

$$0.35x = 43 - 25 = 18$$

$$x = \frac{18}{0.35} = 51.4$$

Quantity of hot water required for a 115-litre bath

$$= 51.4 \times \frac{115}{100} = 59.1 \text{ litres}$$