CHAPTER 11

11.Pipes and Pipe Appurtenances

CHAPTER 11: PIPES AND PIPE APPURTENANCES

11.1 General

Pipes and pipe appurtenances are an integral part of a piped water supply system, which are to be selected based on their physical, chemical, hydraulic, structural characteristics and environmental effects (freezing in cold regions, dessert, etc.), possible wear and tear depending on the topography and local conditions (change in the landscape such as in hilly region) on them as well as water characteristics that are subjected to be handled at various stages in the system. Apart from this, the availability of pipes and pipe appurtenances of a particular material at a reasonable economic cost plays a role in selection in various regions.

Piping materials play a vital role in the engineering of the water supply system. The water distribution and transmission system set up to deliver potable water to the consumers' end accounts for an appreciable part of the capital outlay of a water supply system. The success of a project and the cost, to a great extent, depends on piping materials. Hence, proper selection of pipe materials plays an important role in the project economy, and it is always preferred to choose piping materials that meet all technical requirements but are cheaper. There is a wide variety of piping materials present in the market. Piping material is a broad term and is not limited to only the material of the pipe. It signifies the material of all piping components, pipes, fittings, valves, and other items.

While selecting appropriate pipe material for water supply schemes, it shall be ensured that the specifications for the pipes and other appurtenances should conform to relevant BIS standards as well as the guidelines given in the manual on water supply and treatment, and they must be scrupulously followed while selecting the pipes and appurtenances for the water supply systems. Any pipe (like MDPE pipe) and specials that don’t have BIS specification but are used in Water Supply System, shall approach BIS for standardization.

Also, the major criterion in pipe wall selection may not only be the temperature and pressure but also the availability of fittings and flanges. Piping is a system, and other items must be considered during selection ensuring their compatibility.

11.1.1 Pipe Materials

Pipelines are major investments in water supply projects, and as such, “Pipes” represent a large proportion of the capital invested in water supply undertakings and are of particular importance. Therefore, pipe materials shall have to be judiciously selected not only from the point of view of durability, life, and overall cost, which includes, besides the pipe cost, the installation and recurring operation, repair, and maintenance costs necessary to ensure the required function and performance of the pipeline throughout its designed lifetime. Every water engineer/designer, while making the choice of pipe material to be used, should give due consideration to the total cost of the pipes, including their transportation and installation costs, their capability to transmit the desired water quantity, and their chemical effect(s), if any, on the water and vice versa the effect of water on the pipe material(s).

11.1.2 Classification of Pipe Materials

Classification Based on Material of Construction

The various types of pipes used are:

I. **Metallic pipes**: Cast Iron (CI), Ductile Iron (DI), Mild Steel (MS), Stainless Steel/Steel, and Galvanised Iron (GI) are sub-classified based on the lining:

A. Unlined Metallic pipes

B. Lined Metallic pipes with cement mortar or epoxy lining

II. **Non-Metallic pipes:** Reinforced Concrete (R.C.), Prestressed Concrete; Cylinder or non-cylinder (PSC), Bar Wrapped Steel Cylinder, Plastic Pipes: PVC (PVC-O, PVC-U), Polyethylene (PE), Glass Reinforced Plastic (GRP)/Fibre Reinforced Plastic (FRP), Asbestos Cement Pressure pipes, etc.

A broad classification of pipes used in water supply systems based on the material of construction is given in Figure 11.1 below:

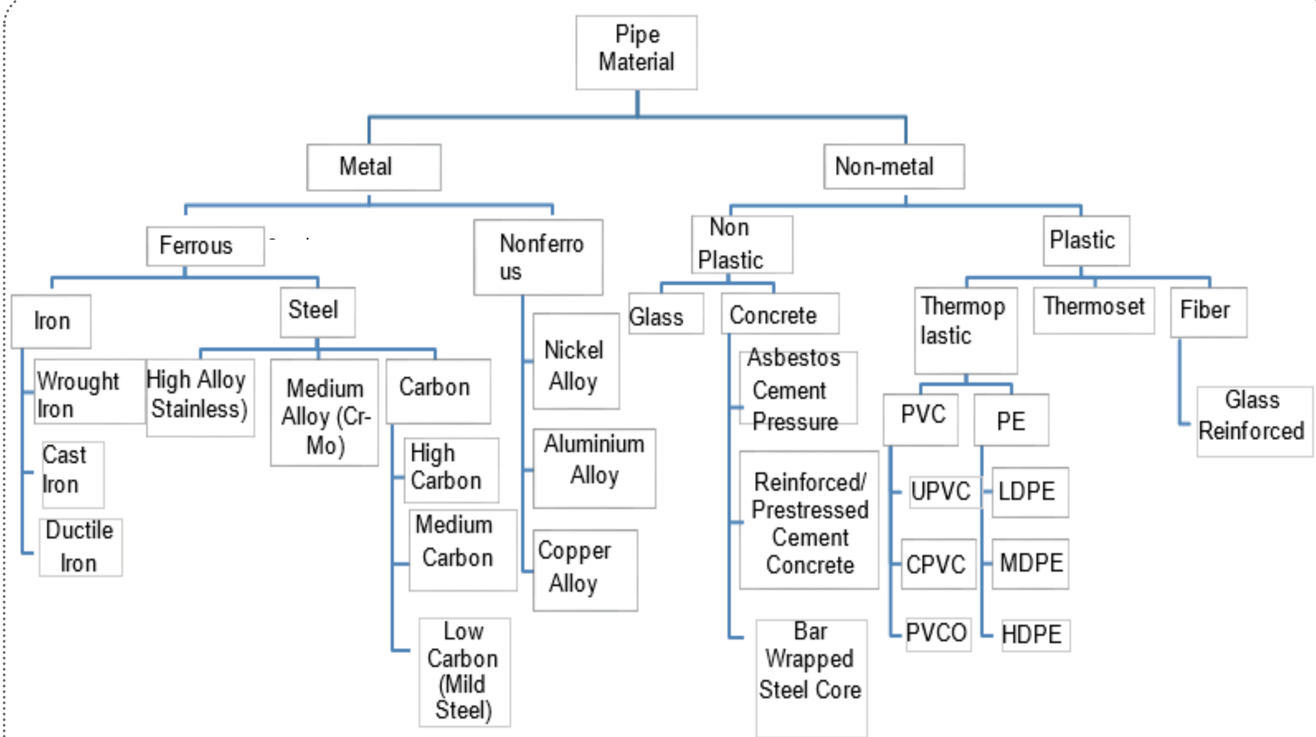


Figure 11.1: Pipes used in water sector

11.1.2.1 Classification Based on Structural Flexibility

Structurally, the pipes must overcome the following forces:

1. Temperature-induced expansion and contraction
2. External loads in the forms of traffic, backfill, and their own weight between supports
3. Unbalanced pressures at bends, contractions, and closures
4. Water hammer
5. Internal pressures equal to the full head of water

Also, pipe-soil interaction is important for sound structural design of buried pipelines.

Pipes can be grouped as rigid, flexible, and semi-rigid based on their structural flexibility. Flexible pipes such as HDPE, PVC, etc., are defined by their ability to yield under loading without fracturing. Rigid pipes such as concrete and clay, are limited in their ability to yield under load without sustaining damage. Some pipe materials exhibit characteristics of both rigid and flexible pipes such as bar wrapped concrete cylinder pipe, ductile iron pipe (EN 1295:2005).

Pipe Groups: Based on their Structural Flexibility

Rigid Pipe	Flexible Pipe	Semi-rigid Pipe
Rigid pipes deflect little; their load carrying capacity is derived from ring bending strength (as determined from crushing tests) and can be increased by bedding factors for various standardised bedding and surrounds. Rigid pipes tend to attract more load than flexible pipes, particularly in wide trench situations.	The flexibility of pipes is defined by the capability of pipes to deflect without showing signs of structural damage. Flexible pipes deflect under load in inverse relation to pipe stiffness and overall soil modulus. Flexible pipes derive their support primarily from passive soil resistance, which develops as the pipe ovalizes under vertical load and deflects horizontally into the side fill. The contribution of pipe stiffness is small.	Semi-rigid pipes, like flexible pipes, deflect under load in inverse relation to pipe stiffness and overall soil modulus. Some pipe materials exhibit characteristics of both rigid and flexible pipes, primarily controlled by their diameters, and are referred to as semi-rigid (As per subsection 7.3.2 of the IS: 15155-2020, The structural properties of the pipe, together with bedding and backfill, shall be designed to limit the deflection of pipe up to not more than $D^2/(1.02 \times 10^5)$ mm, D is the nominal inside diameter of the pipe measured in millimetres.)

The modulus of elasticity is a measure of a material's stiffness and its inherent ability to deform when stress is applied. Metal piping–such as steel–has a high modulus of elasticity, which makes it very rigid. Depending on the type and intensity of the impact, metal piping such as copper is more likely to dent or crease, which can impede fluid flow. Small cracks may also form, weakening wall strength, limiting pressure capabilities, and increasing corrosion concerns. Plastic pipe has a very low modulus of elasticity, which means it has the flexibility to absorb the shock from a less severe impact and, to some extent, can bounce back to its original shape without any structural damage. Shock transferred to the connecting system will also be minimal. The main parameters that affect Young's modulus of material are: (a) temperature (with an increase in temperature, Young's modulus decreases) and (b) presence of impurity in the material like secondary phase particles, non-metallic inclusions, alloying elements, etc.

11.1.3 Selection of Pipe Material

11.1.3.1 Pipe Materials for Transmission Mains and Distribution Network

The determination of the suitability in all respects of the pipes and specials for any work is a matter of decision by the engineer concerned on the basis of requirements for the scheme, on techno-economic criteria. It is important to consider adaptability of pipes suiting the field conditions where bends are common in urban areas and need for providing service connections without damaging pipe characteristics. The Government policy nowadays is to provide service connections to all households, i.e., 100% households/premises.

Several technical factors affect the final choice of pipe material such as internal pressures, internal coating, coefficient of roughness, hydraulic and operating conditions, maximum permissible diameter, internal and external corrosion problems, laying and jointing, type of soil, special conditions, etc.

Selection of pipe materials should be based on the following considerations:

(a) The initial carrying capacity of the pipe and its reduction with use, defined, for example, by the Hazen-Williams coefficient C. Values of C vary for different conduit materials and their relative deterioration in service. They vary in size and shape to some extent.

(b) The strength of the pipe is measured by its ability to resist internal pressures and external loads.

(c) The life and durability of pipe is determined by the resistance of cast iron and steel pipe to corrosion; of concrete and AC pipe to erosion and disintegration and plastic pipe to cracking and disintegration.

(d) The ease or difficulty of transportation, handling and laying and jointing under different conditions of topography, geology, and other prevailing local conditions. This is particularly so in hilly areas.

(e) The safety, economy, and availability of manufactured sizes of pipes and specials.

(f) The availability of skilled personnel in construction and commissioning of pipelines.

(g) The ease or difficulty of repairs during operations and maintenance.

(h) Soil chemistry – The influence of soil's chemical properties namely moisture contents, pH, temperature, soil resistivity, soil type, soil particle size, permeability, differential aeration, and sulphate-reducing bacteria, are reported to be a cause of failures of buried pipe due to reaction with the surface of unprotected buried pipes.

(i) Soil characteristics – The nature of the ground in which the piping is to be laid is to be invariably considered. There is alluvial soil, red soil, black cotton soil, arid/desert soil, laterite soil, saline and alkaline soil, peaty/marshy soil, forest soil, sub-mountain soil, and snowfields found in India as per the soil and land survey of India and according to their characteristics, certain metallic pipes and non-metallic pipes are suitably selected. In hilly areas, metallic pipes are preferably suitable due to undulated topography and rocky land.

(j) Soil resistivity – As per Clause 13.1.1 of IS 3043 (2018), the resistance to earth of a given electrode depends upon the electrical resistivity of the soil in which it is installed. This factor is important in deciding which of many protective systems to adopt for buried pipelines. As also described in SP:57 (1993 reaffirmed 2016) – Handbook on pipes and fittings for water supply (chapter 2, section 2) – corrosion resistance of pipes will not become a criterion for selection of pipe material if proper protective coating is given.

The type of soil largely determines its resistivity and examples are given below in Table 11.1 below.

Table 11.1: Soil Resistivity (as per clause 13.1.1 of IS 3043:2018 - Table 3)

Sl. No.	Type of Soil	Probable value in Ω.m (1 Ω.m = 100 Ω.cm)	Climatic Condition	
			Normal and High Rainfall (for Example, Greater than 500 mm a year)	Low Rainfall and Desert Condition (for Example, less than 250 mm a Year)
			Range of values encountered Ω.m (1 Ω.m = 100 Ω.cm)	Range of values encountered Ω.m (1 Ω.m = 100 Ω.cm)
(1)	*(2)*	*(3)*	*(4)*	*(5)*
i)	Alluvium and lighter clays	(500)	*	*
ii)	Clays (excluding alluvium)	10 (1000)	5 to 20 (500 to 2000)	10 to 100 (1000 to 10000)
iii)	Marls (for example, keuper marl)	20 (2000)	10 to 30 (1000 to 3000)	50 to 300 (500 to 30000)
iv)	Porous limestone (for example, chalk)	50 (5000)	30 to 100 (3000 to 10000)	-
v)	Porous sandstone (for example, keuper sandstone and clay shales)	100 (10000)	30 to 300 (3000 to 30000)	-
vi)	Quartzites, compact and crystalline limestone (for example, carboniferous marble, etc.)	300 (30000)	100 to 1000 (10000 to 100000)	-
vii)	Clay slates and slatey shales	1000 (100000)	300 to 3000 (30000 to 300000)	1000 (100000) upwards
viii)	Granite	1000 (100000)	-	-
ix)	Fossil slates, schists gneiss igneous rocks	2000 (200000)	1000 (100000) upwards	-
* Depends on water level of locality.				

The range of soil resistivity and Class of Soil (in terms of corrosivity) as per IS 3043 (2018) is given in Table 11.2 below:

Table 11.2: Soil Resistivity and Class of soil (in terms of Corrosivity) (as per Clause 13.6.1 of IS 3043:2018 – Table 4)

Sl. No.	Range of Soil Resistivity in Ω.m (1 Ω.m = 100 Ω.cm)	Class of Soil (in terms of corrosivity)
(1)	(2)	(3)
i)	Less than 25 Ω.m (2500 Ω.cm)	Severely Corrosive
ii)	25-50 Ω.m (2500-5000 Ω.cm)	Moderately Corrosive
iii)	50-100 Ω.m (5000-10000 Ω.cm)	Mildly Corrosive
iv)	Above 100 Ω.m (10000 Ω.cm)	Very Mildly corrosive

(k) Pipes Mechanical properties: Certain mechanical properties are also considered while selecting pipe material for a specific service. These are:

- **Modulus of Elasticity (Young's Modulus)** – The ratio of stress to strain and measured using tension tests.
- **Elastic range –** Material returns to its original shape after load is released.
- **Plastic range –** Material is permanently deformed even after the load is released.
- **Yield Strength** – It defines the transition from elastic to plastic phase and it establishes the limiting value at which this transition occurs.
- **Ultimate Tensile Strength** – It defines the limit to which any further addition of load under constant strain would arrest the specimen elongation or thinning and would result in its failure.
- **Ductility** – Expressed in the elongation of a specimen and its reduction in the cross-sectional area before its failure. Established by measuring specimen length before elongation and minimum diameter before failure.
- **Hardness** – Ability of a material to resist deformation. Hardness is tested by Brinell or Rockwell Hardness tests, both of which are indentation-type tests.
- **Toughness** – Ability of a material to resist sudden and brittle fracture due to the rapid application of loads. Measured using the Charpy V-Notch test.

In addition to the above points, while selecting the pipe and pipe materials, health related issues should also be kept on high priority. Many of the materials used for manufacturing pipe are found to cause certain health problems which needs to be properly examined before selection of pipe and pipe materials. The life and durability of the pipe depends on several factors, including inherent strength of the pipe material, the manufacturing process along with quality control, handling, transportation, laying and jointing of the pipeline, surrounding soil conditions and quality of water.

Normally, the design period of pipelines is considered as 30 years for urban areas. Considering the design period, a suitable pipe material shall be selected which also best fits into all other selection criteria. Where the pipelines have been manufactured properly as per specifications, designed, and installed with adequate quality control and strict supervision, pipes have lasted more than the designed life provided the quality of water is non-corrosive. However, pipeline failures for various pipe materials even before the expiry of the designed life, have been reported probably due to lack of rigid quality control during manufacture and installation, improper design, presence of corrosive waters, corrosive soil environment, improper bedding, and other relevant factors. As pipelines are reticulated systems, the combined quality of pipes and pipelines arising out of quality pipe manufacture and sound installation, laying and jointing with strict supervision, standard jointing, bedding, backfilling and hydraulic pressure testing as per codes will determine the service delivery and life of a pipeline.

The metallic pipes are being provided with internal lining, either with cement mortar or epoxy or food grade compatible material so as to reduce corrosion, increase smoothness, and prolong the life of the pipe. Lined metallic pipelines are expected to last beyond the normal design life of 30 years. However, the relative age of such pipes depends on the thickness and quality of lining available for corrosion. The cost of the pipe material and its durability or design life are the two major governing factors in the selection of the pipe material. It is necessary to carry out a detailed economic analysis before selecting a pipe material.

Underground metallic pipelines may require protection against external corrosion depending on the soil environment and corrosive ground water. Protection against external corrosion for MS pipes is provided with guniting with proper cement composition or epoxy coating, inside cement mortar lining with proper thickness, or hot-applied coal tar asphaltic enamel reinforced with fibre glass fabric yarn, non-corrosive sleeves, etc. Resistivity survey of the pipe alignment is important for external corrosion protection.

11.1.3.2 Health Aspects

While selecting the pipe material for drinking water supply systems, the following need to be kept in consideration:

- A leaking distribution system increases the likelihood of safe water leaving the source or treatment facility becoming contaminated before reaching the consumer. The pipe shall be strong enough to withstand external and internal forces without any damage.
- The pipe material or inner lining shall not have any constituent which may be unsuitable for human consumption especially the inner surface.
- Certain pipe materials which may be unsafe for human health are increasingly not utilised or being phased out such as lead, copper, etc.

11.1.3.3 Applicability

The applicability of different pipe materials varies with each site and the system requirements. The pipe material must be compatible with the soil and groundwater chemistry. The pipe material with proper coating must also be compatible with the soil structure and topography of the site, which affects the pipe location and depth, the supports necessary for the pipe fill material, and the required strength of the pipe material.

The following list shows background information to be used in determining what type of pipe best fits a particular situation:

- Maximum pressure conditions (force mains);
- Overburden, dynamic, and static loading;
- Lengths of pipe available;
- Soil conditions, soil chemistry, water table, stability;
- Joining materials required;
- Installation equipment required;
- Joint tightness/thrust control;
- Size range requirements;
- Field and shop fabrication considerations;
- Compatibility with existing systems;
- Thrust blocks, anchor blocks, valve chambers and other required structures to be included;
- Valves (number, size, and cost);
- Corrosion/cathodic protection requirements; and
- Maintenance requirements.

11.1.3.4 Installation Cost Consideration

Installation costs make up a major part of the total cost of a project. Differences in the cost of the actual pipe do not change the total cost of the project much. However, the following factors should be considered concerning installation costs and the choice of pipe:

- Weight of the pipe: A pipe that is lightweight can be handled easier and faster.
- Ease of assembling: Push-on joints can be assembled much faster than bolted joints.
- Pipe strength: If one type of pipe requires special bedding to withstand external pressures while another pipe does not, the choice can impact installation costs significantly.

11.1.3.5 Check List of Selection of Pipe Material

The life and durability of the pipe depends on several factors including inherent strength of the pipe material, the manufacturing process along with quality control, handling, transportation, laying and jointing of the pipeline, surrounding soil conditions and quality of water. Normally, the design period of pipelines is considered as 30 years. Where the pipelines have been manufactured properly as per specifications, designed and installed with adequate quality control and strict supervision, some of them have lasted more than the designed life provided the quality of water is non-corrosive. However, pipeline failures for various pipe materials even before the expiry of the designed life have been reported probably due to lack of rigid quality control during manufacture and installation, improper design, presence of corrosive waters, corrosive soil environment, improper bedding and other relevant factors. Lined metallic pipelines are expected to last beyond the normal design life of 30 years. However, the relative age of such pipes depends on the thickness and quality of lining available for corrosion. The cost of the pipe material and its durability or design life are the two major governing factors in the selection of the pipe material. The pipeline may have very long life but may also be relatively expensive in terms of capital and recurring costs and, therefore, it is very necessary to carry out a detailed techno economic analysis before selecting a pipe material.

As pipelines are reticulated systems, the combined quality of pipes & pipelines arising out of quality pipe manufacture and sound installation, laying and jointing with strict supervision, standard jointing, bedding, back-filling and hydraulic pressure testing as per codes will determine the service delivery and life of a pipeline. The metallic pipes are being provided with internal lining either with cement mortar or epoxy or food/water grade compatible material so as to reduce corrosion, increase smoothness and prolong the life. Underground metallic pipelines may require protection against external corrosion depending on the soil environment and corrosive ground water. Protection against external corrosion is provided with cement mortar guniting or hot applied coal-tar asphaltic enamel reinforced with fiberglass fabric yarn, non-corrosive sleeves, etc.

The structural design and indeed the choice of pipe material will be governed by factors such as the hydraulics of the flow system and the prevailing local conditions. It is, therefore, a common practice to design pipeline system for maximum discharges at non-silting and non-erodible velocities to minimize friction losses.Generally, the pipe material and size of the pipe for a given scheme is determined by hydraulics and economic factors. As such, the determination of the suitability in all respects of the pipeline for any work is a matter of decision by the engineer concerned on the basis of the requirements for the scheme. However, selection of pipe materials must be based on the following main considerations including other criterion explained in this sub chapter.

(a) The initial carrying capacity of the pipe and its reduction with use, defined, for example, by the Hazen-Williams coefficient C. Values of C vary for different conduit materials and their relative deterioration in service. They vary with size and shape to some extent

(b) The strength of the pipe as measured by its ability to resist internal pressures and external loads.

(c) The life and durability of pipe as determined by the resistance of different pipes.

(d) The ease or difficulty of transportation, handling and laying and jointing under different conditions of topography, geology and other prevailing local conditions.

(e) The safety, economy and availability of manufactured sizes of pipes and specials.

(f) The availability of skilled personnel in construction and commissioning of pipelines.

(g) The ease or difficulty of operations and maintenance.

(h) Health factor: In addition to the above points, while selecting the pipe and pipe materials, health related issues should also be kept on high priority.

11.1.3.6 Quality Monitoring and Implementation of Pipeline Projects

Water utilities often procure pipes from one manufacturer/ supplier under one contract, procure the valves and fittings from another manufacturer/ supplier under another contract and have them installed under another contract rather than entrusting the entire work of manufacture, Supply, Laying, Jointing, Testing and Commissioning of pipelines to a single agency. This procedure is resorted to on the plea that it results in economy and saves time.

It is seen that wherever single contracts are not awarded for the entire work of Manufacture, Supply, Laying, Jointing, Testing and Commissioning of pipelines to a single agency, the responsibility for performance of the pipelines could not be assigned to any particular agency. Time delays if any, in procurement of fittings and valves will also affect the completion of the contract and also results in cost overruns. Quite often, at the time of commissioning, deficiencies are noticed which might be due to failure at the manufacturing stage or due to transportation handling, or laying/jointing defects or failure of fittings and valves.

Hence it is desirable that all pipeline contracts are awarded on a single contract responsibility so that quality assurance at various stages of manufacture, supply, delivery, laying, jointing and testing is taken care of by a single agency and the timely completion also rests with a single agency; this may result in receipt of competitive offers and hence results in economy. Further, the water utility's time and resources which otherwise are spent in monitoring the performance of several small contracts can be better utilised for quality management of the contract. This may ensure economy by timely completion and quality construction.

However it is necessary that the specifications for single contract responsibility have to be comprehensive and provide for penalty in delays so that the time and cost over runs can be avoided. There will be several site specific conditions and circumstances for the pipeline installations which vary to such an extent that it is very difficult to recommend a simple/ single all inclusive set of specifications for the pipeline contracts.

To make the contractor accountable, the aforementioned recommendations for quality monitoring and implementation of Pipeline Projects shall be adhered to so as to avoid any delay in implementation and ensure quality of pipe material.

However, while contract for laying of pipeline works are awarded this should include a clause on the defect liability provisions for making the defect good during the defect liability period or the entire contract period whichever is more as per the contract model (EPC/BOT, etc.) including retaining a security bond equivalent to a certain percentage of the tender value (usually 1% to 10% relevant to the contract value) for the agreed performance guarantee during the entire liability period.

The following check list for drafting specifications for Manufacture, Supply, Laying, Jointing, Testing and commissioning of pipelines for procurement through a single agency is as follows. Judicious selection of items which cover cross country or city installations is required.

Check List for Specifications for Manufacture, Supply, Laying, Jointing, Testing and Commissioning Pipelines

PART I Procurement

Section 1 - General

1.1 Scope of work

1.2 Definitions of client, contractor, engineer etc.

1.3 Drawings and documents referred to

1.4 Reference Standards

1.5 Penal clauses for failure to meet the time schedule & performance standards and requirements.

1.6 Basis for Prices; to include all pipes, fittings, valves, jointing materials, including labour, cost of factory testing, lining, coating, marking and all other incidental expenses for manufacture, transportation, insurance and delivery at site. (any exclusions/ inclusions may be clearly specified)

Section 2 - Detailed Requirements - Pipes

2.1 Material for pipes (standards for materials), manufacturing operations, testing and inspection

2.2 Diameter of pipe

2.3 Wall thickness/ other dimensions of the pipe

2.4 Class of pipe

2.5 Laying length

2.6 Pipe ends-flanged-socket/ spigot/plain

2.7 Special pipe lengths and special fittings

2.8 Working Pressures

2.9 Pipe lining and coating both for buried and exposed pipes

Section 3 - Transportation and delivery at site

3.1 Type of trucks used for transportation-length / weight

3.2 Handling equipment for loading and unloading

Section 4 - Field Joints for Pipes

4.1 Requirements for machined couplings/ ends

4.2 Flanged/joints, pitch circle, blots type, gasket quality

4.3 Welded joints-runs-thickness

PART II INSTALLATION

Section 1 - Instruction to Bidders

1.1 Procedure for invitation of bids

1.2 Instructions to bidders

1.3 Bidders proposal to include plan/ programme for construction

1.4 Agreement and performance bonds

Section 2 - General Specifications

2.1 Definitions

2.2 Scope of Work

2.3 Payment conditions

2.4 Statutory Requirements- Payment of wages-Policy-Environment control-safety

2.5 Personnel

Section 3 - Detailed Specifications

3.1 Time Schedule

3.2 Construction facilities - Right of way - storage space - interference with other services

3.3 Work and materials

3.4 Concrete

3.5 Excavation - Bracing of excavation - Safety to public - Disposal of excess material from excavation

3.6 Maintenance, removal and reconstruction of other interfering facilities

3.7 Safeguarding of excavations and protection of property

3.8 Backfill

3.9 Resurfacing of roads within city and outside

Section 4 - Pipes

4.1 Approval of drawings for laying

4.2 Distribution along trench

4.3 Preparation of bedding

4.4 Lowering and laying

4.5 Jointing

11.2 Cast Iron Pipes

11.2.1 General

Cast iron (CI) pressure pipes may be classified in two categories, i.e., vertically cast iron (IS:1537-1976, reaffirmed 2020) and centrifugally cast (spun) iron (IS:1536-2001, reaffirmed 2021) pipes for water and sewage. Vertically cast iron has been largely superseded by centrifugally cast (spun) iron up to a diameter ranging from 80 mm to 1050 mm for socket and spigot pipes (class LA, A, and B) and flanged pipes with screwed flanges (Class B). Though the vertically cast iron pipe is heavy in weight, low in tensile strength, and liable to defects of inner surface, it is widely used because of its good lasting qualities.

Cast Iron pipes and fittings are being manufactured in this country for several years. Due to its strength and corrosion resistance, CI pipes can be used in corrosive soils and for waters of slightly aggressive character. It is preferable to have coating inside and outside of the pipe.

Vertically cast iron pipes are manufactured by vertical casting in sand moulds. The metal used for the manufacture of this pipe is not less than grade 15. The pipes shall be stripped with all precautions necessary to avoid wrapping or shrinking defects. The pipes shall be such that they could be cut, drilled, or machined. Cast iron flanged pipes and fittings are usually cast in the larger diameters. Smaller sizes have loose flanges screwed on the ends of double spigot-spun pipe.

The method of cast iron pipe production used universally today is to form pipes by spinning or centrifugal action. Compared with vertical casting in sand moulds, the spun process results in faster production, longer pipes with vastly improved metal qualities, smoother inner surface and reduced thickness and consequent lightweight.

Centrifugally cast iron pipes are available in diameters from 80 mm to 1050 mm and are covered with protective coatings. Pipes are supplied in 3.66 m and 5.5 m lengths and a variety of joints are available including socket and spigot and flanged joints. The CI pipes have been classified as LA, A, and B according to their thickness. Class LA pipes have been taken as the basis for evolving the series of pipes. Class A allows a 10% increase in thickness over class LA. Class B allows a 20% increase in thickness over class LA. For vertically cast pipes, Class LA has not been taken as standard. For special uses, Classes C, D, E, etc. may be derived after allowing corresponding increases of thickness of 30, 40, 50 per cent, etc., over Class LA.

When the pipes are to be used for conveying potable water, the inside coating shall not contain any constituent soluble in water or any ingredient which could impart any taste or odour or impart health hazard.

Experiments in centrifugal casting of iron pipes were started in 1914 by a French Engineer which ultimately resulted in the commercial production of spun pipes. Spun pipes are about three-fourths of the weight of vertically cast pipes of the same class. The greater tensile strength of the spun iron is due to close grain allowing use of thinner wall than for that of a vertically cast iron pipe of equal length. It is possible by this process to increase the length of the pipe whilst a further advantage lies in the smoothness of the inner surface.

11.2.2 Laying and Jointing

11.2.2.1 Laying

Before laying the pipes, a detailed map of the area showing the alignment, sluice valves, scour valves, air valves, and fire hydrants along with the existing intercepting sewers, telephone and electric cables, and gas pipes will have to be studied. Care should be taken to avoid damage to the existing sewer, telephone and electric cables, and gas pipes. The pipeline may be laid on the side of the street where the population is dense. Pipes are laid underground with a minimum cover of 1 metre on the top of the pipe.

Laying of pipes for water supply system is generally governed by respective Indian Standards (IS) as well as the regulations laid down by the Municipalities and Corporations in the States/UTs.

These regulations are intended to ensure proper laying of pipes giving due consideration to economy and safety of workers engaged in laying.

The pipes shall be straight. When rolled along two gantries separated by approximately two-thirds the length of the pipe to be checked, the maximum deviation from a straight line (in mm) shall not be greater than 1.25 times the length (in metres) of the pipes.

Excavation may be done by hand or by machine. The trench shall be so dug that the pipe may be laid to the required gradient and at the required depth. When the pipeline is under a roadway, a minimum cover of 1.0 m is recommended for adoption, but it may be modified to suit local conditions by taking necessary precautions. However, the structural strength of the pipe, based on dead load and live load over the pipe, should also be analysed. The trench shall be so braced and drained that the workmen may work therein safely and efficiently. The discharge of the trench dewatering pumps shall be conveyed either to drainage channels or to natural drains and shall not be allowed to be spread in the vicinity of the worksite.

The width of the trench at bottom between faces of sheeting shall be such as to provide not less than 200 mm clearance on either side of the pipe, except where rock excavation is involved. Additional width shall be provided at positions of sockets and flanges for jointing. Depths of pits at such places shall also be sufficient to permit finishing of joints.

Ledge rock, boulders, and large stones shall be removed to provide a clearance of at least 150 mm below and on each side of pipes in case of valves and fillings for pipes 600 mm in diameter or less, and 200 mm for pipes larger than 600 mm in diameter.

While unloading, pipes shall not be thrown down, but may be carefully unloaded on inclined timber skids. Pipes shall not be dragged over other pipes and along concrete and similar pavements to avoid damage to pipes.

The pipes and fittings shall be inspected for defects and be rung with a light hammer, preferably while suspended, to detect cracks. Smearing the outside with chalk dust helps in the location of cracks. If doubt persists, further confirmation may be obtained by pouring a little kerosene on the inside of the pipe at the suspected spot. If a crack is present, the kerosene seeps through and shows on the outer surface. The pipe should be properly inspected on the site. Any pipe found unsuitable before and after laying, shall be rejected.

11.2.2.2 Jointing

Several types of joints such as rubber gasket joint known as Tyton joint, mechanical joint known as screw gland joint, and conventional joint known as lead joint are used. Joints are classified into the following three categories depending upon their capacity for movement.

a) Rigid joints

Rigid joints are those that allow no movement at all and comprise of flanged, welded and turned, and bored joints. Flanged joints require perfect alignment and close fittings are frequently used where a longitudinal thrust must be taken such as at the valves and meters. The gaskets used between flanges of pipes shall be of compressed fibre board or natural or synthetic rubber. Welded joints produce a continuous line of pipes with the advantage that interior and exterior coatings can be made properly and are not subsequently disrupted by the movement of joints.

b) Semi rigid joints

Semi rigid joint is represented by a spigot and socket with a caulked lead joint. A semi rigid joint allows partial movement due to vibration, etc. The socketed end of the pipe should be kept against the flow of water and the spigot end of the other pipe is inserted into this socket. A twisted spun yarn is filled into this gap and it is then adjusted by the yarning tool and is then caulked well. A rope is then placed at the outer end of the socket and is made a tight fit by applying wet clay, leaving two holes for the escape of the entrapped air inside. The rope is taken out and molten lead is poured into the annular space by means of a funnel. The clay is then removed and the lead is caulked with a caulking tool.

Lead wool may be used in wet conditions. Lead covered yarn is of great use in repair work, since the leaded yarn caulked into place will keep back water under very low pressure while the joint is being made. Alternate yarn should also be explored and replaced with lead covered yarn in water supply due to adverse health impact on human being. Yarning or packing material shall also be considered for a) spun yarn, b) moulded or tubular natural or synthetic rubber rings, c) asbestos rope, or d) treated paper rope. These may be decided by the authority taking into consideration the quality of water.

c) Flexible joints

Flexible joints are used where rigidity is undesirable such as with filling of granular medium and when two sections cannot be welded. They comprise mainly mechanical and rubber ring joints or Tyton joints which permit some degree of deflection at each joint and are therefore able to stand vibration and movement. In rubber jointing, a special type of rubber gaskets is used to connect cast iron pipes which are cast with a special type of spigot and socket in the groove, the spigot end being lubricated with grease and slipped into the socket by means of a jack used on the other end. The working conditions of absence of light, presence of water, and relatively cool uniform temperature are all conducive to the preservation of rubber and consequently, this type of joint is expected to last as long as the pipes. Hence, rubber jointing is preferred to lead jointing.

11.2.2.3 Fittings

All pipes, fittings, valves, and hydrants shall be carefully lowered into the trench by means of derrick, ropes, chain pulley blocks or other suitable tools and equipment depending on the weight and length of the pipes to prevent damage to pipe materials and protective coatings and linings.

All lumps, blisters and excess coating material shall be removed from socket and spigot end of each pipe and outside of the spigot and inside of the socket shall be wire-brushed and wiped clean and dry and free from oil and grease before the pipe is laid. After placing a length of pipe in the trench, the spigot end shall be centred in the socket and the pipe forced home and aligned to gradient. The pipe shall be secured in place with approved back fill material packed on both sides except at socket.

In general, the socket end should face the upstream while laying the pipeline on level ground. However, the socket end should face the downstream subject to the strength of the joint and workmanship as per the guidelines. When the pipeline runs uphill, the socket ends should face the up gradient. When the pipes run beneath the heavy loads, suitable size of casing pipes or culverts may be provided to protect the casing of pipe. High-pressure mains need anchorage at dead ends and bends as appreciable thrust occurs which tend to cause draw and even “blow out” joints. Where thrust is appreciable, concrete blocks should be installed at all points where movement may occur.

Anchorages are necessary to resist the tendency of the pipes to pull apart at bends or other points of unbalanced pressure, or when they are laid on steep gradients and the resistance of their joints to longitudinal or shear stresses is either exceeded or inadequate. They are also used to restrain or direct the expansion and contraction of rigidly joined pipes under the influence of temperature changes. Anchor or thrust blocks shall be designed in accordance with IS: 5330-1984 reaffirmed 2020.

11.2.3 Testing of the Pipeline

After a new pipe has been laid, jointed, and backfilled, it shall be subjected to a pressure test and leakage test at a pressure to be specified by the authority for a duration of two hours.

After laying and jointing, the pipeline must be pressure tested to ensure that pipes and joints are sound enough to withstand the maximum pressure likely to be developed under working conditions.

11.2.3.1 Testing of Pressure Pipes

The field test pressure to be imposed should be not less than the maximum of the following:

a) 1.50 times the maximum sustained operating pressure.
b) 1.50 times the maximum pipeline static pressure.
c) maximum sustained operating pressure plus maximum surge pressure (in case of pumping mains);
d) sum of the maximum pipeline static pressure and the maximum surge pressure, subject to a maximum equal to the work test pressure for any pipe fitting incorporated;
e) testing pressure in accordance with the provisions of IS of relevant pipe material used.

- Operating pressure
  Maximum allowable operating pressure (MAOP) is the maximum pressure that can be safely operated by a pipeline. The thickness of the wall, pipe outer diameter, and specified minimum yield stress are used to calculate the MAOP of a pipe. Barlow's Formula relates the internal pressure that a pipe can withstand to its dimensions and the strength of its materials.

  The formula is $P = 2 \times T \times \frac{S}{D}$

  Where,

  P = pressure
  S = allowable stress
  T = wall thickness
  D = outside diameter

- Static pressure
  In hydrodynamics, it can be experimentally verified that each point of a fluid at rest exerts the same pressure around it in all directions. This pressure is called static pressure. This quantity is also known as hydrostatic pressure and does not depend on the velocity of flow, like dynamic pressure. The static pressure is part of the total pressure of a system, whose value still considers the quantities of the dynamic pressure and the gravitational potential energy of the system.

- Surge pressure
  A surge in pressure within a piping system, known as water or fluid hammer, occurs whenever the linear flow rate of fluid in pipe changes quickly – when pumps start or stop, valves open or close with quick acting actuation devices, or entrapped air moves within the system. The longer the pipeline and the faster the fluid is moving, the greater potential

for shock. Surges in pressure place stress on piping materials and joints and can cause physical movement of the piping system. Engineering designs must incorporate controls that can maintain surge pressures within the piping system's capabilities and eliminate or minimise physical motion of the system. It is very possible to have surge pressures twice as high as normal operating pressure. Long-term performance of the piping system can be affected by repetitive shock waves, potentially resulting in leaks and other costly damage. Some surge pressure problems result from poor piping system design – no matter what material is used for the system. Reducing the pipe size too quickly, for example, can result in surge pressure issues. The system may include 8-inch pipe when entering a tee and reduce down to two 3-inch pipes coming out of the tee. This type of situation creates a surge pressure inside the tee as the fluid has to greatly increase in linear velocity to push the same volume flow rate through a smaller cross-sectional flow area. Different materials perform differently in surge pressure situations depending upon their strength and elasticity. Understanding the material used in a piping system and designing the system to regulate pressure and fluid flow velocities according to its capabilities are important for the system's long-term performance. Proper sizing of pipe throughout the system, regulation of the speed with which valves and pumps actuate, and incorporation of surge dampening devices can limit the impact of hydraulic shock and keep the total system pressure within the design parameters. By combining quality piping and proper design, long-term performance can be ensured. Hydraulic Grade Line (HGL) – The hydraulic grade is the sum of the pressure head and elevation head. The hydraulic head represents the height to which a water column would rise in a piezometer. The plot of the hydraulic grade in a profile is often referred to as the hydraulic grade line, or HGL.

If the visual inspection satisfies that there is no leakage, the test can be passed. Where the field test pressure is less than two-third the work test pressure, the period of test should be increased to at least 24 hours. The test pressure shall be gradually raised at the rate of 1 kg/cm^2/min (0.1 N/mm^2/min). The field test pressure should wherever possible be not less than two-third work test pressure appropriate to the class of pipe except in the case of spun iron pipes and should be applied and maintained for at least four hours.

If the pressure measurements are not made at the lowest point of the section, an allowance should be made for the difference in static head between the lowest point and the point of measurement to ensure that the maximum pressure is not exceeded at the lowest point. If a drop in pressure occurs, the quantity of water added in order to re-establish the test pressure should be carefully measured. This should not exceed 0.1 litre per mm of pipe diameter per KM of pipeline per day for each 30 metre head of pressure applied. In case of gravity pipes, maximum working pressure shall be two-third work test pressure.

11.2.3.2 Procedure for Leakage Test

A leakage test shall be conducted concurrently with the pressure test. The allowable leakage, as per the clause 7.3.2 of BIS Code IS: 3114 (1994, reaffirmed 2019), during the pipe installation should not exceed the qL value (in cm^3/hour) calculated by the following formula:

$$qL = \frac{ND\sqrt{P}}{3.3} \qquad (11.1)$$

Where,

qL= Allowable leakage, cm^3/hour

N = No. of joints in the length of pipeline

D = Diameter, mm

P = The average test pressure during the leakage test, kgf/cm^2

Where any test of pipe laid indicates leakage greater than that specified as per the above formula, the defective pipe(s) or joint(s) shall be repaired/replaced until the leakage is within the specified allowance.

11.2.4 Advantages and Disadvantages

The advantages of pipe are:

- Good lasting qualities.
- Good strength, strong, and durable.
- Good corrosion resistance, if coated, and can be used in soils and for water of slightly aggressive character.
- Well suited for pressure mains and laterals where tapping is made for house connections.

The disadvantages of pipe are:

- Heavy weight,
- Short length,
- Low tensile strength,
- Liability to defect of inner surface,
- Careful handling is required during transportation and jointing.

11.3 Ductile Iron (DI) Pipes

11.3.1 General

Ductile iron, also called nodular iron or spheroidal graphite iron, is characterised by the presence of graphite in nodular or spheroidal form in the resultant casting. It differs from cast iron by greater tensile strength and its significant elongation at break. Benefits of lower-cost production can be expected in a case where natural resources are used, allowing the disposal cost to be reduced. For a given nominal diameter, ductile iron pipes are duly designed with a larger internal diameter in order to reduce the head loss on energy pumping and the operation cost such as the electric power usage cost.

DI pipes have excellent properties of machinability, impact resistance, high wear and tear resistance, high tensile strength, ductility, and corrosion resistance. DI pipes having same composition of CI pipe, it will have same expected life as that of CI pipes. DI pipes are strong, both inner and outer surfaces are smooth, free from lumps, cracks blisters and scars. Ductile Iion pipes stand up to hydraulic pressure tests as required by service regulations. The DI pipes are available in the range of 80 mm to 1200 mm diameter; in lengths of 5.5 to 6 m. For diameter more than 1000 mm, necessary precautions should be adopted for proper jointing. For use and laying of DI pipes, IS 12288:1987, Reaffirmed 2022 may be referred.

11.3.2 Laying and Jointing

Laying

Pipes should be lowered into the trench with tackle suitable for the weight of pipes. For smaller sizes, up to 250 mm nominal bore, the pipe may be lowered by the use of ropes but for heavier pipes, either a well-designed set of shear legs or mobile crane should be used. When a lifting gear is used, the positioning of the sling to ensure a proper balance, should be checked when the pipe is just clear of the ground. If sheathed pipes are being laid, suitable wide slings or scissor dogs should be used. All construction debris should be cleared from the inside of the pipe either before or just after a joint is made.

It is recommended that above ground installations of spigot and socket pipes be provided with one support per pipe, the supports being positioned behind the socket of each pipe. Pipes should be fixed to the supports with mild steel straps so that axial movement due to expansion or contraction resulting from temperature fluctuation, is taken up at individual joints in the pipeline. In addition, joints should be assembled with the spigot end withdrawn 5 to 10 mm from the bottom of the socket to accommodate these thermal movements. Detailed specification on DI pipes may be referred at IS 8329: 2000 (Reaffirmed 2020).

The width of the trench at bottom between the faces of sheeting shall be such as to provide not less than 200 mm clearance on either side of the pipe except where rock excavation is involved. Trenches shall be of such extra width, when required, as will permit the convenient placing of timber supports, strutting and planking, and handling of specials.

Special consideration should be given to the depth of the trench. In agricultural land, the depth should be sufficient to provide a cover of not less than 900 mm so that the pipeline will not interfere with the cultivation of the land. In rocky ground, rough grazing or swamps, the cover may be reduced, provided the water in the pipeline is not likely to freeze due to frost.

Where pipes are to be bedded directly on the bottom of the trench, it should be levelled and trimmed to permit even bedding of the pipeline. Where excavation is through rocks or boulders, the special bedding for DI pipes shall be as per BIS specifications.

For the purpose of backfilling, the depth of the trench shall be considered as divided into the following three zones from the bottom of the trench to its top:

a. Zone A: From the bottom of the trench to the level of the centre line of the pipe,
b. Zone B; From the level of the centre line of the pipe to level 300 mm above the top of the pipe, and
c. Zone C: From a level 300 mm above the top of the pipe to the top of the trench.

All backfill material shall be free from cinders, ashes, slag, refuse, rubbish, vegetable or organic material, lumpy or frozen material, boulders, rocks or stone or other material, which in the opinion of the authority, is unsuitable or deleterious. However, material containing stones up to 200 mm as their greatest dimension may be used in Zone C, unless specified otherwise herein.

Sand used for backfill shall be a natural sand, graded from fine to coarse. The total weight of loam and clay in it shall not exceed 10 per cent. All material shall pass through a sieve or aperture size 2.00 mm {IS: 2405 (Part II) -1980, Reaffirmed 2018}, and not more than 5 per cent shall remain on IS sieve or aperture size 0.63 mm.

Gravel used for backfill shall be natural gravel, having durable particles graded from fine to coarse in a reasonably uniform combination with no boulders or stones larger than 50 mm in size. It shall not contain excessive amount of loam and clay and not more than 15 per cent shall remain on a sieve of aperture size 75 micron.

For more details on backfilling and pipeline anchoring, BIS code IS 12288: 1987 (Reaffirmed year: 2022)- Code of Practice for Use and Laying of Ductile Iron Pipes may be referred.

Jointing

All pipelines having unanchored flexible joints require anchorage at changes of direction and at dead ends to resist the static thrusts developed by internal pressure. Dynamic thrusts caused by flowing water act in the same direction as static thrusts.

Three main types of joints are used with ductile iron pipes and fittings (Refer BIS Code IS 8329-2000 (Reaffirmed year: 2020) - Centrifugally Cast (Spun) Ductile Iron Pressure Pipes for Water, Gas and Sewage):

a) Socket and spigot flexible joints:
   (i) Push-on joint
   (ii) Mechanical joints
b) Rigid flanged joint
c) Restrained joint (bolted and boltless)

The spigot and socket flexible joint should be designed to permit angular deflection and axial movement to compensate ground movement and thermal expansion and contraction. They incorporate gasket of elastomeric material and the joints may be of the simple push-on type or mechanical joints. Flexible joints require to be externally anchored at all changes in direction such as at bends, etc., and at blank end to resist the thrust created by internal pressure and to prevent the withdrawal of spigots. Figure 11.2 shows flexible joint (push in type) and flanged joint.

In case of push-on joints, if any, they shall be suitably chamfered to facilitate smooth entry of spigot in the socket of the pipes or fittings fitted with rubber gasket. Push-on joint fittings are normally not used for sizes above DN 1 600. The material of rubber gaskets for use with mechanical joints and push-on joints shall conform to IS: 5382-2018–Rubber Seals—Joint Rings for Water Supply, Drainage and Sewerage Pipelines — Specification for Materials (Second Revision).

Figure 11.2: Flexible Joint (Push in type) and Flanged Joint

Rubber gaskets used with push-on joints or mechanical joints shall conform to (IS 5382-2018). Material of rubber gaskets for push-on mechanical or flanged joints shall be compatible with the fluid to be conveyed at the working pressure and temperature. Rubber gaskets for mechanical joint for conveyance of town gas may be suitably protected so that the elastomer does not come in direct contact with the gas. While conveying potable water, the gaskets should not deteriorate the quality of water and should not impart any bad taste or foul odour.

The dimensions and tolerances of the flanges of pipes and fittings shall be such, so as to ensure the interconnection between all flanged components (pipes, fittings, valves) of the same DN and PN and adequate joint performance. For screwed and welded on flanged pipes, the minimum classes for working pressure criteria are given in Clause 4.5 of IS 8329:2000, reaffirmed year 2020. Flanged joints are made on pipes having a machined flange at each end of the pipe. The seal is usually effected by means of a flat rubber gasket compressed between two flanges by means of bolts which also serve to connect the pipe rigidly. Gaskets of other materials, both metallic and non-metallic, are used for special applications.

In case of flange and mechanical joint casting, the flange shall be at right angle to the axis of the joint. The bolt holes shall be either cored or drilled. The centre of bolt holes circle shall be concentric with the bore circle and shall be located off the centre line. Where there are two or more flanges, the bolt holes shall be correctly aligned between them. The flanges shall be plain faced or with raised boss over the contact surface with a tool mark finishing having a pitch of 1 (±) 0.3 mm; serrations may be spiral or concentric.

An alternative and economical method of providing thrust restraint is the use of restrained joints. A restrained joint is a special type of push-on or mechanical joint that is designed to provide longitudinal restraint. Restrained joint systems function in a manner similar to thrust blocks, in so far as the reaction of the entire restrained unit of piping with the soil balances the thrust forces. Refer ISO 21052:2021 for determining the restraining length. In swamps or marshes where the soil is unstable or in other situations where the bearing strength of the soil is extremely poor, the entire pipeline shall be restrained joint system to provide adequate thrust restraint. As per the IS 8329-2000 (Reaffirmed year 2020), for high-pressure mains where working pressure is substantial, depending on site condition, a suitable flexible joint may be preferred where the joint is restrained against axial movement and the restraint joint may be considered in the transmission/gravity main where the working pressure is more than 8 kg/cm^2. Restrained joint pipe and fittings shall be used as carrier pipe for road crossings/railway crossings. In hilly areas where pipeline is laid on a slope, DI pipes with restrained joint shall also be used to avoid pipe slippage and joint separation. Figure 11.3 shows DI Boltless Restrained joint and Figure 11.4 shows DI bolted restrained joints.

Figure 11.3: DI Boltless Restrained joint

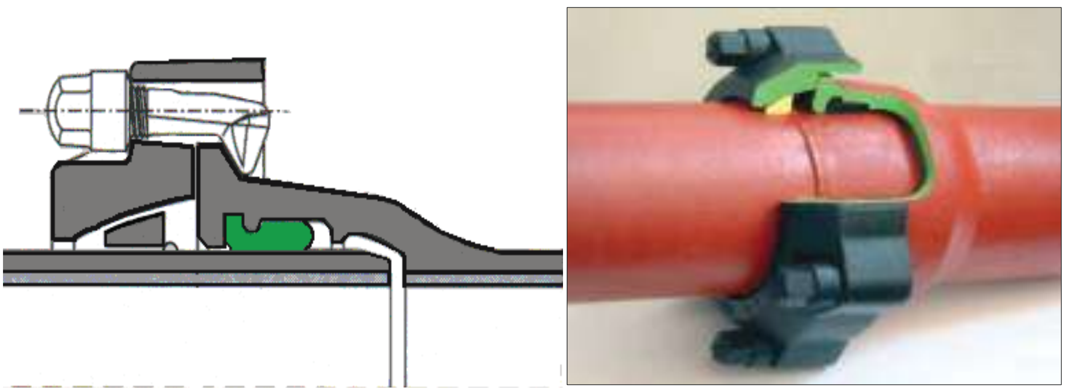


Figure 11.4: DI Bolted Restrained Joints

Procedure for jointing will vary according to the type of joint being used. Basic requirements for all types are:

a) Cleanliness of all parts,
b) Correct location of components,
c) Centralisation of spigot within socket, and
d) Strict compliance with manufacturer's jointing instructions.

Where the pipeline is likely to be subjected to movement due to subsidence or temperature variations, the use of flexible joints is recommended. A gap should be left between the end of the spigot and the back of the socket to accommodate such movement.

11.3.3 Fittings

The ductile iron fittings are manufactured conforming to (IS 9523-2000, Reaffirmed 2020), for ductile iron fittings. The frequency of testing is related to the system of production and quality control at production level. The maximum batch size shall be 4 MT of crude castings, excluding the risers.

Mechanical tests shall be carried out during manufacturing by batch sampling system. The samples, being representative of finished product, are tested for tensile strength, elongation, and hardness to verify mechanical requirements. One test for castings produced within 24-hours period shall be adequate. The results obtained shall be taken as to represent all the fittings of all sizes made during that period.

For checking, Brinell hardness test may be carried out on the test bar. Fittings shall be supplied in either 'as cast' condition or 'heat treated' condition.

For hydrostatic test, the fittings shall be kept under pressure for 10 seconds. They shall withstand the pressure test without showing any sign of leakage, sweating or other defect of any kind. The test shall be conducted before the application of surface coating.

When the pipe used under the conditions for which they are designed, in permanent or in temporary contact with water intended for human consumption, ductile iron pipes and their joints shall not have detrimental effects on the properties of the water for its intended use

11.3.4 Special Lining and Coatings for DI Pipes and Fittings

IS 8329 specifies bituminous or epoxy coating over Zinc Aluminium coating in ductile iron pipes. Industry has also come up with special coatings which are manufactured as per International Standards, like BS – EN, ISO, etc. The coatings are as follows.

11.3.4.1 Fusion-Bonded Epoxy (FBE) coating

Fusion-bonded epoxy (FBE) coating of steel materials is primer-less, one-part, heat-curable, thermosetting powdered epoxy coating which is designed to provide maximum corrosion protection to the substrate steel. It is a coating of very fast curing and thermosetting protective powder which utilises heat to melt and adhere the coating material to the steel substrate. It is based on specially selected epoxy resins and hardeners. The epoxy is formulated to meet the specifications related to protection of steel as an anti-corrosion coating. Heat cured FBE coatings are 100% solids consisting of thermosetting materials which achieve a high bond to metal surface because of a heat-generated chemical reaction. FBE is applied to coat DI pipes and fittings with powdered epoxy by fusion bonding process. The coatings enhance the corrosion-resistant properties of the piping system. It gives high gloss and smooth coatings with excellent adhesion. Difficult shapes can be coated evenly and provides enhanced corrosion restraint properties. FBE coating is widely used for coating of steel pipes, pipe fittings, pumps and valves used for the transmission of oil, gas, slurry, and water. This inert coating is suitable for extreme corrosive soils. Figure 11.5 shows application of fusion-bonded epoxy coating in various surfaces.

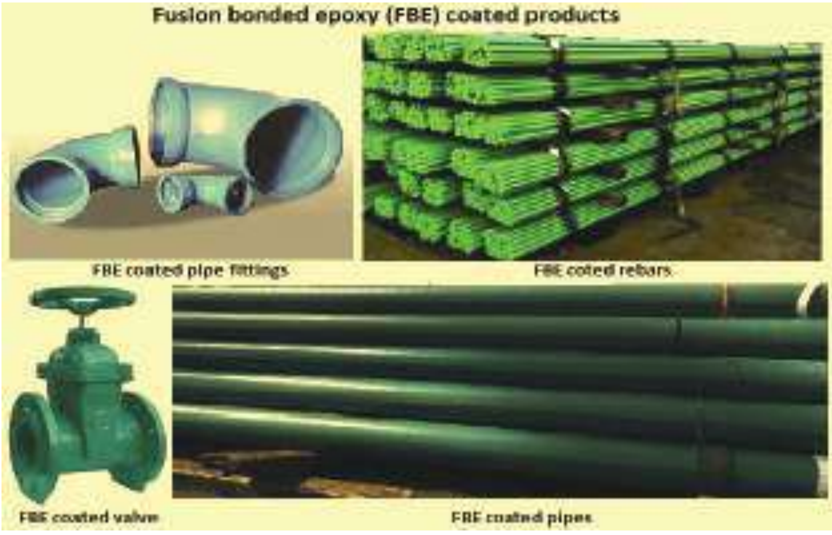


Figure 11.5: Application of fusion-bonded epoxy coating in various surfaces

11.3.4.2 Polyurethane (PU) Coating

A polyurethane coating is a polyurethane layer applied to the surface of a substrate for the purpose of protecting it. These coatings help protect substrates from various types of defects such as corrosion, weathering, abrasion and other deteriorating processes. The “special” coatings are designed to give greater external corrosion protection for pipes to be installed in aggressive soil conditions or for greater internal corrosion protection for pipes transporting highly corrosive liquids. The coating thickness is 700 microns as per EN 15189. The internal PU lining is applied in accordance with BS EN 15655:2018. Linings and coatings are applied in metallic pipelines are used for transporting abrasive and corrosive fluids as well as the pipes are laid in extremely corrosive environment. It is well suited for saline soil, coastal areas, ground with chemical contamination, refuse sites, farmyard, etc. Figure 11.6 shows polyurethane coated pipe.

Figure 11.6: Polyurethane coated pipe

11.3.4.3 High Alumina Cement Mortar Lining

Centrifugally applied inside metallic pipes in place of common cement mortar lining, high alumina cement mortar lining creates a mildly alkaline surface and protects the base metal of metallic pipe from corrosion and tuberculation and provides a tough surface to corrosive and abrasive fluids. High alumina cement should be conforming to BS EN 14647:2005.

11.3.4.4 Ceramic Epoxy Lining

Specialised lining applied inside the metallic pipeline which offers a hard and stable surface with high abrasion resistance. These linings are used for sewage conveyance or ash slurry conveyance or for conveying corrosive fluids. The above is in general used for carrying sewage.

11.3.5 Testing of the Pipelines

After a new pipeline is laid and jointed, hydraulic testing shall be done for:

a) mechanical soundness and leak tightness of pipes and fittings;
b) leak tightness of joints; and
c) soundness of any construction work, in particular, that of the anchorages.

Hydrostatic testing may be performed for the completed pipeline either in one length or in sections; the length of section depending upon:

(i) availability of suitable water,
(ii) number of joints to be inspected, and
(iii) difference in elevation between one part of the pipeline and another.

Where the joints are left uncovered until after testing, sufficient material should be backfilled over the centre of each pipe to prevent movement under the test pressure. Progressively as experience is gained, lengths of about 1.5 km or more, should be tested in one section, subject to consideration of length of trench which can be left open in particular circumstances.

As per ISO 10802: 2020, the test pressure at the lowest point of the test section shall be not less than the limit specified in a) or b), whichever is greater.

a) For PW ≤ 10 bar: PST = 1.5 × PW
b) For PW > 10 bar: PST = PW + 5
c) The maximum PW: PST = PMDc

Where,

PW: highest pressure that occurs at a time and a point in the pipeline when operating continuously under stable conditions, without surge;
PST: pressure to which a pipeline or a pipeline section is subjected for testing purposes;

PMDc: maximum operating pressure of the system or of the pressure zone fixed by the designer considering future developments including surge in case of surge is calculated (pumping and water mains).

If the test is not satisfactory, the fault should be found and rectified. Where there is difficulty in locating a fault, the section under test should be subdivided and each part tested separately. Methods employed for finding leaks include:

(i) Visual inspection of each joint if, not covered by the backfill;
(ii) Use of a bar probe to detect signs of water in the vicinity of joints, if backfilled;
(iii) Aural inspection using a stethoscope or listening stick in contact with the pipeline;
(iv) Use of electronic listening device which detects and amplifies the sound or vibrations due to escaping of water, actual contact between the probe and the pipe is not essential;
(v) Injection of a dye into the test water particularly suitable in water-logged ground; and

(vi) Introduction of nitrous oxide in solution into the test water and using an infrared gas concentration indicator to detect the presence of any nitrous oxide that has escaped through the leak.

11.3.6 Advantages and Disadvantages

The advantages of pipe are:

- High resistance against breakage due to impact;
- High tensile strength, comparable to that of mild steel so that the pipes can be used for higher working pressure and can counter water hammer effectively;
- Traditional corrosion resistance, comparable to that of cast iron
- Lighter in mass as compared to cast iron pipes;
- Strong material properties and flexibility of joints contribute to prevent leakages;
- A comprehensive range of fittings manufactured and available;
- Easy incorporation of branches, service connections, etc.
- Well-developed mains and leakage detection systems.

The disadvantages of pipe are:

- Centrifugally cast pipe coatings required for protection against aggressive external operating environments.
- Risk of stray current corrosion.

11.4 Galvanised Iron (GI) Pipes

11.4.1 General

Galvanised iron (GI) pipes are manufactured using mild steel strips of low carbon steel coils. The strips are passed through a series of fin rolls to give them a circular shape. The slit ends of the strips are then welded together by continuously passing high-frequency electric current across the edges. The welded steel pipes are then passed through sizing sections where any dimensional deviations are corrected. The pipes are then cut into desired lengths by automatic cutting machines. The tubes are then pressure tested for any leaks. The galvanisation and varnishing of pipes are done as per specific requirements. Further details may be referred to in IS 4736: 1986 Reaffirmed 2021, IS 1239 (Part 1): 2004, Reaffirmed 2019 and IS 1239 (Part 2): 2011, Reaffirmed 2021. Although negative manufacturing tolerances of 8% or more have been mentioned for different types of steel tubes and sockets in thickness of pipes in relevant IS code, some of the pipe manufactured lots may be defective. Therefore, practically for safety of pipe these tolerances can be reviewed by ULB considering the importance of field conditions typically prevalent in their area. Alternatively, the design working pressure can be considered with suitable factor of safety.

The GI Pipes are generally used for distribution of treated or raw water. These pipes are cheaper, light weight, and easy to transport. The health aspects should be given highest priority before selecting the pipe material for drinking water supply purposes as the pipe material is highly corrosive. It is not preferable to use GI pipes for house service connection (HSC).

The GI pipes are available in size range of 15 mm nominal bore to 150 mm outside diameter. 15 mm nominal bore to 150 mm nominal bore in the different classes of tubes like light, medium and heavy depending on wall thickness, are distinguished by colour bands such as light tubes (yellow), medium tubes (blue) and heavy tubes (red).

11.4.2 Laying and Jointing

All screwed tubes are supplied with pipe threads conforming to IS 554:1999, Reaffirmed 2019. Tubes, as per the IS 1239 (Part 1): 2004, Reaffirmed 2019, are supplied screwed with taper threads and fitted with one socket having parallel thread. The socket conforms to all requirements of IS 1239 (Part 2): 2011, Reaffirmed 2021. Pipes are generally joined using screwed joints. All threads for screw joints shall be clean, machine cut, and all pipes shall be reamed before erection. Each length of pipe as erected shall be upended and rapped to dislodge dirt and scale. Screwed joint shall be made up with good quality thread compound and applied to the male thread only. After having been set up, a joint must not be backed off unless the joint is completely broken, the threads cleaned, and new compound applied. Flange joints may be used if necessary. For pipe laid under ditches, pipe bedding shall be compacted for the entire length of the pipe, good alignment shall be preserved, and fittings may be used where necessary. Tubulars, sockets, and fittings shall be galvanised before screwing.

11.4.3 Testing of the Pipelines

Hydrostatic test is carried out at a pressure of 5 MPa (50.98 Kg-f/cm^2) (1 MPa =10.197 Kg-f/cm^2) and the same is maintained for at least three seconds and shall not show any leakage in the pipe.

Each tube shall be tested for leak tightness as an in-process test at manufacturer's works either by hydrostatic test or alternatively by eddy current test. Mass of zinc coating shall be determined in accordance with IS 4736: 1986, (Reaffirmed Year: 2021). The test for uniformity of zinc coating shall be done in accordance with IS 2633: 1986, (Reaffirmed Year: 2021).

The adhesion of zinc coating on fittings shall be determined by pivoted hammer test in accordance with IS 2629:1985 (Reaffirmed 2021). The zinc coating shall be reasonably smooth and free from such imperfections as flux, ash and dross inclusions, bare patches, black spots, pimples, lumpiness, runs, rust stains, bulky white deposits, and blisters.

11.4.4 Advantages and Disadvantages

Advantages of pipe are:

- Higher durability and longevity;
- Weld consistency and integrity;
- Amenable to rigorous fabrication;
- Superior finish and anti-rust coating;
- Greater corrosion resistance on the outer surface due to galvanisation;
- Superior bend ability and ease of cutting and threading.

Disadvantages of pipe are:

- Galvanised iron should never be used underground unless properly covered, which can be inconvenient for many jobs.
- It often hides significant defects beneath the zinc coating on the steel.
- Galvanised iron pipes may contain lead, which corrodes quickly and reduces the lifespan of the piping.
- Galvanised iron may leave rough patches inside pipes, resulting in serious failures and stoppages that can be expensive to repair.
- Prone to corrosion and leakage at the ferrule point, due to exposure of steel surface due to drilling to water.
- Greater incrustation inside the pipe increases head loss.

11.5 Steel Pipes

11.5.1 General

Steel pipes shall be manufactured with the steel produced by the open hearth or electric furnace or one of the basic oxygen processes. Other process may also be used by agreement between the purchaser and the manufacturer. The pipes shall be manufactured by the processes of seamless pipes, electric resistance welded pipes, and submerged arc welded pipes. The thickness of the steel pipe is controlled due to the need to make the pipe stiff enough to keep its circular shape during storage, transport, laying, and also to take the load of trench backfilling and vehicles. Injurious defects in pipe wall, provided their depth does not exceed one-third of the specified wall thickness, shall be repaired by welding.

Steel pipes of smaller diameter can be made from solid bar sections by hot or cold drawing processes and these tubes are referred to as seamless, but the larger sizes are made by welding together the edges of suitably curved plates, the sockets being formed later in a press (IS 3589: 2001, Reaffirmed 2022). 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 pipes (IS 3589:2001, Reaffirmed 2022), it is possible to make steel pipe of lower wall thickness and lower weight. The minimum thickness of steel pipe shall be as per Table 5 of IS 3589. Specials of all kinds can be fabricated without difficulty to suit the different site conditions.

The IS 5822 (1994, Reaffirmed 2019) code of practice for laying of electrically welded steel pipes for water supply covers the methods of laying electrically welded mild steel pipes of outside diameters 168.3 mm to 2032 mm (as covered in IS 3589: 2001, Reaffirmed 2022), laid either above ground or underground for water supply.

11.5.2 Laying and Jointing

11.5.2.1 Laying

(A) Soil Resistivity Survey

Before laying of MS pipes, soil resistivity survey should be carried out.

The corrosion of underground MS pipes is related to the soil resistivity. If soil resistivity is lower, there are chances of corrosion. The resistivity rating is given in Table 11.2 under subsection 11.1.3.1.

Soil resistivity testing with accurate collection of data is the best indicator of the corrosivity of the soil for buried metallic structures and has a significant impact on the design of cathodic protection systems. The most common test methodology for field collection of soil data is the Wenner four-pin method. When properly collected, and using appropriate analytical techniques, the soil resistance field data can provide an accurate assessment of soil resistivity values for use in designing an appropriate cathodic protection system. The corrosion rate of the water pipeline is an essential parameter to predict pipeline damage. If the soil resistivity is 5000 ohm.cm and less (Table 11.2 under subsection 11.1.3.1), proper anti-corrosion measures should be taken. For example, external coating and wrapping of mild steel pipes is recommended to be done according to the IS 10221 (2008), Reaffirmed 2021 – Clause 8.2 and other relevant clauses. The trench shall be so dug that the pipe may be laid to the required alignment and at required depth. When the pipeline is under a roadway, a minimum cover of 1.0 m is recommended, but it may be modified to suit local conditions by taking necessary precautions. The trench shall be shored, wherever necessary, and kept dry so that the workman may work therein safely, and efficiently. The discharge of the trench dewatering pumps shall be conveyed either to drainage channels or to natural drains and shall not be allowed to be spread in the vicinity of the worksite. Open-cut trenches shall be sheeted and braced as required by any governing state laws and municipal regulations and as may be necessary to protect life, property, or the work. For all pipelines laid above ground, provision for expansion and contraction on account of temperature variation should be made either by providing expansion joints at predetermined intervals or by providing loops where leakage through expansion joints cannot be permitted.

Trenching includes all excavation which is carried out by hand or by machine. The width of the trench shall be kept to a minimum, consistent with the working space required. At the bottom between the faces, it shall be such as to provide not less than 200 mm clearance on either side of the pipe. The bottom of the trench shall be properly trimmed to permit even bedding of the pipeline. For pipes larger than 1,200 mm diameter in earth and murum the curvature of the bottom of the trench should match the curvature of the pipe as far as possible. Where rock or boulders are encountered, the trench shall be trimmed to a depth of at least 100 mm below the level at which the bottom of the barrel of the pipe is to be laid and filled to a like depth with lean cement concrete or with a non-compressible material like sand of adequate depth to give the curved seating. For details on laying of welded steel pipe, IS 5822-1994, Reaffirmed 2019 may be referred to.

Anchors to be designed as per IS 5330 (1984, Reaffirmed 2020), should be provided on the pipeline at the position of line valves or sectionalising valves, at the blank flange, at the tapers and at the mid-point between two consecutive expansion joints, in the case of above ground pipeline. Supports should be designed to support the pipeline without causing excessive local stresses. Due allowance shall be made for the weight of water, hydrostatic head, frictional resistance at the supports, etc. Proper bearing surface, such as flat base, roller and rocker, should be provided where controlled movements are required.

The internal design pressure shall not be less than the maximum pressure to which the pipeline is likely to be subjected including allowance for surge pressure, if any. The pipe selected shall be strong enough to withstand the effect of partial vacuum corresponding to one-third the atmospheric pressure which may occur within the pipe and due to any pressure exerted by water or soil around it.

Buried steel pipelines are liable to external corrosion and should be protected by the use of suitable coatings and shall be in accordance with IS 10221: 2008, Reaffirmed 2021. Pipelines laid above ground are liable to atmospheric corrosion and should be adequately protected.

(B) PROTECTIVE COATINGS

It must be borne in mind, however, that steel mains need protection from corrosion, internally and externally. Against internal corrosion, steel pipes are given epoxy lining or hot-applied coal tar/asphalt lining or rich cement mortar lining at works or in the field by the centrifugal process.

i. Three-Layer Polyethylene (3 LPE) Coating

External three-layer polyethylene coating applied over steel pipes have the following layers as given in the Figure 11.7 below.

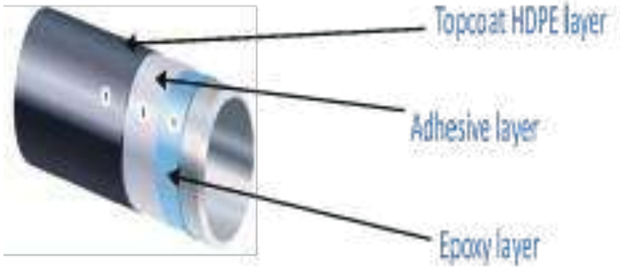


Figure 11.7: Special coating in Mild Steel pipe

a) **1st Primer layer of anti-corrosive fusion-bonded epoxy (FBE)**: In this layer, epoxy powder is spray-applied with electrostatic guns in typical thickness of 80 – 250 µm. The epoxy layer improves the bond with the steel base metal and arrests cathodic disbandment of the anti-corrosive coating with the metal surface.

b) **2nd Intermediate layer of copolymer adhesive**: Copolymer bonding layer extruded in typical thickness of 200 µm to bond the outer polyethylene layer to the epoxy prime coat.

c) **3rd Layer topcoat polyethylene**: Outer top layer comprising of polyethylene extruded in typical thickness of 1.8 – 3.5 mm, at service temperature up to 80 °C.

The three coats (3LPE) provide mechanical strength and anti-corrosive properties to the base metal of pipe.

Applicable Standards: 3LPE coating is applied as per International Standards (DIN 30670:2012, CAN.Z245.21.2018, ISO 21809-1:2018 specifications).
Application: 3LPE coating is applied to pipes when it is exposed to severe corrosive environment.

ii. Bituminous tape Coating (IS 10221-2008)

Anti-corrosive pipe wrapping tape is used for the protection of underground metallic pipelines from corrosion; fibre glass reinforced, bituminous tape comprising thermofusible film on both sides, helps in protection against corrosion, UV and water ingress. The wrapping tape is applied by the help of a blow torch in outer surface of steel pipes. Figure 11.8 shows torch application for bituminous wrap coating and Figure 11.9 shows application of tape coating in pipeline.

Figure 11.8: Torch application for bituminous wrap coating

Figure 11.9: Application of tape coating in pipeline

iii. Internal Food Grade Solvent-Free Epoxy Coating

Food grade solvent-free liquid epoxy coating is applied inside water conveyance pipes. Apart from providing anti-corrosive protection, the coatings prevent chemical action, marine and algal growth inside the pipe surface, as well as reduce the friction losses in the pipe. Hot airless spray method is used for coating the internal surface of the pipe up to a thickness of 1.5 mm. Applicable standards are: Annex B for IS 3589:2001, Reaffirmed 2022, AWWA C210:2015. Figure 11.10 shows hot airless spray of food grade epoxy lining inside pipeline and Figure 11.11 shows internal food grade solvent-free epoxy coating.

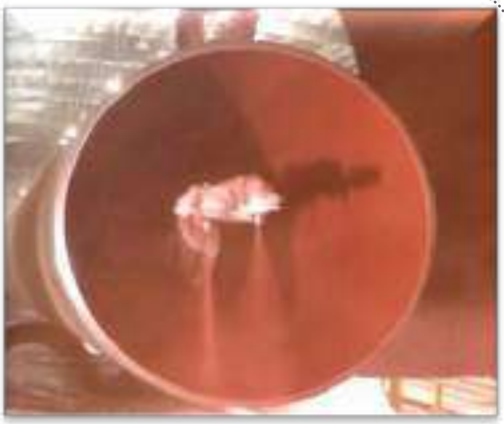


Figure 11.10: Hot airless spray of Food grade epoxy lining inside pipeline

Figure 11.11: Internal Food Grade Solvent-Free Epoxy coating

iv. Guniting

The outer coating for underground pipeline may be in cement-sand guniting or hot-applied coal tar asphaltic enamel reinforced with fibre glass fabric yarn. The other materials may also be adopted for internal lining which should not provide adverse impact on health.

11.5.2.2 Jointing

The requirements for mild steel pipes up to 150 mm nominal diameter are covered in IS 1239 (Part 1): 2004, Reaffirmed 2019 and the requirements for mild steel and wrought steel fittings are covered in IS 1239 (Part 2): 2011, Reaffirmed 2021. These pipes can be joined by means of the socket and screw or by welding. The requirements for steel pipes with diameters greater than 150 mm are covered in IS 3589: 2001, Reaffirmed 2022. The requirements for spiral welded pipes are given in IS 5504: 1997, Reaffirmed 2018. Higher diameter steel pipes and spiral welded pipes are joined by welding only.

Small size mild steel pipes have got 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 tighten it. While laying, the pipes already stocked along the trenches are lowered down into the trenches with the help of 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 mortar 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 preferred. In areas prone to subsidence, this joint is satisfactory but flexible joints must be provided to isolate valves and branches. When welding is adopted, plain-ended pipes may be joined by butt welds or sleeved pipes by means of fillet welds.

For laying long straight lengths of pipelines, butt joint technique may be employed. Steel pipes used for water supply include hydraulic lap welded, electric fusion welded, submerged arc welded and spiral welded pipes. The latter are being made from steel strip.

If the pipes are joined by a form of flexible joint, it provides an additional safeguard against failure. Steel pipes being flexible are best suited for high dynamic loading.

A. Expansion Joints

Para. 8.3.2 of the BIS code IS: 5822:1994, (Reaffirmed in 2019) – "Code of Practice for Laying of Electrically Welded Steel Pipes for Water Supply" mentions that for all pipelines laid above ground, provision for expansion and contraction on account of temperature variation should be made either by providing expansion joints at predetermined intervals or by providing loops where leakage through expansion joints cannot be permitted. Where expansion joints are provided, it is necessary to create restraining points on the pipeline to ensure proper functioning of these joints. The pipe laying work should preferably start from the restrained points on either side working towards centre where the expansion joint should be fitted last. Spacing of expansion joint depends on local conditions. Provision of expansion joint at intervals of 300 m on exposed steel pipeline is generally recommended. Expansion joints should always be provided between two fixed supports or anchorages.

B. Welded Joints Testing

Radiographic tests (non-destructive testing of fusion welded butt joints in steel pipes)

The BIS Code IS 4853:1982, (Reaffirmed 2020): covers the radiographic inspection of fusion welded butt joints in steel pipes up to the maximum size of 50 mm wall thickness, which may be referred to.

11.5.3 Fittings

For steel tubes, tubulars, and other wrought steel fittings, IS 1239 (Part I) (2004, Reaffirmed 2019) may be referred to.

11.5.4 Testing of the Pipelines

Before putting it into commission, the welded pipeline shall be tested both for its strength and leakage.

The manufacturer shall carry out the specified tests applicable to each type of pipe, and they shall, if required by the purchaser, supply a certificate stating that the pipes comply with the specified requirements.

Where the purchaser requires tests, the number of pipes on which mechanical tests shall be performed, shall be as follows:

(i) Up to and including 101.6 mm outside diameter – one pipe in each 400 tubes as made

(ii) Over 101.6 mm outside diameter – one pipe in each 200 pipes as made

If the number of samples specified in this clause, when applied to a particular order, necessitates a number of pipes which includes a fraction, the fraction shall be treated as unity.

Tensile test should be carried out in accordance with IS: 3601:2006, (Reaffirmed 2022).

The welded joints shall be tested in accordance with procedure laid down in the relevant BIS Standards. One test specimen taken from at least one field joint out of any 10 shall be subjected to test.

Each valved section of the pipe shall be slowly filled with clean water and all air shall be expelled from the pipeline through hydrants, air valves, and blow-offs fixed on the pipeline. Before starting the pressure test, the expansion joints should be tightened.

11.5.4.1 Pressure Test

The field test pressure to be imposed should be not less than the greatest of the following:

a) 1.5 times the maximum sustained operating pressure.
b) 1.5 times the maximum pipeline static pressure.
c) maximum sustained operating pressure plus maximum surge pressure (in case of pumping mains);
d) sum of the maximum pipeline static pressure and the maximum surge pressure, subject to a maximum equal to the work test pressure for any pipe fitting incorporated;
e) testing pressure in accordance with the provisions of IS of relevant pipe material used.

Where the field test pressure is less than two-thirds the factory test pressure, the period of test should be at least 24 hours. The test pressure shall be gradually raised at the rate of nearly 0.1 N/mm^2 per minute.

Each valve section of pipe shall be filled with water slowly and the specified test pressure, based on the elevation of lowest point of the linear 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.

Under the test pressure no leak or sweating shall be visible at all section of pipes, fittings, valves, hydrants, and welded joints. Any 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 to the authority.

11.5.5 Advantages and Disadvantages

The advantages of pipe are:

- 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.
- Compared to cast iron pipes of the same size, steel pipes are lightweight. Steel pipes perform well in unusual circumstances, such as non-uniform bedding, settling soils, or when subjected to external loads due to their longitudinal strength.
- Easy installation of steel pipes is an advantage over cast iron pipes of similar strength. Steel pipes have smooth outer surfaces which makes installation using micro-tunnelling possible.
- Steel pipes have low frictional resistance to the flow of water. The thin walls of steel pipe generate a larger inside diameter which allows greater flow capacity.
- Risk of leaking mainly exists at the joints. Since steel pipes can be welded at the joints, the risk of leaking is much less.
- Service life of steel pipes depends on the rate of corrosion and abrasion. Impurities in water cause pipe abrasion to occur more rapidly.
- Reliability is a factor which can assure that pipe can tolerate any unprecedented event such as flood, soil movement, earthquake, etc. Steel is considered tough because of wide ductile range and ultimate stress resistance.

- A versatile pipe material will easily adapt to required modifications.If there are any changes in the bedding of the pipe, the beam strength of the steel can compensate.

The disadvantages of pipe are:

- Steel pipes required epoxy coating inside and 3LPE coating from outside and cathodic protection of whole pipeline.
- Welding joints for steel water pipe are complicated and require skilled labour.
- Steel pipe is susceptible to internal tuberculation and external corrosion, and is subjected to electrolysis, if not properly protected.
- Use of anti-corrosion products increases the price of production and maintenance of steel pipe.

Air vacuum valves are necessary in large diameter pipes to prevent collapse.

11.6 Asbestos Cement (AC) Pressure Pipes

11.6.1 General

Asbestos cement pressure (AC pressure) pipes are made of a mixture of chrysotile asbestos paste (only contains 8%-10%) and cement (50%), clay (30-35%) and fly ash, wood, pulp, etc., which are not considered harmful for human health. Even here the asbestos fibres are locked with cement matrix particles and there is no scope for its disintegration/spreading in the air in normal circumstances. The paste is compressed by steel rollers to form a laminated material of great strength and density. Its carrying capacity remains substantially constant as when first laid, irrespective of the quality of water. It can be drilled and tapped for house service connection through a saddle piece as per clause 9.1 and 9.1.1 of IS 6530 1972, Reaffirmed 2022. The hole of required size shall be drilled through the pipe and the boss (cushion) provided in the top strap. Ferrule piece shall be connected after making threads in the boss and pipe. Suitable rubber packing shall be used between the straps and the pipe to provide cushioning as well sealing against leakages.

AC pressure pipes are manufactured from classes 10 to 25 and nominal diameters of 80 mm to 1000 mm with the test pressure of 10 to 25 Kg/cm^2. AC pressure pipe can meet the general requirements of water supply undertakings for rising main as well as distribution main. It is classified as class 10, 15, 20, and 25, which have test pressures 10, 15, 20, and 25 Kg/cm^2 respectively. Working pressures shall not be greater than 50% of test pressure for pumping mains and 67% for gravity mains. The BIS Code for the highest class of ACP pipe is class 25 having test pressure of 25kg/cm^2 and working pressure of 12.5 kg/cm^2, which is equivalent to Class K7 of Ductile Iron Pipe having working pressure of 12kg/cm^2.

ACP pipe being non-metallic, once buried, the metal detector is ineffective in locating such pipes, therefore, metallic locating tapes or copper wires can be placed alongside the ACP pipe without causing significant cost, to facilitate locating buried ACP pipes.

These pipes are not suitable for use in sulphate soils. Due to expansion and contraction of black cotton soil, usage of these pipes may be avoided as far as possible in black cotton (B.C.) soils, except where the depth of B.C. soil is clearly less than 0.9 metre below ground level.

Storage of AC pipes shall be done on firm level and clean ground and wedges shall be provided at the bottom layer to keep the stack stable. The stack shall be in pyramid shape or the pipes laid lengthwise and crosswise in alternate layers. The pyramid stack is advisable in smaller diameter pipes for conserving space in storing them. The height of the stack shall not exceed 1.5 m.

11.6.2 Laying and Jointing

11.6.2.1 Laying

The pipes shall have a minimum soil cover of 750 mm when laid under foot paths and sidewalks, 900 mm when laid under roads with light traffic or under cultivated soils, and 1250 mm when laid under roads with heavy traffic. When the soil has a poor bearing capacity and is subject to heavy traffic, the pipes shall be laid on a concrete cradle. An extra trench depth of 100 mm shall be provided for each jointing pit.

The pipes shall be lowered into the trenches either by hand passing or by means of two ropes. One end of each rope shall be tied to a wooden or steel peg driven into the ground and the other end shall be held by men which when slowly released will lower the pipe into the trench. The width of the trench should be uniform throughout the length and greater than the outside diameter of the pipe by 300 mm on either side of the pipe. The depth of the trench is usually kept 1 metre above the top of the pipe. For heavy traffic, a cover of at least 1.25 metre is provided on the top of the pipe.

In unstable soils, such as soft soils and dry lumpy soils, it shall be checked whether the soils can support the pipelines and if required, suitable special foundation shall be provided. In places where rock is encountered, a cushion of fine earth or sand shall be provided for a depth of 150 mm by excavating extra depth of the trench, if necessary, and the pipes laid over the cushion. Where the gradient of the bed slopes is more than 30°, it may be necessary to anchor a few pipes against their sliding downwards.

The excavation of the trench shall be so carried out that the digging of the trenches does not get far ahead of the laying operations. By doing this, the risk of falling of the sides and flooding of trenches shall be avoided. The walls of the trench shall be cut generally to a slope of ¼:1 or ½:1, depending on the nature of the soil. If the trench bottom is extremely hard or rocky or loose stony soil, the trench should be excavated at least 150 mm below the trench grade.

Prior to being placed in the trench, pipes should be visually inspected for evidence of damage as any damage to the pipe may impair its strength or integrity consequently. 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 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 their being lowered into the trench they are aligned for jointing. The bed of the trench should be uniform. Utmost care must be taken while loading, transportation, unloading, stacking, and carrying to the site to avoid damage to the pipes. Figure 11.12 shows Cutting of AC Pressure Pipes and Figure 11.13 shows Laying of AC Pressure Pipes in Rocks.

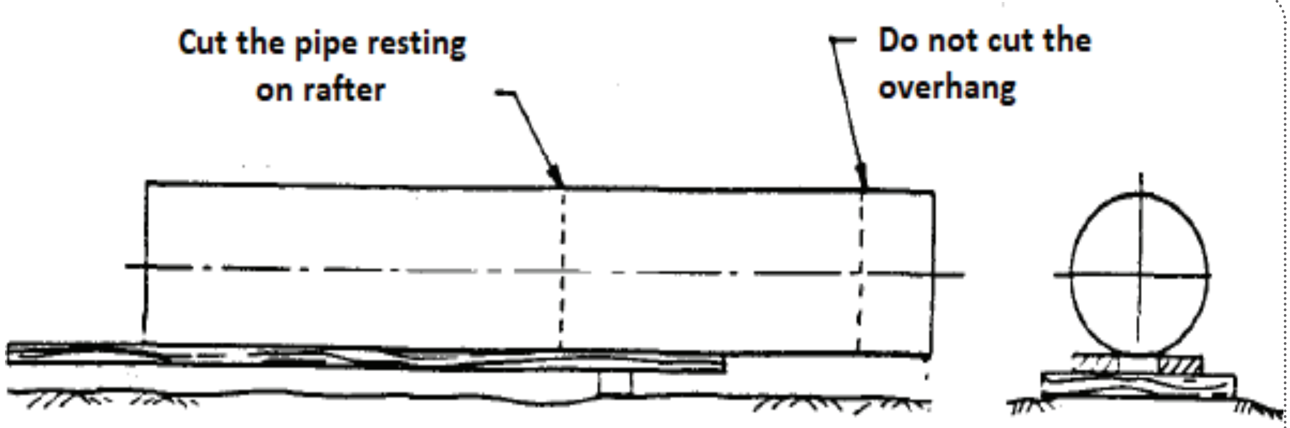


Figure 11.12: Cutting of AC Pressure Pipes

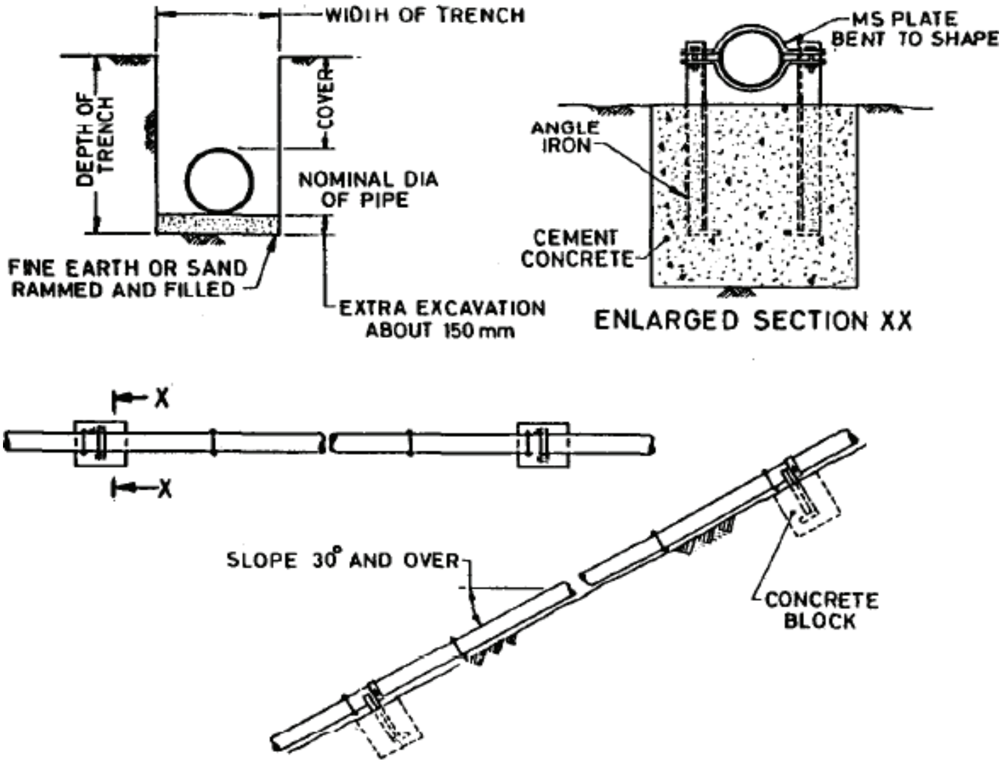


Figure 11.13: Laying of AC Pressure Pipes in Rocks

11.6.2.2 Jointing

Before commencing jointing, the pipes shall be cleaned; the joints and the ends of the pipe shall be cleaned, preferably with a hard wire brush to remove loose particles.

Two types of joints are normally provided with AC pressure pipes and they are:

a. Cast iron detachable (CID) joints (IS 8794: 1988, (Reaffirmed Year 2022))
b. AC coupling joints (IS 1592: 2003, (Reaffirmed Year 2018))

a) Cast Iron Detachable Joints

This consists of two cast iron flanges, a cast iron central collar and two rubber rings along with a set of nuts and bolts for the particular joint. For this joint, the AC pipes should have flush ends. For jointing a flange, a rubber ring and a collar are slipped to the first pipe in that order; a flange and a rubber ring being introduced from the jointingof the next pipe. Both the pipes are now aligned, the collar centralised, and the joints of the flanges tightened with nuts and bolts. Figure 11.14 shows Cast Iron Detachable Joints.

b) Asbestos Cement Coupling Joint

This consists of an AC coupling and three special rubber rings. The pipes for these joints have chamfered ends. These rubber rings are positioned in the grooves inside the coupling, then grease is applied on the chamfered end and the pipe and coupling is pushed with the help of a jack against the pipe. The mouth of the pipe is then placed in the mouth of the coupling end and then pushed so as to bring the two chamfered ends dose to each other. Wherever necessary, change over from cast iron pipe to AC pipes or vice versa, should be done with the help of suitable adapters. IS 6530: 1972, Reaffirmed 2022, may be followed for laying AC pipes. Figure 11.15 shows Asbestos Cement Coupling Joint.

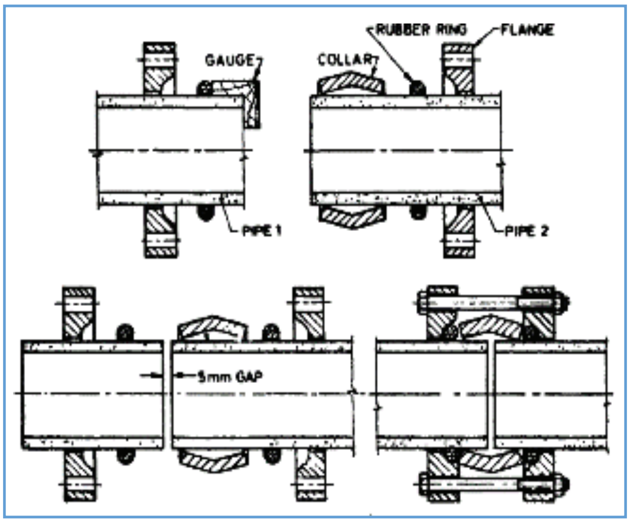


Figure 11.14: Cast Iron Detachable Joints

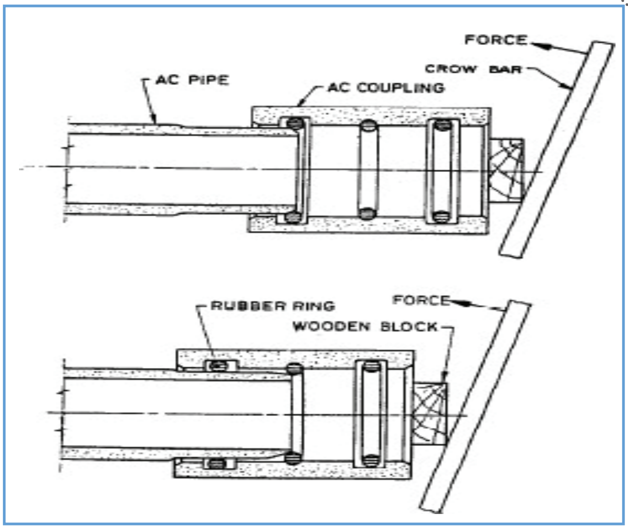


Figure 11.15: Asbestos Cement Coupling Joint

However, in the past, projects implemented with AC pipes joined with an inordinate use of Cast Iron Detachable (CID) joints in the main water distribution network (limited to be used only in T-points, bends, etc.) have not only resulted in huge capital cost due to higher cost of the joints than the pipe material, but also resulted in huge leakages at the joints over time, as Cast Iron joints are prone to corrosion. Therefore, confirming to BIS IS 1592:2003 (Reaffirmed 2018), the main distribution network of the water supply scheme should be jointed with the AC coupling and three rubber special rings fitted inside the coupling as it provides an air- and water-tight grip with leak-proof joints. AC couplings are economical, non-corrosive, and easy to repair and maintain. During maintenance, the damaged pipe section can be easily replaced with a light hammer in the joints, the AC coupling can be broken, and the damaged pipe can be replaced with a new AC pipe. The couplings are also easily available as they are manufactured in India.

Although, the BIS Code IS 10299:1982 (Reaffirmed 2020) specifies the CI saddle pieces for service connection in Asbestos Cement Pressure Pipes, DI saddles with epoxy powder coating shall be used with AC pipe instead of the cast iron detachable (CID) saddle to avoid any corrosion or leakages.

11.6.3 Fittings

When a fitting is used to make a vertical bend, it shall be anchored to a concrete thrust block designed to have enough weight to resist the upward and outward thrust. Similarly, at joints deflected in vertical plane, it shall be ensured that the weight of the pipe, the water in the pipe, and the weight of the soil over the pipe provide resistance to upward movement. If it is not enough, ballast or concrete shall be placed around the pipe in sufficient weight to counteract the thrust.

Pipes on the slope need to be anchored only when there is a possibility of the backfillaround the pipe sloping down the hill and carrying the pipe with it. Generally, for slopesup to 30°, good well-drained soil carefully tampered in layers of 100 mm under and over the pipe, right up to the top of the trench, will not require anchoring.

Normally, when a pipeline is laid, a certain number of cast iron fittings such as tees, bends, reducers, etc., and special fittings such as air and sluice valves are required. All cast iron fittings shall be plain-ended to suit the outside diameter of asbestos cement pressure pipes and to the class and diameter of pipe manufactured. When using such cast iron fittings, they are joined by cast iron detachable joints only. For any cast iron specials having flanges, they are jointed in the pipeline with cast iron flange adaptors having one end flanged and the other plain-ended. However, DI fittings should be preferred over CI fittings in all the applications.

11.6.4 Testing of the Pipelines

After all sections have been jointed together on completion of section testing, a test on the complete pipeline should be carried out. Asbestos cement pipes always absorb a certain amount of water. Therefore, after the line is filled, it should be allowed to stand for 24 hrs before pressure testing, and the line shall be again filled. This test should be carried out at a pressure not less than the working pressure of the pipeline, care being taken to ensure that the pressure at the lowest point in the pipeline does not exceed the maximum. During the test, an inspection should be made of all work which has not been subjected to sectional tests. The test pressure shall be gradually raised at the rate of approximately 1 kg/cm^3/min. The duration of the test period, if not specified, shall be sufficient to make a careful check on the pipeline section. After the test has been completed, the trench shall be filled back.

The procedure for pressure testing as adopted 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 metres long.
b) One of the valves is closed and the 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 of for filling the fine as may be required. The pipeline after it is filled should be allowed to stand for 24 hours before pressure testing).
c) After filling, the sluice valve is closed and the pipe section is isolated.
d) Pressure gauges are fitted at suitable intervals on the crown into the holes meant for the purpose.
e) The pipe section is then connected to the delivery side of a pump through a small valve.
f) The pump is then operated till the pressure inside reaches the designed value which can be read from the pressure gauges fixed.
g) After the required pressure has been attained, the valve is closed and the pump disconnected.
h) The pipe is then kept under the desired pressure during inspection for any defect, i.e., leakages at the joints, etc. The water will then be emptied through scour valves and defects observed in the test will be rectified.

11.6.5 Advantages and Disadvantages

The advantages of pipe are:

- The inside surface of pipe is smooth.
- The joining of pipes is very good and flexible.
- The pipes are anti-corrosive and cheap in cost.
- Light in weight to handle and transport.
- Least storage cost as it can be stored in open space at worksite and also anti-theft due to its no resale value.

The disadvantages of pipe are:

- Not suitable for black cotton soil and sulphate contained soil.
- Not suitable for hilly hard rocky terrain.

11.7 Reinforced Cement Concrete Pipes (RCC)

11.7.1 General

RCC pipes used in water supplies are classified as P1, P2, and P3 with test pressures of 2.0, 4.0, and 6.0 Kg/cm^2 respectively. For use as gravity mains, the working pressure should not exceed two-third of the test pressure. For use as pumping mains, the working pressure should not exceed half of the test pressure.

Generally concrete pipes have corrosion-resistant properties similar to those of prestressed concrete pipes although they have their own features which significantly affect corrosion performance. Reinforced concrete pipes either spun (centrifugal spinning) or vibrated cast (vibratory processes) shall be designed such that the maximum tensile stress in the circumferential steel due to specified hydrostatic test pressure does not exceed the limit of 125 N/mm^2 (IS 458:2021) (1274.65 Kgf/cm^2) in the case of mild steel rods, and 140 N/mm^2 in the case of hard-drawn steel wires and high strength deformed steel bars and wires. Centrifugally spun pipes are subjected to high rotational forces during manufacture with improved corrosion resistance properties. The line of development most likely to bring concrete pressure pipes into more general acceptance is the use of PSC pipes which are widely used to replace reinforced concrete pipes.

11.7.2 Laying and Jointing

11.7.2.1 Laying

Concrete pipes should be carefully loaded, transported, and unloaded avoiding impact. Free working space on either side of the pipe shall be provided in the trench which shall not be greater than one-third of the diameter of the pipe but not less than 150 mm on either side. Pipes should be lowered into the trench with tackle suitable for the weight of pipes, such as well-designed shear slings with chain block or mobile crane. While lifting, the position of the sling should be checked when the pipe is just clear off the ground to ensure proper balance.

In general, the IS 783: 1985, (Reaffirmed Year: 2022) Code of Practice for Laying of Concrete Pipes may be referred to. Laying of pipes shall proceed upgrade of a slope. If the pipes have spigot and socket joints the socket ends shall face upstream. The pipes shall be joined in such a way to provide as little unevenness as possible along the inside of the pipe. Where the natural foundation is inadequate, the pipes shall be laid in a concrete cradle supported on proper foundation or any other suitably designed structure. If a concrete cradle is used, the depth of concrete below the bottom of the pipes shall be at least one-fourth the internal diameter of pipe with the range of 100 mm to 300 mm. It shall extend up to the sides of the pipe at least to a distance of one-fourth the diameter for larger than 300 mm.

The pipe 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 300 mm above the pipe subject to the condition that the jointing material has hardened (12 hours at the most). The backfill material shall be free from boulders, roots of trees, etc. The tamping shall be by hand or by other hand operated mechanical means. The water content of the soil shall be as near the optimum moisture content as possible. Filling of 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 900 mm above the top of the pipe.

Where gradient steeper than 1 in 6 is contemplated, consideration should be given to the construction of suitable transverse anchor blocks. For gradients between 1 in 7 and 1 in 12, the need for transverse anchor blocks will depend on ground conditions. For slopes flatter than 1 in 12, there is seldom a need to provide anchor blocks.

11.7.2.2 Jointing

Joints may be of any of the following types:

(i) Bandage joint
(ii) Spigot and socket joint (rigid and semi-flexible)
(iii) Collar joint (rigid and semi-flexible)
(iv) Flush joint (internal and external)

In all pressure pipelines, the recesses at the ends of the pipe shall be filled with jute braiding dipped in hot bitumen. The quantity of jute and bitumen in the ring 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 diameter of the pipe and the bearing capacity of soil. For small pipe up to 250 mm diameter, six pipes can be jacked together at a time. Before and during jacking, care should 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 1:1.5 mixture of cement and sand just sufficiently moistened to hold together in the form of a clod when compressed in the hand. The caulking shall be so firm that it shall be difficult to drive the point of a penknife into it. The caulking shall be employed at both the 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 instead of jute braiding soaked in bitumen. It shall be kept wet for 10 days for maturing.

A. Rigid Joints

In this, the water seal is affected by cement mortar or similar material which will not allow any movement between the two pipes.

Socket and Spigot Joint: The annular space between socket and spigot is filled with cement mortar (1:2). This joint is used for a low-pressure pipeline. Figure 11.16 shows a spigot and socket joint.

Collar Joint: Collars of 150 to 200 mm wide cover the joint between two pipes. A slightly damp mixture of cement and sand is rammed with caulking tool. Figure 11.17 shows collar joint (rigid).

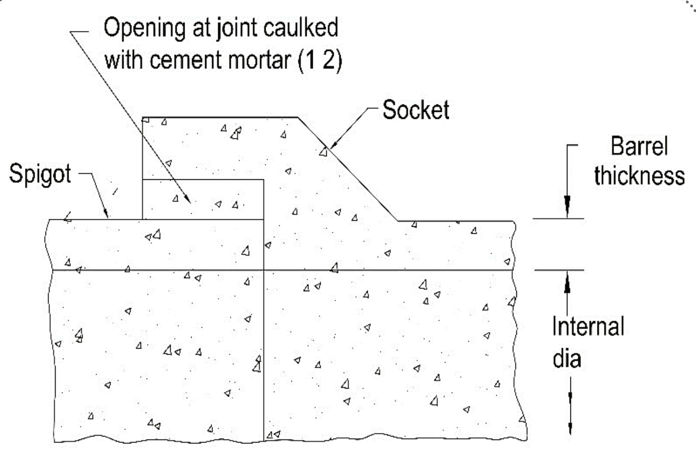


Figure 11.16: Spigot and Socket Joint

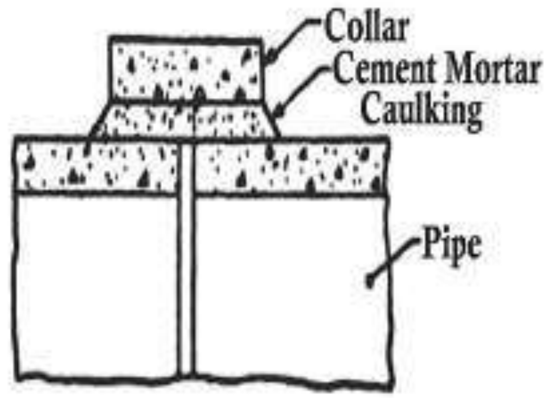


Figure 11.17: Collar Joint (Rigid)

Flush Joint

Internal Flush joint – This joint is generally used for culvert pipes of 900 mm diameter and over. The ends of the pipes are specially shaped to form a self-centring joint with an internal jointing space 1–3 cm wide. The finished joint is flush with both inside and outside with the pipe wall. The jointing space is filled with cement mortar mixed sufficiently dry to remain in position when forced with a trowel or rammer.

External Flush Joint – This joint is suitable for pipes which are too small for jointing from inside. Great care shall be taken in handling to ensure that the projecting ends are not damaged, as no repairs can be readily effected from inside the pipe. Details of the joint are shown in Figure 11.18 below.

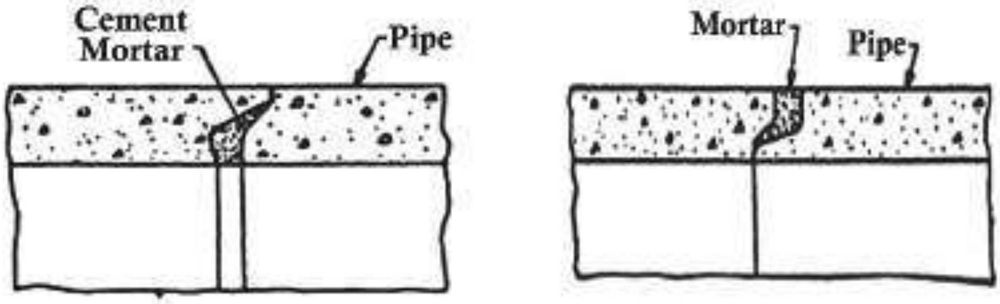


Figure 11.18: Internal and External Flush Joint

B. Flexible Joints

The water seal is effected because of compact pressure between the sealing rubber ring (or similar material) and the pipe surface. These are mainly two types.
Roll on Joint – A rubber ring (circular in cross-section) is placed at or near the end of the spigot and rolls along it as the spigot enters the socket.

Confined Gasket – Rubber ring of circular cross-section is held in the groove formed on the spigot. Sometimes, the cross-section is in the shape of a lip. The lips are opened due to water pressure which ensures water seal. For assembly of this joint, a lubricant has to be applied to the sliding surfaces. The lubricant washes off when the pipe is in service. Figure 11.19 shows a confined O-ring joint and roll on joint.

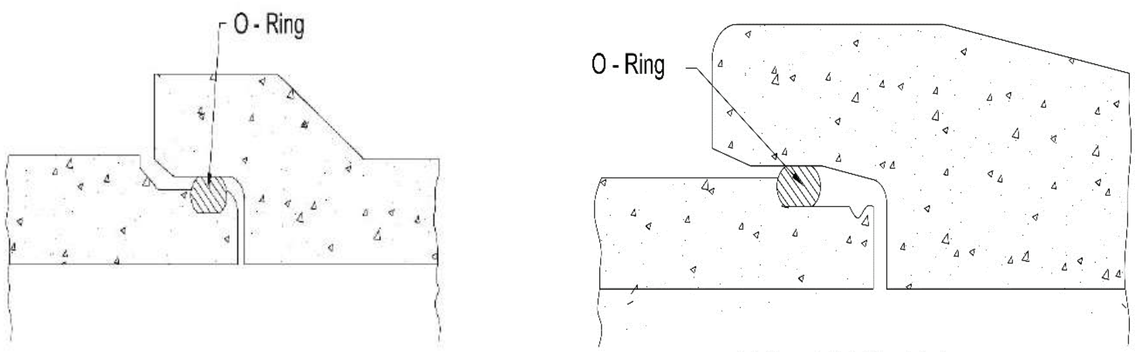


Figure 11.19: Confined O-ring joint and Roll on Joint

All pipelines should be tested before being brought into service. When testing the pipeline hydraulically, the line shall be kept filled completely with water for a week. The pressure shall then be increased gradually to full test pressure as indicated above at testing of the pipeline section under cast iron pipe and maintained at this pressure during the period of test with the permissible allowance indicated therein.

11.7.3 Advantages and Disadvantages

The advantages of pipe are:

- Good corrosion resistance,
- Widespread availability,
- High strength,
- Good load supporting capacity.

The disadvantages of pipe are:

- Require careful installation to avoid cracking,
- Heavy,
- Susceptible to attack from aggressive soils,
- Poor adaptability in installation,
- Making house connection is difficult as it is difficult to fix in ferrule which may cause leakage and weak connection.

11.8 Prestressed Concrete Pipes (PSC)

11.8.1 General

While reinforced cement concrete (RCC) pipes can cater to the needs where pressures are up to 6 kg/cm^2 and CI and steel pipes cater to the needs of higher pressures around 24 kg/cm^2, the prestressed concrete (PSC) pipes cater to intermediate pressure range, where RCC pipes would not be suitable.

The strength of a PSC pipe is achieved by helically winding high tensile steel wire under tension around a concrete core thereby putting the core into compression. When the pipe is pressurised, the stresses induced relieve the compressive stress, but they are not sufficient to subject the core to tensile stresses. The prestress wire is protected against corrosion by a surrounding of cementitious cover coat giving at least 18 mm thick cover. The PSC pipes are suited for water supply mains where pressures in the range of 6 kg/cm^2 to 20 kg/cm^2 are encountered.

Two types of PSC pipes are in use:

(i) **Cylinder-type:** Consists of a concrete lined steel cylinder monolith with other parts to be joint to cylinder. Steel joint rings welded to its ends wrapped with a helix of highly stressed wire and coated with dense cement mortar or concrete. Prestressed concrete cylinder pipe has the following two general types of construction:

   a. a steel cylinder lined with a concrete core; or
   b. a steel cylinder embedded in a concrete core.

   In either type of construction, manufacturing begins with a full-length welded steel cylinder. Joint rings are attached to each end and the cylinder is hydrostatically tested to ensure water tightness. A concrete core with a minimum thickness of one-sixteenth times the pipe diameter, or as per IS 784-2019, is placed either by the centrifugal process, radial compaction, or by vertical casting. After the core is cured, the pipe is helically wrapped with high strength, hard-drawn wire using a stress of 75 per cent of the minimum specified tensile strength. The wrapping stress is calculated on the basis of 75% the value of minimum ultimate tensile strength as per IS 1785: 1983, Reaffirmed 2018. The wire spacing is accurately controlled to produce a predetermined residual compression in the concrete core. The wire is embedded in a thick cement slurry and coated with a dense mortar that is rich in cement content.

The joints between PSC (cylinder-type) pipe will be site welded joint/rubber ring joint.

Size Range**:** Effective length of cylindrical pipe shall be up to 7.0 m. However, for pipes of diameter up to and including 300 mm, the effective length shall not exceed 3.0 m. Nominal internal diameter for cylindrical pipes is varying from 200 mm to 2500 mm (IS 784: 2019).

The technology for manufacture of these pipes is now available with Indian manufacturers.

(ii) **Non-cylinder type:** Consists of a concrete core which is pre-compressed both in longitudinal and circumferential directions by a highly stressed wire. The wire wrapping is protected by a coat of cement mortar or concrete.

Physical behaviour of PSC pipes under internal and external load is superior to RCC pipes. The PSC pipe wall is always in a state of compression which is the most favourable factor for permeability. These pipes can resist high external loads. The protective cover of cement and mortar which covers the tensioned wire wrapping by its ability to create and maintain alkaline environment around the steel inhibits corrosion. PSC pipes are joined with flexible rubber rings.

The deflection possible during laying of main is relatively small and the pipes cannot be cut to size to close gaps in the pipeline. Special closure units (consisting of a short double spigot piece and a plain-ended concrete lined/anti-corrosive food grade paint steel tube with a follower ring assembled at each end) are manufactured for this purpose. The closure unit (minimum length 1.27 m) must be ordered specially to the exact length.

Specials such as bends, bevel pipes, flanged tees, tapers, and adapters to flange the couplings are generally fabricated as mild steel fittings lined and coated with concrete/anti-corrosive food grade paint. It is worthwhile when designing the pipeline to make provision for as many branches as are likely to be required in the future and then to install sluice valves or blank flanges on these branches. It is possible to make connections to the installed pipeline by emptying, breaking out, and using a special closure unit.

11.8.2 Laying and Jointing

PSC non-cylinder pressure pipes are provided with flexible joints; the joints being made by the use of rubber gasket. They have socket spigot ends to suit the rubber ring joint. The rubber gasket is intended to keep the joint watertight under all normal conditions of service including expansion, contraction, and normal earth settlement. The quality of rubber used for the gasket should be waterproof, flexible, and should have a low permanent set. Figure 11.20 shows PSC (Non-Cylinder Type) Pipe Confined Joint Details and Figure 11.21 shows PSC (Non-Cylinder Type) Pipe Roll on Joint Details.

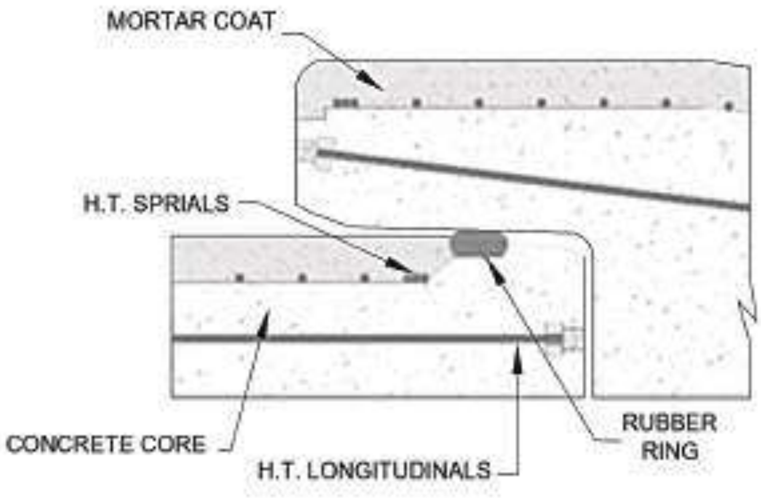


Figure 11.20: PSC (Non-Cylinder Type) Pipe Confined Joint Details

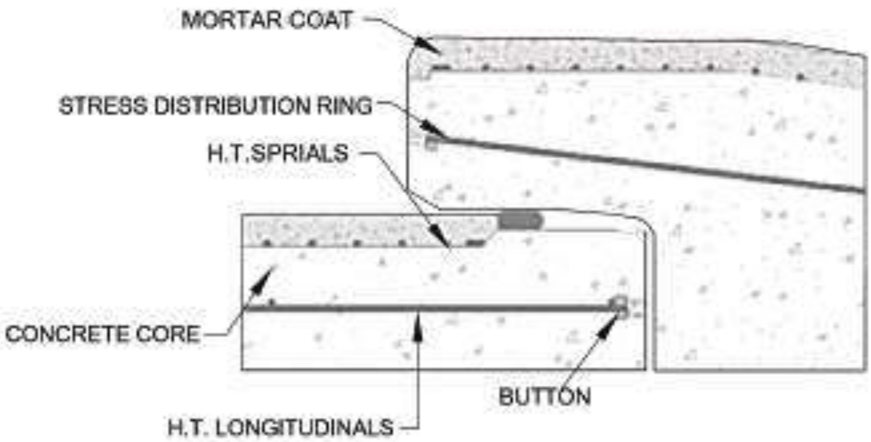


Figure 11.21: PSC (Non-Cylinder Type) Pipe Roll on Joint Details

Unless otherwise specified, joints between PSC cylinder pipes shall be of spigot and socket-type with a rubber ring or with steel joint rings embedded at the ends for site welding. In case of pipes for culverts, joints may be spigot and socket, roll on gasket joint, confined gasket joint or flush joint. The rubber ring joint design shall take into consideration the tolerance for rubber cord, tolerance for socket and spigot diameters, allowable deflection at joint and permanent set in the rubber ring. Figure 11.22 shows PCCP Pipe Sliding Overlap Welded Joint and Figure 11.23 PCCP Pipe Confined Rubber Ring Joint.

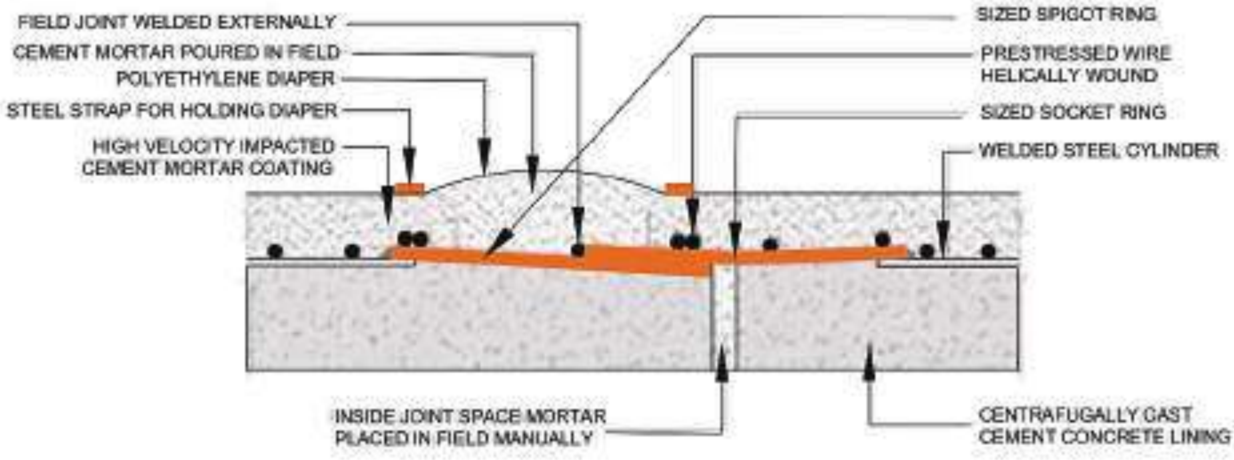


Figure 11.22: PCCP Pipe Sliding Overlap Welded Joint

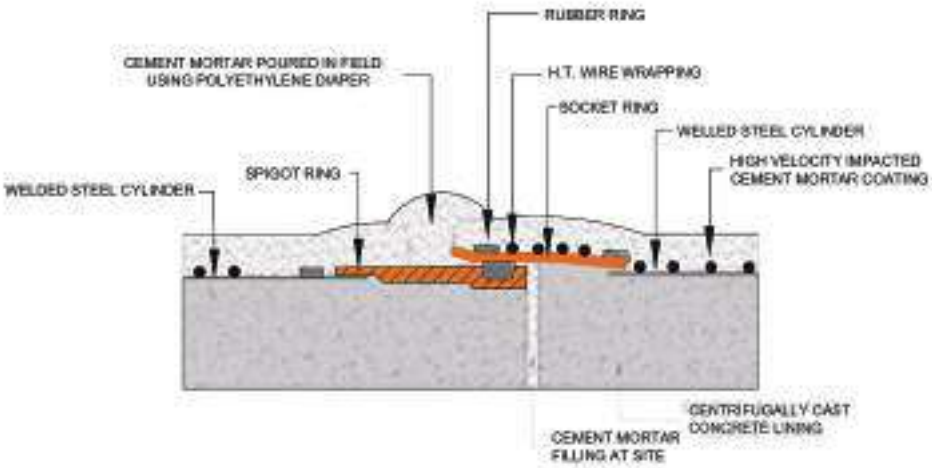


Figure 11.23: PCCP Pipe Confined Rubber Ring Joint

The sealing rings shall be of such size that when jointed, it shall provide a positive seal within the recommended range of maximum joint deflection not more than two splices in each ring shall be permitted.

The steel for fabricated steel plate specials, is cut, shaped, and welded so that the finished special has the required shape and internal dimension. Adjacent segments are joined by butt welding. Before lining and coating, the welding of specials shall be tested by use of hot oil or dye penetrant according to IS 3658: 1999, Reaffirmed 2020, and defects, if any, shall be rectified. The steel plate thickness for specials shall be as given in IS 1916. In dye penetrant inspection, a whitewash is applied over the weld on one side of the cylinder, on other side when coloured paraffin or similar product is applied over the weld, no coloured spot shall appear on the whitewash before 4 hrs. If any coloured spots appear before 4 hours, weld shall be repaired and retested.

The special shall be jointed to the pipe by same rubber ring joint as for pipes.

11.8.3 Testing of Pipelines

The pressure testing of PSC cylinder and non-cylinder pipes is the same as mentioned above at testing of the pipeline section under cast iron pipe. However, the quantity of water added in order to re-establish the test pressure should not exceed three litres (instead of 0.1 litres) per mm diameter, per km per 24 hours per 30 m head for non-absorbent pipes as per IS 783:1985, Reaffirmed 2022. The field test pressure shall be maintained for one hour. If the visual inspection indicates that there is no leakage, the test can be passed.

11.8.4 Advantages and Disadvantages

The advantages of pipe are:

- Good corrosion resistance,
- Widespread availability,
- High strength,
- Good load supporting capacity,
- Suitable for higher diameter pipeline (more than 1200 mm),
- Suitable for use in corrosive environment.

The disadvantages of pipe are:

- Require careful installation to avoid cracking,
- Heavy,
- Susceptible to attack from aggressive soils,
- Poor adaptability in installation,
- Difficult to repair and additional machine ends (sockets, spigots, barrels, etc.) need to be kept in inventory.

11.9 Bar/Wire Wrapped Steel Cylinder Pipes with Mortar Lining and Coating

11.9.1 General

Bar/Wire wrapped steel cylinder pipes with mortar lining and coating are available in diameters of 250 mm to 1900 mm and higher diameter pipes can be designed for working pressures up to 25 kgs/cm^2. Effective length of pipes shall be 4 m to 8 m. Longer length pipes can also be custom made. The manufacturer shall declare the length of pipe for any given design and the tolerance shall be applicable to that.

Manufacture of bar/wire wrapped steel cylinder pipes with mortar lining and coating begins with fabrication of a thin steel pipe cylinder. Thicker steel joint rings are welded at both ends. Each steel cylinder is hydrostatically tested. A cement mortar lining is placed by centrifugal process inside the cylinder. After the lining is cured by steam or water, mild steel rod is wrapped on the cylinder using moderate tension in the bar. The wrapping is to be done under controlled tension ensuring intimate contact with the cylinder. The cylinder and bar wrapping are covered with a cement slurry and a dense mortar coating that is rich in cement. The coating is cured by steam or water.

A welded steel sheet cylinder, which may be with steel socket and spigot rings welded to its ends for rubber ring joints or with steel rings welded to its ends for welded joints, lined with cement mortar centrifugally applied within the steel cylinder and spigot ring, with reinforcement consisting of continuous steel bar/wire helically wound around the outside of the cylinder and securely fastened by welding to the steel socket and spigot/joint rings, and subsequently coated with dense cement mortar covering the steel cylinder and bar/wires except for necessarily exposed socket and spigot joints rings. Figure 11.24 shows typical longitudinal section.

The wall thickness shall not be less than the design thickness by more than 5 per cent or 5 mm whichever is greater. The manufacturer shall declare the wall thickness for any given design. Tolerance on length of pipe shall be +2.5 per cent and -1 per cent of the specified length. The cement mortar coating shall provide a minimum cover of 19 mm over the bar/wire reinforcement or 25 mm over the cylinder, whichever is greater (as per IS 15155:2020).

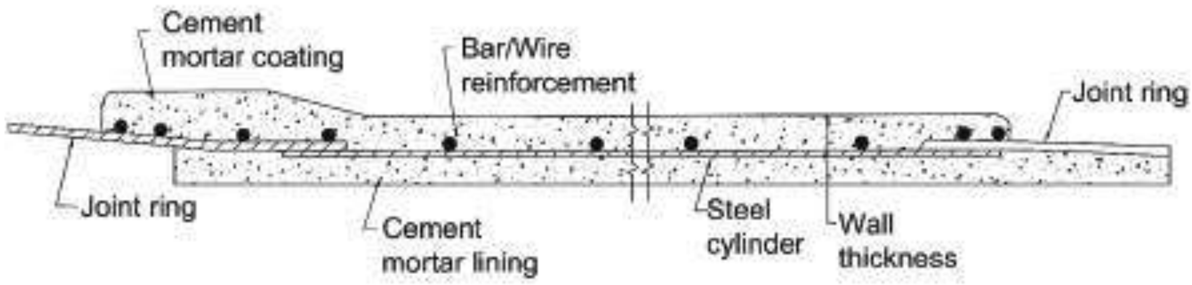


Figure 11.24: Typical Longitudinal Section

The purchaser may specify the application of an external or internal bituminous epoxy or other approved coating to be applied. When the pipes are to be used for carrying potable water, the inside lining shall not contain any constituents soluble in such water or any ingredient which could impart any taste or odour to the potable water.

11.9.2 Laying and Jointing

The standard joint consists of steel joint rings and a continuous solid rubber ring gasket. The field joint can be overlapping/sliding, butt welded or with confined rubber ring as per the client’s requirement. In the case of welded and rubber joints, the exterior joint recess is normally grouted, and the internal joint space may or may not be pointed with mortar. These pipes can be laid in black cotton soil with additional precautions in bedding.

11.9.3 Testing of Pipelines

The pressure testing of BWSC pipes is the same as mentioned above at testing of the pipeline section under cast iron pipe. However, the quantity of water added in order to re-establish the test pressure should not exceed three litres (instead of 0.1 litres) per mm dia. per km per 24 hours per 30 m head as per the (IS 783:1985, Reaffirmed 2022).

The field test pressure shall be maintained for one hour. If the visual inspection indicates that there is no leakage, the test can be passed.

11.9.4 Advantages and Disadvantages

The advantages of pipe are:

- Pipes are having semi-rigid or semi-metallic properties and resistant to impact.
- Stiffer than conventional steel pipes.
- Corrugated surface increases its structural stability.

The disadvantages of the pipe are:

- Heavier than pipes like DI, HDPE, PVC, GRP pipes which makes it difficult to handle.
- Rough handling may damage the outer coat or inner lining.

11.10 Plastic Pipes

Plastic pipes are produced by extrusion process followed by calibration to ensure maintenance of accurate internal diameter with smooth internal bores. These pipes generally come in lengths of 6 metres. A wide range of injection moulded fittings, including tees, elbows, reducers, caps, pipe saddles, inserts and threaded adapters for pipe sizes up to 200 mm are available.

In house installations, plastic pipes cannot be used for electrical earthing being a non-conductive material. In colder climates, plastic pipes cannot be softened by conventional and electric equipment. Where pumps are used with plastics pipes, starting, and stopping are the occasions when damage may occur. The water hammer causes compression of the water in the pipe and consequently results in stretching of the pipe and where necessary, pressure relief devices should be included in the pipelines. Accurate records of laying of plastic pipes are very essential as they cannot be located by conventional electronic pipe locators.

In order to take care of the possible deteriorating effect by direct sunlight, it should be prevented by direct exposure to sunlight. For carefully executed installations using properly manufactured plastic pipes, no taste and odour problems should normally be encountered while in operation. The quality of plastic pipes should also be checked for its suitability from a bacteriological point of view.

11.10.1 PVC Pipes

11.10.1.1 General

The PVC pipes are much lighter than conventional pipe materials. Because of their lightweight, PVC pipes are easy to handle, transport, and install. 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 burned 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 AC. Thermal conductivity of PVC is very low compared to metals. Consequently, water transported in these pipes remains at a more uniform temperature.

Rigid PVC pipes weigh only one-fifth of conventional steel pipes of comparable sizes. PVC pipes are available in sizes of outer dia. 20, 25, 32, 50, 63, 75, 90, 110, 140, 160, 250, 290, and 315 mm at working pressures of 2, 5 ,4, 6, 10 Kg/cm^2 as per IS 4985 – 1988, Reaffirmed 2015. The wall of the plain pipe shall not transmit more than 0.2 per cent of the visible light falling on it when tested in accordance with IS 12235 (Part 1-19): 2004, Reaffirmed 2019.

Since deterioration and decomposition of plastics are accelerated by ultraviolet light and frequent changes in temperature which are particularly severe in India, it is not advisable to use PVC pipes above ground. The deterioration starts with discolouration, surface cracking, and ultimately ends with brittleness, and the life of the pipe may be reduced to 15–20 years.

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 storing to prevent damage to the pipes. Under no circumstances should the pipes be dragged along the ground. Pipes should be given adequate support at all times. These pipes should not be stacked in large piles, especially under warm temperature conditions, as the bottom pipes may be structurally distorted thus increasing the 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, and free from loose stones. Pipes stored thus 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. It is advisable to follow the practices mentioned as per IS 7634 (Part 1): 1975, Reaffirmed 2017 and IS 7634 (Part 3):2003, Reaffirmed 2018.

11.10.1.2 Laying and Jointing

A. Laying

The trench bottom should be carefully examined for the presence of hard objects such as flints, rocks, projections, or tree roots. In uniform, relatively soft fine-grained soils found to be free of such objects and where the trench bottom can readily be brought to an even finish providing a uniform support for the pipes over their lengths, the pipes may normally be laid directly on the trench bottom. In other cases, the trench should be cut correspondingly deeper and the pipes laid on a prepared under-bedding, which may be drawn from the excavated material if suitable.

The trench bed must be free from any rock projections. The trench bottom, where it is rocky and uneven, a layer of sand or alluvial earth equal to one-third diameter of the pipe or 100 mm, whichever is less, should be provided under the pipes.

As a rule, trenching should not be carried out too far ahead of pipe laying. The trench should be as narrow as practicable. This may be kept from 0.30 m over the outside diameter of pipe and depth may be kept at 0.60–1.0 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 sufficient length has been laid, the trench is filled.

In laying long lengths of pipe, prefabricated double socketed connections are frequently used to join successive pipe lengths of either the same or one different size. The socket in this case must be formed over a steel mandrel. A short length of pipe is flared at both ends and used as the socket connection. The mandrel used is sized such that the internal dia. of the flared socket matches the outer dia. of the spigot to be connected.

If trucks, lorries, or other heavy traffic will pass across the pipeline, concrete tiles 600 × 600 mm of suitable thickness and reinforcement should be laid about 2.0 m above the pipe to distribute the load. If the pipeline crosses a river, the pipe should be buried at least 2.0 m below bed level to protect the pipe. Individual pedestal approach may also be followed in those cases of long stretches of the river. The pipeline may also be laid down attached with the bridge piers across the river.

For bending, the cleaned pipe is filled with sand and compacted by tapping with wooden stick and 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, the sand poured out and the pipe (bend) cooled again. Heating in hot air over hot oil bath, hot gas or other heating devices are also practised. Joints may be heat-welded, flamed, with rubber gaskets, or made with solvent cement. Threaded joints are also feasible, but are not recommended.

11.10.1.3 Jointing

A socket and spigot joint is usually preferred for all PVC pipes up to 150 mm in dia. The socket length should at least be one and a half times the outer dia. for sizes up to 100 mm dia., and equal to the outer dia. for larger sizes.

Jointing of PVC pipes can be made in following ways:

(i) Solvent cement
(ii) Rubber ring joint
(iii) Flanged joint
(iv) Threaded joint

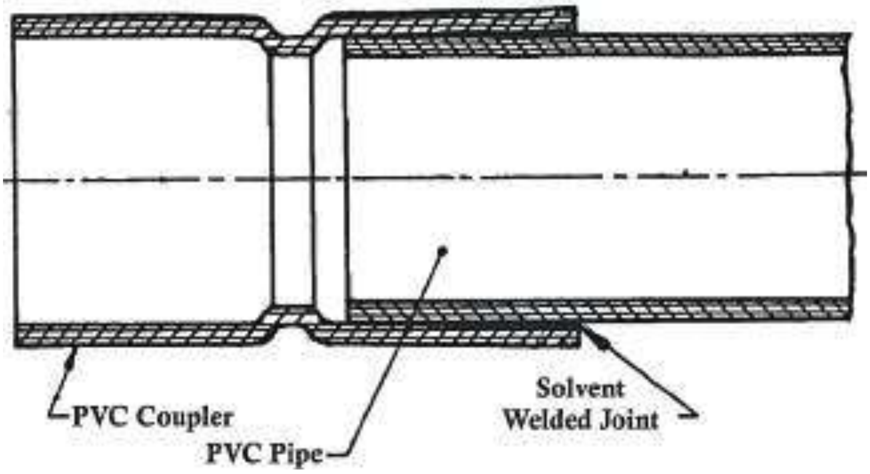


Figure 11.25: PVC Solvent Welded Joint

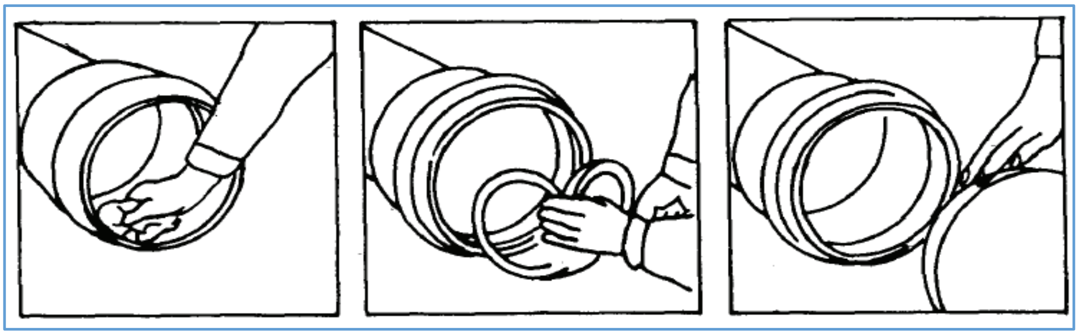


Figure 11.26: Sealing Ring Joint Assembly

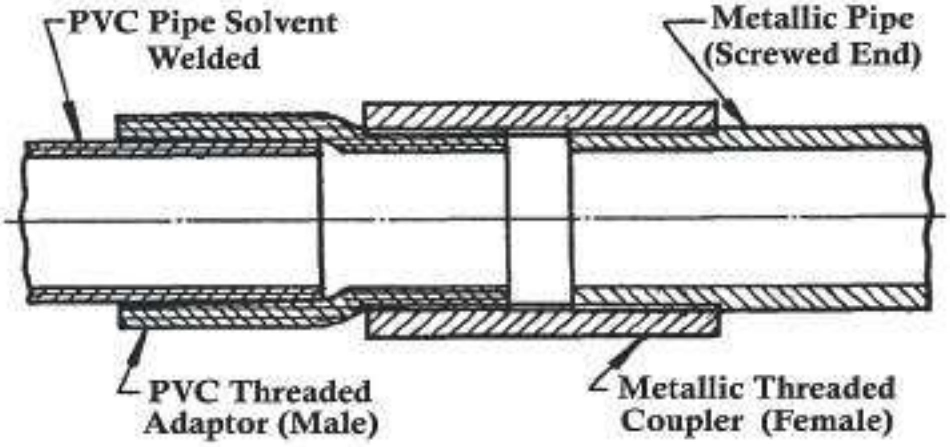


Figure 11.27: Threaded Joints with PVC

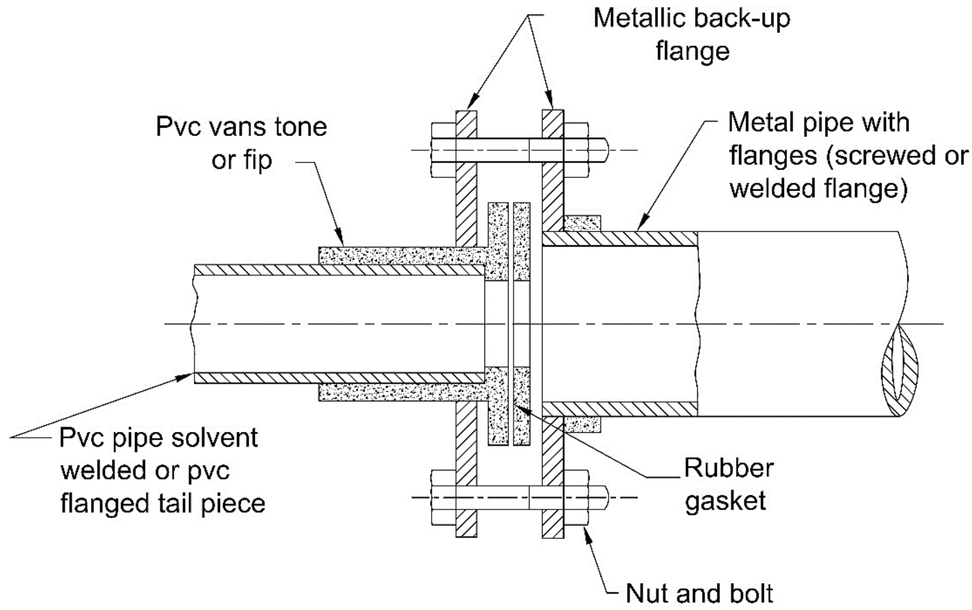


Figure 11.28: Flanged Joints with PVC

The Figure 11.25 above shows PVC solvent welded joint, Figure 11.26 shows sealing ring joint assembly, Figure 11.27 shows threaded joints with PVC, and Figure 11.28 shows flanged joints with PVC.

For pipe installation, solvent gluing is preferable to welding. The glued spigot socket connection has greater strength than can ever be achieved by welding. The surfaces to be glued are thoroughly scoured with dry cloth and preferably chamfered to 30^o. If the pipes have become heavily contaminated by grease or oil, methylene cement is evenly applied with a brush to the outside surface of the spigot on one pipe, and to the inside of the socket on the other. The spigot is then inserted immediately in the socket up to the shoulder and thereafter, a quarter (90^o) turn is given to evenly distribute the cement over the treated surface. The excess cement which is pushed out of the socket must be removed at once with a clean cloth. Jointing must be carried out in minimum possible time; time of making complete joint not being more than one minute. Joints should not be disturbed for at least five minutes. Half strength is attained in 30 minutes and full in 24 hours. Gluing should be avoided in rainy or foggy weather, as the colour of glue will turn cloudy and milky as a result of water contamination.

Normally, PVC pipes should not be threaded. For the connections of PVC pipes to metal pipes, a piece of a special thick wall PVC connecting tube threaded at one end is used. The other end is connected to the normal PVC pipe by means of a glued spigot and socket joint. Before installation, the condition of the threads should be carefully examined for cracks and impurities. Glue can be used for making the joints leak proof. Yarn and other materials generally used with metal pipe and fittings should not be used. Generally, it is advisable to use PVC as the spigot portion of the joint.

For further details on laying and jointing of PVC pipes, reference may be made to IS 4985 -2000, Reaffirmed 2015, IS 7634 (Part 1):1975 Reaffirmed 2017, IS 7634 (Part 2): 2012, Reaffirmed 2017 and IS 7634 (Part 3):2003, Reaffirmed 2018.

Testing of pipelines

The pressure testing method, which is commonly in use, is filling the pipe with water, taking care to evacuate any entrapped air and slowly raising the system to appropriate test pressure. The pressure testing may be followed as same as mentioned above at testing of the pipeline section under cast iron pipe.

After the specified test time has elapsed, usually one hour, a measured quantity of water is pumped into the line to bring it to the original test pressure if there has been loss of pressure during the test. The pipe shall be tested as per para. 11.1 of IS 4985 (2021).

Advantage and Disadvantage

The advantages of pipe are:

- Resistance to corrosion,
- Lightweight,
- Toughness,
- Rigidity,
- Ease of laying, jointing, and maintenance,
- Ease of fabrication.

The disadvantages of pipe are:

- Deteriorating effect by direct sunlight,
- Water hammer causes stretching of the pipe,
- Non-conductive material.

11.10.2 Unplasticized Polyvinyl Chloride (UPVC) Pipes

11.10.2.1 General

The UPVC pipe is a plastic pipe made of polyvinyl chloride (PVC) resin and containing no plasticiser. Plastics belong to the group of newer pipe materials. With the development of chemical industry technology, it is possible to produce non-toxic grade pipes, so it has the function of usually polyvinyl chloride, and it has added some excellent functions, specifically its corrosion resistance and softness, so it is especially suitable for water supply networks. UPVC pipes are highly economical in comparison to pipes made from other materials. Plastic pipes offer high corrosion resistance to aggressive chemical media. Moreover, due to very smooth surfaces, the pipes are not prone to crust formation on the internal surface, which can have a detrimental effect on the water carrying capacity of the pipe. The pipes shall not have any detrimental effect on the composition of water flowing through them.

Pipes made from cast iron, fabricated steel and other materials are in use for a long time in various applications. Pipes for supplying drinking water are mostly made of polyethylene (PE) or polyvinyl chloride (PVC). Unplasticized PVC pipes are greatly used for transportation of water. It is an extruded product from a blend of polymer resin and various additives.

11.10.2.2 Laying and Jointing

A. Laying

Prolonged exposure of the pipes to sunlight must be avoided. Pipes must be protected from ultraviolet light (sunlight), which would otherwise cause discolouration and can reduce the impact strength of the pipe.

The depth of the trench shall be minimum 1.0 m. The width of the trench should be uniform throughout the length and greater than the outside diameter of the pipe by 300 mm on either side of the pipe. It should be ensured that the pipe have been laid along the central line of the trench. The trench bottom shall be constructed to provide a firm, stable, and uniform support for the full length of the pipeline. There should not be any sharp objects on the trench surface while laying the pipeline. Any large rocks, hard pan, or stones larger than 20 mm should be removed to permit a minimum bedding thickness of 100–150 mm under the pipe.

Place the pipe and fittings into the trench using ropes or by hand or mechanical means. The pipes should not be thrown into the trench or allow any part of the pipe to take an unrestrained fall onto the trench bottom.

Laying of the pipes in the trench should happen after ensuring that bell holes have been provided for at the appropriate places in the bedding (pipes of diameter 110 mm or less, with no live load application, do not require bell holes in the trench bottom). The trenches should be refilled carefully after testing of the pipeline. The pipes should be laid with the spigots entered into the sockets in the same direction as the intended flow of water.

B. Jointing

Commonly used joints are (i) Solvent welded joints; (ii) Elastomeric sealing ring joints; (iii) Mechanical compression joints; (iv) Flanged joints; (v) Screwed or threaded joints; and (vi) Union coupled joints.

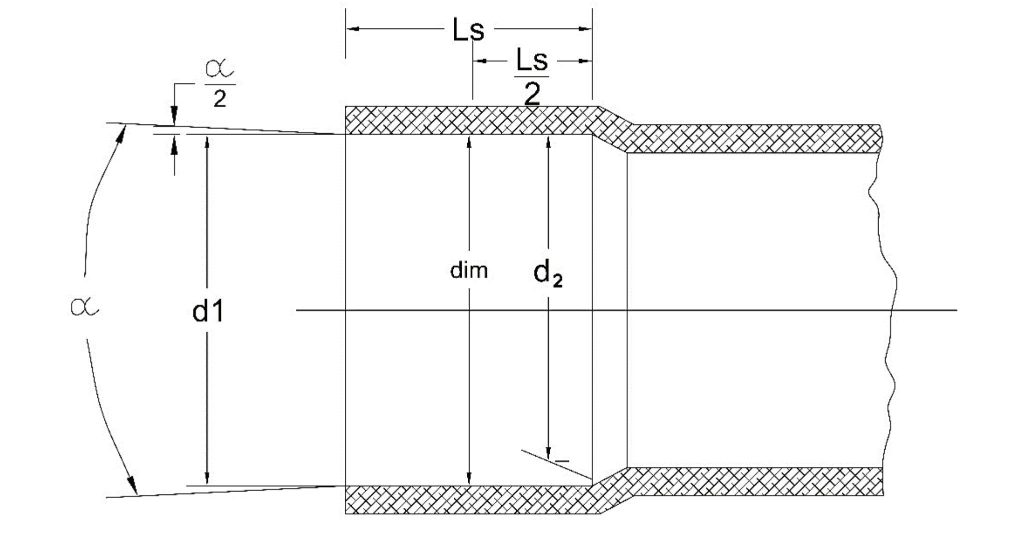
Sockets formed on the ends of the pipes shall be reasonably parallel to the axis of the pipe. The minimum length of any socket shall be given by the expression. Figure 11.29 shows socket dimensions for solvent cement joints and Figure 11.30 shows sockets for use with elastomeric sealing rings.

$$L_s = 0.5dn + 6mm \tag{11.3}$$

Where

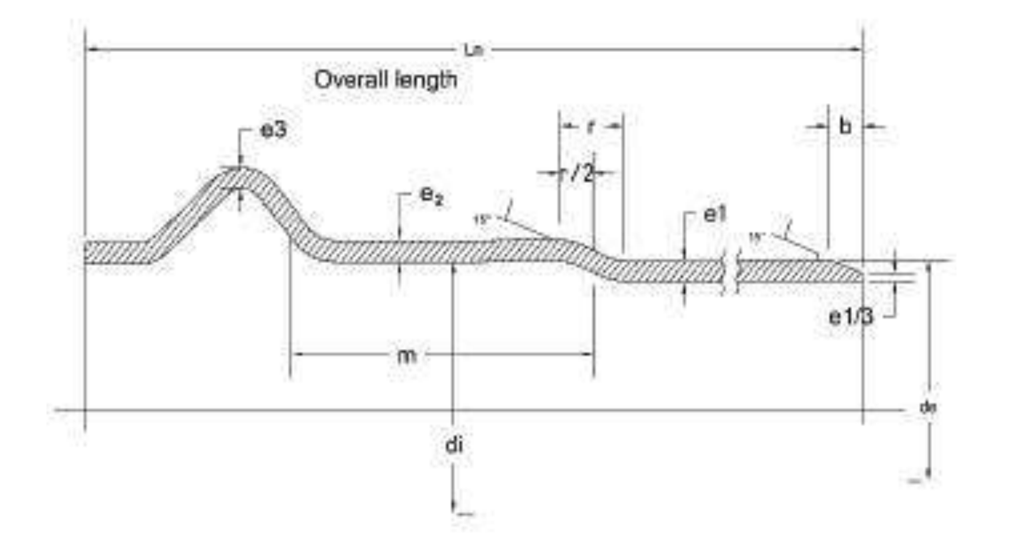
L = minimum socket length, and

dn = nominal outside diameter of the pipe.



Where:
d_{im} = diameter at mid-point of socket length;
d_1 = diameter at mouth;
d_2 = diameter at root;
L_s = socket length; and
α = total included angle of taper

Figure 11.29: Socket Dimensions for Solvent Cement Joints



Where:
m = minimum depth of engagement;
d_e = outer diameter at any point; and
d_i = inner diameter of socket, measured at mid-point of socket length, m

Figure 11.30: Sockets for use with Elastomeric Sealing Rings

The ends of the pipes meant for solvent cementing (both plain and bell ended) shall be cleanly cut and shall be reasonably square to the axis of the pipe or may be chamfered at the plain end. Pipes with plain end(s) to be used for elastomeric sealing ring-type joints shall be chamfered at approximately 15° to the axis of the pipe. Approximately two-thirds of the full wall thickness shall be chamfered.

11.10.2.3 Testing of pipelines

Pressure testing method which is commonly in used is filling the pipe with water, taking care to evacuate any entrapped air, and slowly raising the system to appropriate test pressure. The pressure testing may be followed as mentioned in IS 4985.

11.10.2.4 Advantages and Disadvantages

The advantages of pipe are:

- Very lightweight,
- Easy to install,
- Good corrosion resistance and cheap in cost,
- Smooth surface reduces friction losses,
- Long pipe sections reduce leakage/infiltration potential,
- Flexible.

The disadvantages of pipe are:

- Susceptible to chemical attack especially solvents,
- Strength affected by sunlight,
- Not suitable for above ground installations,
- Require great care during laying,
- Susceptible to damages due to external pressure and blows in above ground level application.

11.10.3 Oriented Polyvinyl Chloride (OPVC) Pipes

11.10.3.1 General

Amorphous polymer of PVC in which the molecules are located randomly. However, under certain conditions of pressure, temperature, and speed by stretching the material, it is possible to orient the polymer molecules in the same direction. The result is a plastic with a layered structure known as oriented polyvinyl chloride pipes of highest orientation class 500, with homogeneous socket elastomeric sealing ring.

It is a new technology for manufacturing pipes, which involves process of controlling circumferential and axial orientation of the molecular structure resulting in the formation of laminar structure of the material used in the pipe construction, commonly named as oriented polyvinyl chloride (OPVC). It is manufactured as per Indian Standard IS 16647: 2017 (Reaffirmed 2022) – Oriented Unplasticized Polyvinyl Chloride (PVC-O) Pipes for Water Supply –Specification. This standard specifies the requirements of oriented unplasticized polyvinyl chloride (PVC-O) pipes, for piping systems intended to be used underground, or above ground, but not exposed to direct sunlight, for water supply.

Oriented pipes made from a defined PVC-U compound and with a well-defined orientation level in circumferential and axial direction, shall be evaluated according to the procedures specified in ISO 16422/ISO 9080 on the basis of tests given in 9.1.1 (see also 5.6.3).

Testing of compound mix used in manufacturing of pipes for its conformity for minimum required strength requirements, which require testing time of 10,000 hrs., is not covered in the IS 16647: 2017 (Reaffirmed 2022) due to the limited testing facility available, at present, in the country. The manufacturers have to ensure this before supplying pipes.

The piping system is intended for the conveyance of water, including potable water, up to and including 45 °C. The pipes are manufactured for different sizes in India, i.e., 110 mm, 160 mm, 200 mm, 250 mm, 315 mm, and 400 mm with pressure ratings of PN 12.5, PN 16, PN 20, and PN 25. The pipes are recommended for water temperatures ranging from 1 °C to 45 °C. At temperatures higher than 27 °C and up to 45 °C, the strength of the pipe reduces and working pressure shall therefore be modified using the derating factor as obtained from the graph given in Annexure B of IS 16647:2017 (Reaffirmed 2022).

The material from which the pipe is produced shall consist substantially of unplasticized polyvinyl chloride to which may be added only those additives that are needed to facilitate the manufacture of the pipe and the production of sound and durable pipe of good surface finish, mechanical strength, and opacity under conditions of use. Store the pipes horizontally on a flat surface and place supports every 1.5 m to avoid the bending of the product. Do not stack pipes more than 1.5 m height, as this can damage lower pipes or even the upper pipes can fall. In case of prolonged sun exposure, protect pallets with an opaque material. White colour is preferable as it avoids overheating of the pipes.

11.10.3.2 Laying and Jointing

When checked without a magnification glass, the internal and external surfaces of the pipe shall be smooth, clean, and free from scoring, cavities, and other surface defects. The ends of the pipe shall be either cut cleanly and reasonably square to the axis of the pipe or chamfered at the plain end at approximately 15° to the axis of the pipe. The pipes shall be supplied with the length not less than the declared nominal pipe length. It is recommended that the nominal pipe length to be supplied may be 6 m, 10 m, and 12 m. The pipes may be supplied in other lengths where so agreed upon between the manufacturer and the purchaser.

Before placing the pipe, a sand bed should be prepared (a fine granular material may be used instead of sand) with a thickness from 10 cm to 15 cm. The pipe should be well aligned and levelled. The trench shall be free of stones at the bottom and at the sides. Stones smaller than 10 - 20 mm are allowed, but it cannot be the main size of the ground particles. The pipe shall lie on the sand bed. Once the pipe is placed, chamberlain sides shall be filled with the selected material and compacted to achieve >95 per cent proctor normal (PN). The trench shall be filled with the selected material and compacted laterally until the upper part of the pipe is buried at least 30 cm. Minimum width of the trench based on nominal diameter of pipes to be laid and/or depth of trench is specified in IS 16647: 2017. As a rule of thumb, when there is no road traffic involved, the pipe's crown will be at a minimum depth of 0.6 m; with road traffic, the minimum depth is 1.0 m.

Assembly details are as under:

a) Remove the protection caps, if any.
b) Verify that the pipe is clean and in good condition. Paying attention to the sockets and spigot ends.
c) Check that the chamfer is correct and free of cracks.
d) Verify that the seal is in its place, clean and free of foreign materials (stones, sand, etc.).
e) Lubricate the chamfer of the spigot and the seal with joint lubricant.
f) Line up the pipe as much as possible, horizontally and vertically.
g) Insert only the chamfer edge of the socket, just to support the pipe but leaving the socket lip free.
h) In the case of pipes with a nominal diameter of ≤250 mm, a firm and dry push should be given to seize the momentum produced by the free movement in the lip of the socket and introduce it until the mark is hidden into the socket.
i) When installing diameters >250 mm, one should use mechanical means to introduce the pipe using materials such as wood, hoists, tackles, or slings.

11.10.3.3 Testing of pipelines

Testing shall be performed only after the pipeline has been properly filled, flushed, and purged of all air. The specified test pressure shall be applied by means of an approved pumping assembly connected to the pipe properly and to prevent pipe movement, the contractor shall have placed enough backfill prior to filling and testing of the pipe. If necessary, the test pressure shall be maintained by additional pumping for the specified time during which the system and all exposed pipe, fittings valves, and hydrants shall be carefully examined for leakage. All visible leaks shall be stopped. All defective elements shall be repaired or removed and replaced. The test shall be repeated until the test requirements have been met. Pressure testing method, which is commonly in use, is filling the pipe with water, taking care to evacuate any entrapped air and slowly raising the system to appropriate test pressure. The pressure testing may be followed as mentioned in IS 16647: 2017 (Reaffirmed 2022) - Oriented Unplasticized Polyvinyl Chloride (PVC-O) Pipes for Water Supply.

Resistance to hydrostatic pressure shall be verified using the induced stresses derived from the analysis of the test data in accordance with IS 16462: 2016 (Reaffirmed Year: 2021) Plastic Piping and Ducting Systems – Determination of the Long-Term Hydrostatic Strength of Thermoplastics Materials in Pipe Form by Extrapolation. For a period of 10 hrs. at 27 °C and 1000 hrs. at 27 °C, the 99.5 per cent LPL value shall be taken as the minimum stress level. The test shall be carried out not earlier than 24 hrs. after the pipes have been manufactured (IS 16462: 2016 (Reaffirmed Year: 2021) Plastic Piping and Ducting Systems- Determination of the Long-Term Hydrostatic Strength of Thermoplastics Materials in Pipe Form by Extrapolation).

11.10.3.4 Advantages & Disadvantages

The advantages of pipe are:

- Light in weight and easy to handle.
- The high flexibility of the pipes enables withstanding large deformations without suffering structural damages.
- PVC-O is immune to corrosion so it does not require any coating or special protection.

- These pipes can endure higher internal pressures than other PVC pipes.
- The lower celerity figure of the pipes virtually eliminates the possibility of breakages that can occur during the process of opening/closing valves or when starting pumping operations.

The disadvantages of pipe are:

- Susceptible to chemical attack especially solvents.
- As OPVC pipe reduces its strength due to direct sunlight, the pipes shall be stacked with proper covered storage and shall not be used above ground installations.
- For OPVC fittings, no BIS is available at present.
- OPVC pipes shall not be used in rocky strata without proper special bedding. At present, there is no BIS specification for rocky areas.

11.10.4 Chlorinated Polyvinyl Chloride (CPVC) Pipes

11.10.4.1 General

The material from which the pipe is produced shall consist substantially of chlorinated polyvinyl chloride (CPVC) to which may be added only those additives that are needed to facilitate the manufacture of the pipe and the production of a sound and durable pipe of good surface finish, mechanical strength, and opacity under conditions of use.

The CPVC polymer from which the pipe compound is to be manufactured shall have chlorine content not less than 66.5 per cent. The CPVC pipe compounds containing additives such as modifiers, lubricants, fillers, etc., from which the pipes are to be manufactured, shall have a density between 1450 kg/m^3 and 1650 kg/m^3, when tested in accordance with IS 15778 2007, Reaffirmed 2022.

The outside diameter at any point shall be measured according to the method given in IS 12235 (Part 1): 2004, Reaffirmed 2019.

BIS IS 15778: 2007, Reaffirmed 2022- class 7.1.1 mentions that the permissible variation between the outside diameter at any point (de) and the nominal diameter (da) of a pipe (also called tolerance on ovality) shall not exceed the greater of the following two values:

(a) 0.5 mm, and
(b) 0.012 d_n mm rounded off to the next higher 0.1 mm, where d_n is the nominal diameter of pipe in mm.

The wall of the plain pipe shall not transmit more than 0.1 per cent of the visible light falling on it when tested in accordance with IS 12235 (Part 3): 2004, Reaffirmed 2019. The ends of the pipes meant for solvent cementing shall be cleanly cut and shall be reasonably square to the axis of the pipe or maybe chamfered at the plain end.

11.10.4.2 Laying and Jointing

CPVC pipes of all sizes are packed in polyethylene packing rolls and both the ends of the packed rolls are sealed with air bubble film cap in order to provide protection during handling and transportation. Visually inspect pipe ends before making the joint. The use of a chamfering tool will help identify any cracks by catching on to them.

Pipe may be cut quickly and efficiently by several methods. Wheel-type plastic tubing cutters are preferred. A ratchet-type cutter or fine-tooth saw are other options. However, when using the ratchet cutter, be certain to score the exterior wall by rotating the cutter blade in circular motion around the pipe. Do this before applying significant downward pressure to finalise the cut. This step leads to a square cut. Cutting tubing as squarely as possible provides optimal bonding area within a joint.

When making a joint, apply a heavy, even coat of cement to the pipe end. Use the same applicator without additional cement to apply a thin coat inside the fitting socket. Do not allow excess cement to puddle in the fitting and pipe assembly. This could result in a weakening of the pipe wall and possible pipe failure when the system is pressurised.

When making a transition connection to metal threads, use a special transition fitting or CPVC male threaded adapter whenever possible. Do not over torque plastic threaded connections. Hand tight plus one-half turn should be adequate. Hang or strap CPVC systems loosely to allow for thermal expansion. Do not use metal straps with sharp edges that might damage the tubing.

Testing of Pipeline

When subjected to internal hydrostatic pressure test in accordance with the procedure given in IS 12235 (Part 8): 2004, Reaffirmed 2019, the pipe shall not fail during the prescribed test duration. The temperatures duration and hydrostatic (hoop) stress for the test shall conform as per IS 12235 (Part 8): 2004, Reaffirmed 2019, the test shall be carried out not earlier than 24 hrs. after the pipes have been manufactured.

11.10.4.3 Advantages and Disadvantages

The advantages of pipe are:

- Lightweight and easy for transportation;
- Requires fewer tools for installation and maintenance;
- Lack of plasticisers which discourages microbial growth;
- Corrosion and abrasion resistance;
- Reground into pellets and recycled; and
- Reduces heat loss due to lower thermal conductivity.

The disadvantages of pipe are:

- High thermal expansion coefficient.

11.10.5 Polyethylene (PE) Pipes

11.10.5.1 General

The IS 4984 (2016, Reaffirmed 2021) – PE pipes for water supply, lays down the requirements for polyethylene (PE) pipes (mains and service pipes) intended for the conveyance of water for human consumption including raw water prior to treatment and also water for general purpose. This standard is applicable for the water supplies with a maximum operating pressure of 2.0 MPa.

As polyethylene pipes are designated by their minimum required strength (MRS), the earlier nomenclature of high-density polyethylene pipes has been renamed as polyethylene pipes and accordingly, the title of the standard has also been modified. Pipes shall be classified according to the grade of the raw material (resin) as PE 63, PE 80, PE 100. The pipe sizes are 16 mm to 2000 mm dia.

These pipes are not brittle, and as such, a hard fall at the time of loading and unloading, etc. may not do any harm to it. Polyethylene is a tough resilient material which may be handled easily. Abrasion resistance is much higher compared to metal or concrete pipes. However, because it is softer than metals, it is prone to damage by abrasion and by objects with a cutting edge. The pipes are highly resistant to notches and scratches and therefore widely used in trenchless installation like horizontal direction drilling (HDD) where damage possibility is very high, apart from joint integrity.

Polyethylene pipes incorporated with 2–2.5% of finely dispersed carbon black, have unlimited resistance against sunlight, and can deliver lifetime service above ground. HDPE materials have excellent resistance against strong acids, alkalis, salts, and most chemicals, which are commonly packed in HDPE drums and barrels. They do not undergo galvanic corrosion, hence, there is no need for any coating or cathodic protection. As there is no corrosion, the water quality in PE pipes is most secured as corrosion products do not get added to it.

11.10.6 High Density Polyethylene (HDPE) Pipes

11.10.6.1 General

HDPE pipe is a type of flexible plastic pipe used for water supply systems. It is made from the high density polyethylene which is suitable for high-pressure pipelines and is available upto 2500 mm dia. (IS 4984: 2022).

The material used for the manufacture of pipes should not constitute toxic hazard, should not support microbial growth, and should not give rise to unpleasant taste or odour, cloudiness, or discolouration of water. The percentage of antioxidant used shall not be more than 0.3 per cent by mass of finished resin.

Among the recent developments is the use of high density polyethylene pipes. These pipes are not brittle and as such a hard fall at the time of loading and unloading, etc., may not do any harm to it. HDPE pipes (IS 4984: 2016) can be joined with detachable joints and can be detached at the time of shifting the pipeline from one place to another. Though for all practical purposes, HDPE pipes are rigid and tough. At the same time, they are also resilient and conform to the topography of land when laid over ground or in trenches (Refer ISO 1427-2:2019). They can withstand movement of heavy traffic. This would not cause damage to the pipes because of their flexural strength.

HDPE pipes are non-susceptible for tracing instruments because of its inertness. Copper or metallic conductor-extruded HDPE pipes have also been developed to increase the traceability of pipes (by instruments) when buried underground.

11.10.6.2 Laying and Jointing

A. Laying

The pipeline may be laid alongside of the trench and jointed there outside of it. Hence, the trench size is relatively small (no man entry trench is needed), which saves lot of civil work, installation time and cost. Thereafter, the jointed pipeline shall be lowered into the trench carefully without causing undue bending. The pipeline shall be laid inside the trench with a slack of up to 2 m/100 m of pipeline. The trench depth should be OD+300 mm.

Polyethylene (PE) pipe requires no special bed preparation for laying the pipe underground, sieved, excavated material is good enough, except that there shall be no sharp objects around the pipe. However, while laying in rocky areas, suitable bedding should be provided around the pipe and compacted, as per BIS specifications.

Polyethylene (PE) pipes are non-metallic, so once buried, metal detector-type locators are ineffective. To facilitate locating a buried PE pipe, metallic locating tapes or copper wires can be placed alongside the pipe. Locating tapes/wires are placed slightly above the crown of the above before the final backfill.

B. Jointing

Polyethylene (PE) pressure piping systems jointed by butt welding, electrofusion and flanges do not require external joint restraints or thrust block joint anchors. The HDPE pipe jointing with the use of electrofusion fittings jointing should be done with an electrical resistance element incorporated in the socket of the fitting which, when connected to an appropriate power supply, melts and fuses the materials of the pipe and fitting together. Electrofusion joint can be made with the use of an electrofusion machine, which should operate automatically only by scanning the barcode on fittings. Since this jointing is done at the outer diameter of the pipe and jointing surface area being more, the joint can be strong and leak proof.

The BIS Standard IS 15927: PART 3: 2011 (Reaffirmed Year: 2021) is available for "Polyethylene Fittings for use with Polyethylene Pipes for the Supply of Gaseous Fuels - Part 3 Electro Fusion Fittings". BIS Standard is not available for Electro Fusion Fittings for PE pipes for supply of water. However, EN ISO 12201-3/ISO 4427-3/BIS EN ISO 15494:2003 is available for such fittings. These fittings can be used in water supply line due to its advantages of fusion joints over other mechanical joints. The jointing can be faster, reliable, simple installation, homogenous joint which can be used in restricted trench space.

Commonly used joints are as follows:

- (i) Fusion welding:
  - a) Butt fusion welding; (Figure 11.31)
  - b) Socket fusion welding; (Figure 11.32)
  - c) Electrofusion welding; (Figure 11.33)
- (ii) Insert-type joints; (Figure 11.34)
- (iii) Compression fittings/push fit joints; (Figure 11.35)
- (iv) Flanged joints; (Figure 11.36)
- (v) Spigot and socket joints.

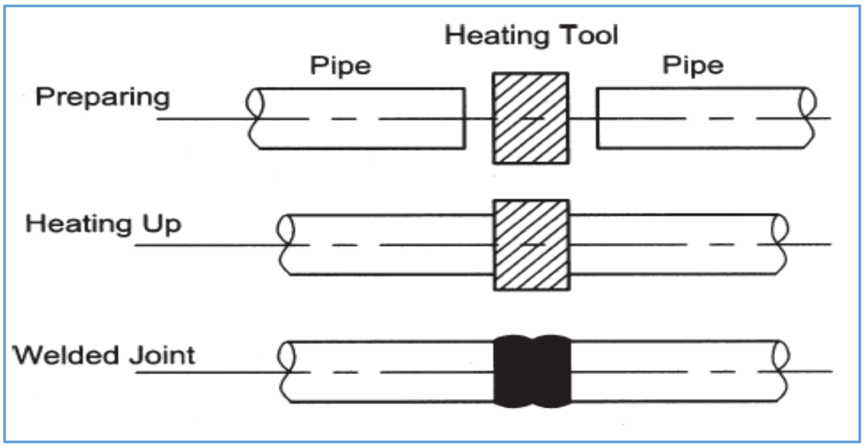


Figure 11.31: Butt Fusion Welding Procedure

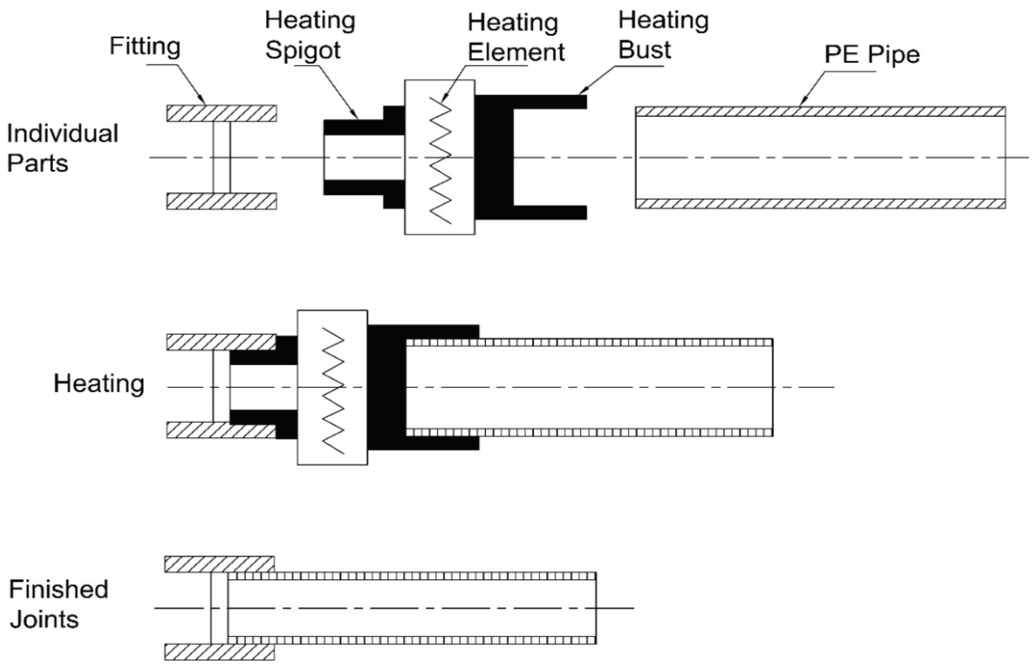


Figure 11.32: Socket Fusion Jointing Procedure

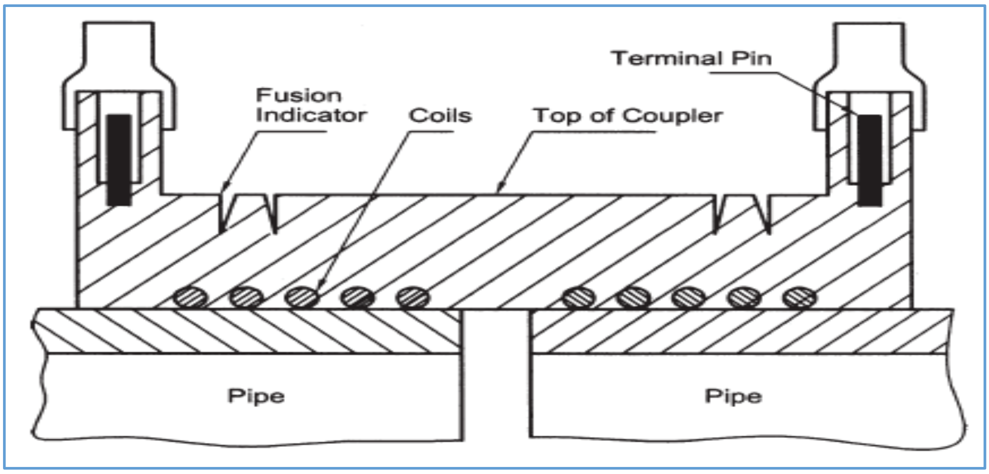


Figure 11.33: Electrofusion Process

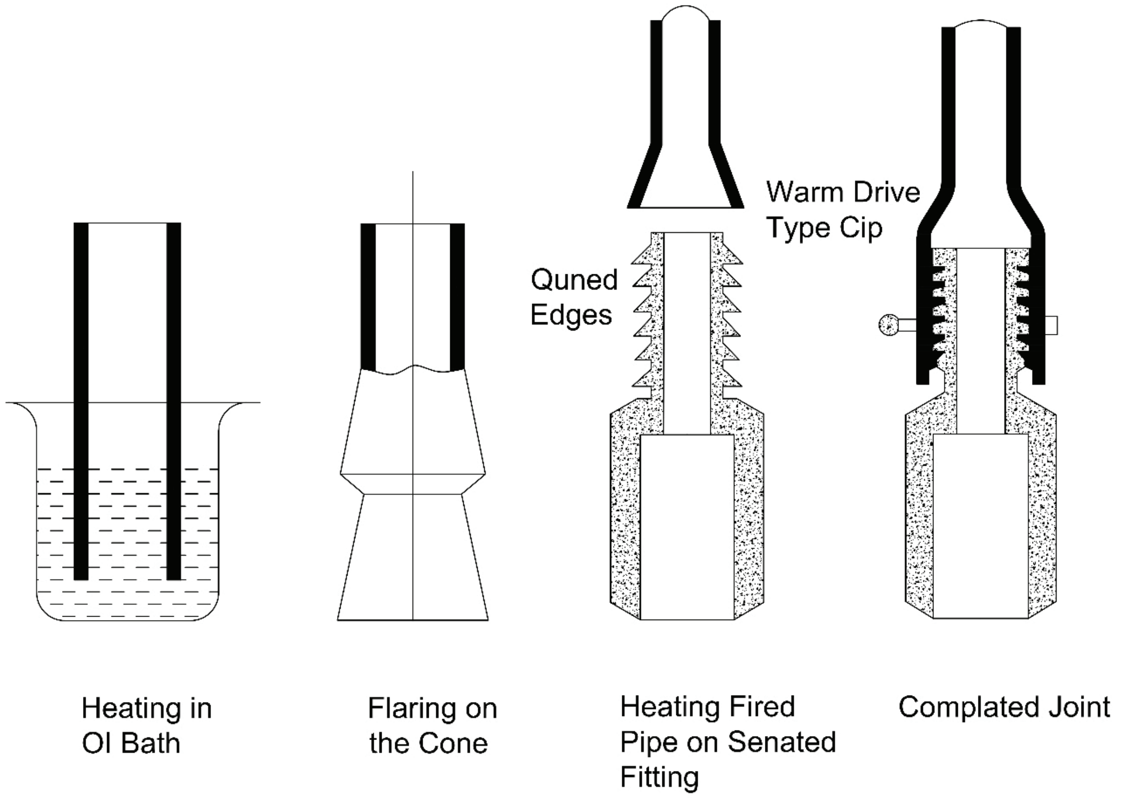


Figure 11.34: Insert-Type Joints

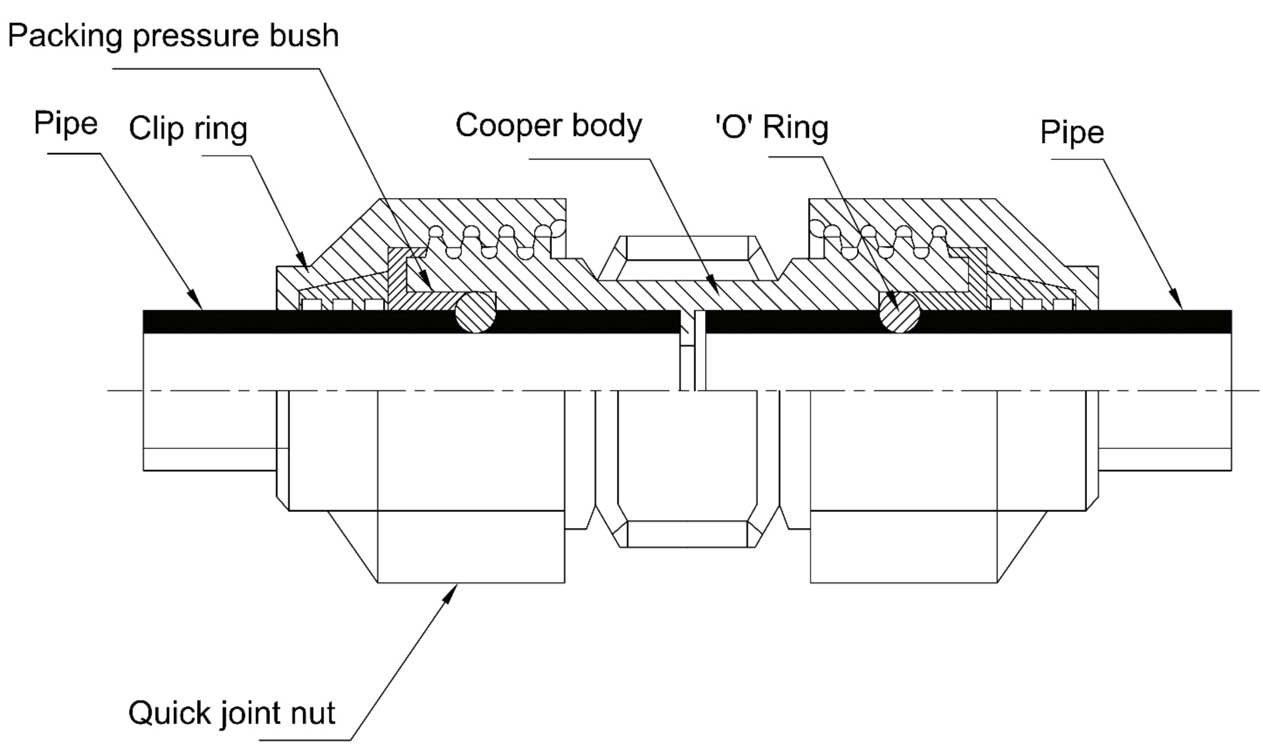


Figure 11.35: Polypropylene Compression Coupler Socket

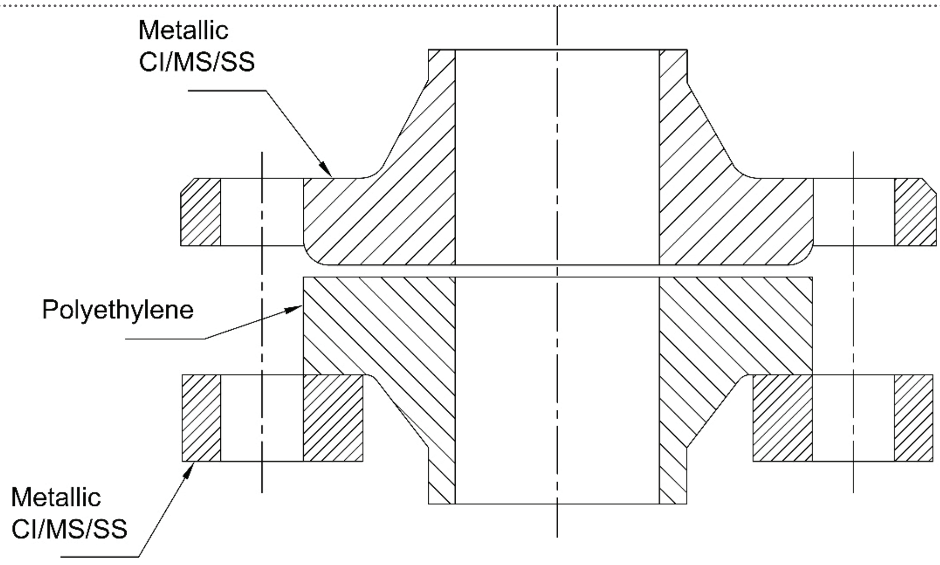


Figure 11.36: Typical Flanged Joint

PE Fittings

Polyethylene pipe fittings are covered under BIS code IS 8008:2022 – Injection Moulded/Machined Polyethylene Fittings for Water Supply-Specification and IS 8360:2022 – Fabricated Polyethylene Fittings for Water Supply-Specification, which may be referred to and used for connecting the pipes and other system appurtenances. These fittings can also be used for connecting to metallic valves (sluice, scour, and air), tanks, pipes, and other mechanical equipment (pumps, etc). However, where there is a likelihood of vibrations and turning torques in such connections, the fitting wall thickness shall be a minimum of one rating higher than the corresponding pipe.

11.10.6.3 Testing of pipelines

Pressure testing method, which is commonly in use, is filling the pipe with water, taking care to evacuate any entrapped air and slowly raising the system to appropriate test pressure. The pressure testing may be followed as mentioned in

(a) IS 7634: Part 2: 2012 (Reaffirmed Year: 2022) – Plastics Pipes Selection, Handling, Storage and Installation for Potable Water Supplies – Code of Practice Part 2 Laying and jointing of polyethylene (PE) pipes, and
(b) IS 4984: 2016 (Reaffirmed Year: 2021) – Polyethylene Pipes for Water Supply – Specification (Fifth Revision).

11.10.6.4 Advantages and Disadvantages

The advantages of pipe are:

- Lightweight,
- Easy to install,
- Good corrosion resistance,
- Smooth surface reduces friction losses,
- Long pipe sections reduce leakage/infiltration potential,
- Flexible.

The disadvantages of pipe are:

- Susceptible to chemical attack especially solvents,
- For above-ground installations, all components with colours other than black should be protected from direct UV light

11.10.7 Medium Density Polyethylene (MDPE) Pipes

11.10.7.1 General

Medium Density Polyethylene Pipes (MDPE), by definition, have a density between 0.926–0.940 gms/cc. A MDPE grade for pipes should have PE80 pressure classification for conveying potable water. Medium density polyethylene pipes are now being manufactured in India conforming to ISO specifications (ISO 4427 and BS 6730-1986) for carrying potable water. However, BIS is not available for these pipes. The MDPE pipes are being preferably used for consumer connection pipes as an alternative to GI pipes. The polyethylene material does not constitute toxic hazard and does not support any microbial growth. Further, it does not impart any taste, odour, or colour to the water.

MDPE pipes are colour-coded black with blue strips in sizes ranging from 20 mm to 110 mm diameter for pressure class of PN3.2, PN4, PN6, PN10, and PN16. The maximum admissible working pressures are worked out for temperature of 20^0 C (ISO4427: 2019). The pipes are supplied in coils and minimum coil diameter is about 18 times the diameter of the pipe.

MDPE compression fittings made of PP, AABS, UPVC are also available in India for use with MDPE pipes. The materials used for the fittings are also suitable for conveying potable water like MDPE pipes. The jointing materials of fittings consist of thermoplastic resins of Polyethylene-type, NBR 'O' ring of nitrile and clamp of polypropylene, copolymer body, zinc plated steel reinforcing ring, nuts, and balls of special NBR gasket.

The MDPE pipes are lightweight, robust, and non-corrodible and hence, they can be used as alternative material for consumer connections. Since the pipes are supplied in coils, there will be no joints under the roads and bends are avoided resulting in fast, simple, and efficient jointing.

MDPE is a popular material for urban water supply and is lightweight, strong, and flexible. MDPE pipes can be used for:

- Water distribution for town, rural, and irrigation projects,
- Cold water plumbing reticulation,
- Household water connections from the main supply,
- Compressed air lines.

11.10.7.2 Laying and Jointing

MDPE compression fittings made of PP, electrofusion fittings (PE 100), ABS, UPVC are available in India for use with MDPE pipes. The material used for the fittings shall also be suitable for conveying potable water. The joining material of compression fitting consist of virgin thermoplastic resin of polyethylene-type, NBR 'O' ring of nitrile and clamp of Polypropylene, copolymer body, zinc plated steel reinforcement ring, nuts, and balls of special NBR gasket. Push fit compression fittings are typically used for sizes 20–63 mm. The joining material of electrofusion fittings consists of virgin PE 100 material resin for permanent fusion jointing with MDPE pipe.

11.10.7.3 Advantages and Disadvantages

The advantages of pipes are:

- Very smooth inner surface; ensures no scaling and choking.
- Has less friction loss and gives better flow at lower heads.
- Easy to transport and store as the pipes available in 100, 200, and 300 m coils.
- No wastage of pipe as it can be cut to requirement at site.
- Less number of joints as the pipe is flexible and easy to repair.
- Easy tapping with specialty tapping joints.

- Tools-off installation possible with precision made fittings.
- Resistance to inorganic acids, alkalis and salts, hydrocarbon gasses.

The disadvantages of pipe are:

- Susceptible to chemical attack especially solvents.
- Strength may be affected by sunlight.

11.11 Glass Fibre Reinforced Plastic (GRP) Pipes

11.11.1 General

Glass fibre reinforced plastic (GRP) pipes are now being manufactured in India conforming to IS 12709: 1994 (Reaffirmed Year: 2019) – Glass fibre Reinforced Plastic (grp) Pipes Joints and Fittings for Use for Potable Water Supply. Five pressure classes of pipes namely, PN 3, PN 6, PN 9, PN 12, and PN 15 correspond to the working pressure ratings of 3.06, 6.12, 9.18, 12.24, and 15.30 kg/sq. m, respectively. Pipes sizes covered under this IS code are 200 mm to 3000 mm dia. Provisions relating to fittings fabricated from GRP pipes or by moulding process have also been covered.

Stiffness is the prime design criteria in the case of underground pipes. GRP pipe stiffness is classified into four classes, depending on the type of installation, overburden above the crown of the pipe and the soil conditions, GRP pipe stiffness is classified into four classes viz. A, B, C, D. The specials are made out of the same pipe material, i.e., glass fibre reinforced plastic (GRP).

GRP pipes are widely used in other countries where corrosion-resistant pipes are required at reasonable costs. GRP can be used as a lining material for conventional pipes, which are subject to corrosion. These pipes can resist external and internal corrosion whether the corrosion mechanism is galvanic or chemical in nature.

11.11.2 Laying

Pipes shall be supplied in nominal length of 6 m, 9 m, and 12 m. A maximum of 10 per cent of the pipe section may be supplied in random lengths. Lengths other than those specified may be supplied as agreed between the purchaser and the manufacturer. The tolerance on nominal lengths shall be within ±25 mm. Wall thickness shall be measured to an accuracy of 0.1 mm.

The width of the trench at the top of the pipe should not be greater than necessary to provide adequate room for joining the pipe in the trench and for compacting the backfill in the zone of the pipe at the side thereof. If necessary, bell holes are permissible at the joints.

GRP pipes being light in weight, can be easily loaded or unloaded by slings, pliable stripes, or ropes. A pipe can be lifted with only one support point or two support points, placed about 4 metres apart. Excavation of trench and back filling of materials is similar to that in the case of CI and MS pipes.

The surface at the trench grade should be continuous, smooth, and free of big rocks more than 1.5 times the thickness of the pipe if rounded, or more than 1.0 times the thickness of the pipe if they have sharp edges and may cause point loading on the pipe. When ledge rock, hard pan, big rocks, timber, or other foreign materials are found, it is advisable to pad the trench bottom with sand or compacted fine-grained soils at least 150 mm thick so as to provide an adequate foundation.

The pipe should be uniformly and continuously supported through its whole length with firm stable bedding material. Pipe bedding material should be sand or gravel as per the requirements on the backfill material. The bedding should be placed so as to give complete contact between the bottom of the trench and the pipe and backfilling should be compacted to provide a minimum compaction corresponding to 90% maximum dry density. Lift should normally not be greater than 30 cm in height and the height differential on each side of the pipe should be limited to this amount so as to prevent lateral movement of the pipe.

Jointing

All joints installed or constructed in the field shall be assembled only by trained technicians. After the completion of pipe installation at site, the pipeline should be tested for 1.5 times the working pressure for 30 minutes with water. All pipe joints shall be watertight. All joints that are found to leak by observation or during testing shall be repaired and retested.

The pipes are joined as per the following techniques: double bell coupling (GRP) for GRP to GRP, flange joint (GRP) for GRP to valves, CA pipes or flanged pipes, mechanical coupling (steel) for GRP to GRP/steel pipe and butt-strap joint (GRP) for GRP to GRP.

Pipes are joined by using double bell couplings in the following manner:

(i) Double bell coupling grooves and rubber gasket rings should be thoroughly cleaned to ensure that no dirt or oil is present.
(ii) Lubricate the rubber gasket with the vegetable oil-based soap which is supplied along with the pipes and insert it in the grooves.
(iii) With uniform pressure, push each loop of the rubber gasket into the gasket groove. Apply a thin film of lubricant over the gaskets.
(iv) Apply a thin film of lubricant to the pipe from the end of the pipe to the back-positioning stripe.
(v) Lift manually or mechanically the double bell coupling and align with the pipe section.
(vi) Push the coupling onto the pipe by using levers. For a large diameter pipe, the coupling may be pushed mechanically with even force on the coupling ring.
(vii) Apply a thin film of lubricant over the pipe to be pushed into the coupling just assembled until the stripes on the pipe are aligned between the edge of the coupling.

Thus, pipes are coupled together, and the rubber gasket acts as a seal making the joint leak proof. Joint types are normally adhesive bonded, however, reinforced overlay and mechanical types such as flanged, threaded, compressed couplings or commercial/proprietary joints are available.

Unrestrained joints of pipe are capable of withstanding internal pressure but not longitudinal forces.

- Coupling or socket and spigot gasket joints provided with groove(s) either on the spigot or in the socket to retain an elastomeric gasket(s) that shall be the sole element of the joint to provide water tightness.
- Mechanical couplings.

Restrained joints are capable of withstanding internal pressure and longitudinal forces,

- Joints similar to coupling or socket and spigot gasket Joints with supplemental restraining elements;
- Butt Joint – with laminated overlay;
- Socket and spigot – with laminated overlay;
- Socket and spigot – adhesive bonded;
- Flanged; and
- Mechanical.

11.11.3 Testing of Pipeline

Working hydraulic pressure in the system shall not exceed the pressure class of the pipe. When surge pressure is considered, the maximum pressure in the system, due to working pressure plus surge pressure, shall not exceed 1.4 times the pressure class of the pipe. Other type of tests may be referred to IS 12709: 1994, Reaffirmed 2019.

11.11.4 Advantages and Disadvantages

The advantages of pipe are:

- High strength to weight ratio;
- Corrosion-resistant;
- Light weight compared to metallic and concrete pipes; and
- Longer length and hence minimum joints enable faster installation and very less chances of leaks.

The disadvantages of pipe are:

- High material cost;
- Brittle, require careful installation;
- High installation cost;
- Not suitable in rocky stretches and above ground installations.

11.12 House Service Connections

Distributing water with 100% consumer metering is most essential. Hence, consumer metering is necessary. Water supply to a house begins with connection of the service pipe with water supply mains. The Service connection pipe and internal plumbing shall conform to National Building Code or related IS code. The connections shall be made only by licensed plumber and be controlled/ vetted by NRW cell of ULB. Restoration/Reinstatement of the road crossings to its original state after making service connection should be included in the BOQ.

11.12.1 Laying and Jointing

11.12.1.1 Medium density Polyethylene Pipes (MDPE)

Medium density polyethylene pipes (MDPE) are now being manufactured in India conforming to ISO specifications (ISO 4427 and BS 6730 - 1986) for carrying potable water. However, no BIS is available for these pipes. MDPE pipes are being used for consumer connection pipes as an alternative to GI pipes. The polyethylene material used for making the MDPE pipes conforms to PE 80 grade and MDPE pipes when used for conveying potable water does not constitute toxic hazard and does not support any microbial growth. Further, it does not impart any taste, odour, or colour to the water.

MDPE pipes are colour-coded black/blue with blue strips in sizes ranging from 20 mm to 110 mm diameter for pressure class of PN3.2, PN4, PN6, PN10, and PN16. The maximum admissible working pressures are worked out for temperature of 20^0C as per ISO 4427. The pipes are supplied in coils and the minimum coil diameter is about 18 times diameter of the pipe.

MDPE compression fittings made of PE, PP, AABS, UP VC are also available in India for use with MDPE pipes. The materials used for the fittings are also suitable for conveying potable water like MDPE pipes. The jointing materials of fittings consist of thermoplastic resins of Polyethylene-type, NBR 'O' ring of Nitrile and Clamp of Polypropylene, copolymer body, Zinc plated steel reinforcing ring, nuts and balls of special NBR gasket.

The MDPE pipes are lightweight, robust, and non-corrodible and hence, can be used as an alternative material for consumer connections. Since the pipes are supplied in coils, there will be no joints under the roads and bends are also avoided resulting in fast, simple, and efficient jointing.

11.12.1.2 Polyethylene-Aluminium-Polyethylene (PE-AL-PE)

Polyethylene-Aluminium-Polyethylene (PE-AL-PE) conforming to IS-15450-2004 (Revised in 2022), is suitable for HSCs. Multilayer composite pipe delivers new standards of quality in the field of water supply and is being used for HSC pipe as a better alternative. The PE-AL-PE multilayer composite pipe comprises one aluminium layer, tie layers of polymeric adhesive, and inner and outer layers of HDPE. The inner and outer polyethylene layers are bonded to metallic aluminium layer by polymeric adhesive during manufacturing of the pipe. It is light, strong and does not support corrosion. BIS has approved PE-AL-PE. Pipes for dia (outer dia) ranging from 14 mm to 75 mm which may be used in service connection pipes for commercial and industrial establishments and bulk demand for residential complexes/group of households. Figure 11.37 shows a PE-AL-PE pipe.

Figure 11.37: PE-AL-PE Pipe

These pipes have non-corroding thermoplastic layers that resist the most aggressive water conditions and hot soil environments. The PE-AL-PE composite pipe are pressure rated for maximum water pressures of 13.8 Kg/cm^2 at 23 °C, 11 Kg/cm^2 at 60 °C and 6 Kg/cm^2 at 80°C. With a Hazen-Williams flow coefficient of C-150, these pipes will not corrode or allow algae build-up inside the pipe which may increase friction losses. Long-term pressure rating of these pipe includes safety factor of 2:1. Hence, the PE-AL-PE pipes easily handles pressure increases created by surges in a water service application. Figure 11.38 shows Jointing of PE-AL-PE pipe.

The PE-AL-PE pipe has resistance to chlorine attack than other non-composite pipes because of the aluminium middle layer. These pipes are lightweight, robust, and non-corrodible and hence, can be used as alternative material for consumer connections.

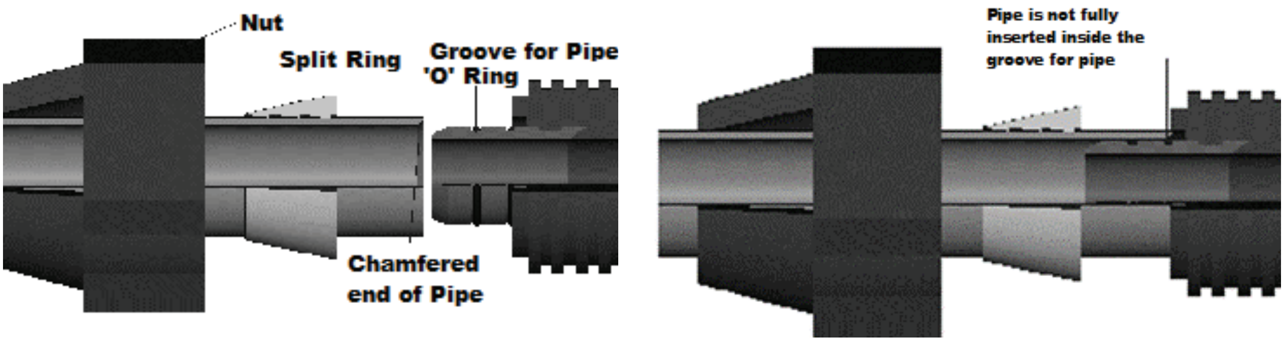


Figure 11.38: Jointing of PE-AL-PE Pipe

11.12.2 Saddle sets in HSCs

Major portion of leakages occur in HSCs. At present, a saddle set with female threaded nipple is used in HSC. However, this practice results into high leakages at the ferrule points and contamination of water in the pipeline. These leakages from HSC should be controlled and reduced by using leak-proof saddle sets and good quality HSC pipes. There are two types of saddles used in the distribution system having plastic pipes (PVC/HDPE) for HSC, one is a mechanical PP saddle set which is used for both PVC/HDPE pipelines and other is a fusion welded Electrofusion saddle set for HDPE pipeline.

On PVC/HDPE pipelines, the mechanical PP clamp saddle (IS 7634 Part 2-2012, Reaffirmed 2022 Fig. 15A) with inbuilt compression fittings manufactured using injection moulded integrated saddle which can be sealed on these pipes by rubber gasket/sealing. The service saddle is manufactured out of alloy of virgin polypropylene (PP) and is made with special additives that provide UV protection. It has higher mechanical strength and ensures smooth flow. The service saddle is available in black/blue colour. The PP service saddle set is used for PVC and HDPE pipes. These saddles are suitable for HSCs in urban areas. Figure 11.39 shows a monolithic service saddle for non-metallic pipes.

On HDPE pipeline, fusion welded electrofusion tapping saddle is installed as per IS 7634-2-2012, Reaffirmed 2022 with inbuilt cutter for tapping HDPE pipe. The electrofusion saddle set shall be made of polyethylene (PE 100) and is made with special additives that provide UV protection. Electrofusion Saddle set as a new technology, fused on HDPE pipe by fusion process which installed without stopping main line and it is leak proof as the joints are fusion welded. The saddle set has both top and bottom part which are screwed on HDPE pipe. The fusion joint made with integrated electrofusion tapping saddle makes complete piping system homogenous and there is no possibility of any contamination of water due to high leak-proof nature. Electrofusion tapping saddle integrated with 8mm cutter shall be used in the pipes in which residual pressure is more than 7 m (0.7 kg/cm2) and 15 mm cutter is used in the pipeline having residual pressure less than 7 m (0.7 kg/cm2). These saddles are also suitable for HSCs in urban areas. The electrofusion tapping saddle is shown Figure 11.40. Typical HSC on HDPE pipe with electrofusion saddle is given in Figure 11.41.

On a metal pipeline, service saddle made of composite polypropylene glass reinforced fibre or DI material is used. The strap saddle is used up to 200 mm dia metallic pipes. and Figure 11.42 shows strap saddle for metallic pipes.

It must be ensured that all service saddles should be fitted with the bottom part for effective clamping and leak proofing.

Figure 11.39: Monolithic Service Saddle for non-metallic pipes

Figure 11.40: Electrofusion Tapping saddle with integrated cutter, Electrofusion transition saddle for HDPE pipe

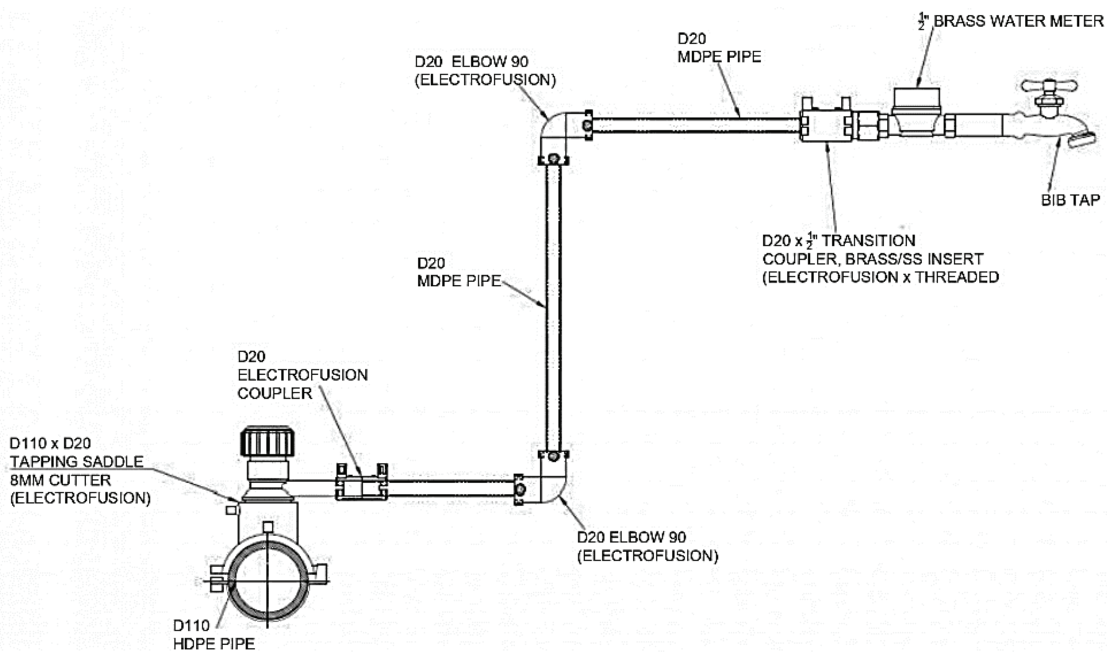


Figure 11.41: The complete HSC is given in figure

Figure 11.42: Strap Saddle for metallic pipes

Department of Drinking Water Supply, Ministry of Jal Shakti has recommended adoption of integrated clamp saddle set with flow control valve (FCV) in HSCs in rural areas under Jal Jeevan Mission 2 to ensure equity and efficiency in water supply services. The integrated saddle with FCV is designed for 5 LPM (± 0.75 lpm) discharge at 0.50 pressure and not exceeding the flow of 7 LPM (± 0.75 LPM) at 1 bar (10 m head) pressure. The integrated saddle set is manufactured using injection with FCV SS316 solid steel bar. FCV/NRV can be designed for higher flow control discharge beyond 7 LPM subject to distribution design for effective water needs beyond 7 LPM. The terminal pressure of 7 m is recommended in rural water supply distribution network where no FCV is used in the HSCs and 12 m is recommended in the rural water supply distribution network, where FCV is used in the HSCs, considering the head loss in the FCV at the ferrule point.

However, the integrated saddle set with FCV may be avoided in the HSCs in urban areas as it may lead to increased head loss at the ferrule point and affect the recommended terminal pressure of 17–21 m for Class I and II cities and 12–15 m for Class III–VI towns.

11.13 Aspects of Plumbing System

Bureau of Indian Standards has issued a handbook on water supply and drainage with special emphasis on plumbing vide IS: SP-35**:** 1987 (Reaffirmed Year: 2014), which shall generally be followed along with relevant latest BIS codes of practices.

Pipe Materials in Plumbing:

The BIS standards IS: 2065**:** 1983 (Reaffirmed Year: 2022) – Code of practice for water supply in buildings covers general requirements and regulations for water supply, plumbing connected to public water supply, licensing of plumbers, design of water supply systems, principles of conveyance and distribution of water within the premises, storage, water fittings and appliances, and inspection and maintenance. Necessary in-line valves at appropriate places have to be installed for control and isolated repairing services in a particular stretch of plumbing piping system. This code does not cover aspects of water supply for firefighting purposes, which are covered under different IS codes.

The BIS specification code IS 12183-1: 1987 (Reaffirmed Year: 2019) Code of Practice for Plumbing in Multi-storeyed Buildings: Part 1 Water Supply deals with water supply in multi-storeyed buildings and covers general requirements and regulations, design considerations, plumbing systems, distribution systems, storage of water, and inspection for water supply in multi-storeyed buildings. Wherever, vertical separation of floors in multi-storeyed buildings is possible, necessary control valve(s) at each floor shall be provided for equitable pressure and flow. Also, in buildings where vertical separation is not possible, pressure in the lower floors may be restricted by use of pressure reducing valves, orifice flanges, or other similar devices. The BIS code recommends that the velocity of water in pipes should be restricted to 2.0 m/s to avoid noise problem. It is recommended to consider a minimum residual head of 21 m at the ferrule at the highest spot of operational zone for Class I and II cities and 15 m for all other towns. Care should be taken to obtain the flow required for the minimum pressure at all parts in the building.

Requirements for water piping, fittings and appliances, inspection, and maintenance covered in IS: 2065 (1983, (Reaffirmed Year: 2022)) shall also be applicable for buildings. All pipe runs, appurtenances, and valves shall be located in a manner to provide easy access for maintenance and repair.

As per the IS code, plumbing refers to (a) the pipes, fixtures, and other apparatus inside a building in the water supply and removing the liquid and waterborne wastes; (b) the installation of foregoing pipes, fixtures, and other apparatus. The plumbing system refers to and includes the water supply and distribution pipes, plumbing fittings and traps, soil, waste, vent pipes, and anti-siphonage pipes, building drains and building sewers, including their respective connections, devices, and appurtenances within the property lines of the premises, and water-treating or water using the equipment.

Premises include passages, buildings, and lands of any tenure, whether open or enclosed, whether built on or not, and whether public or private, in respect of which a water rate or charge is payable to the authority or for which an application is made for the supply of water.

Commonly terms used to construct water pipes in plumbing are:

a) Supply pipe – Pipe connecting to municipal water mains to HSC;
b) Vertical pipe – Any pipe which is installed in a vertical position or which makes an angle of not more than 45° with the vertical;
c) Warning pipe – An overflow pipe fixed so that its outlet, whether inside or outside a building, is in a conspicuous position where the discharge of any water therefrom can be readily seen;
d) Stopcock – A cock fitting in a pipeline for controlling the flow of water;
e) Stop tap – A stop tap includes a stopcock, stop valve, or any other devices for stopping the flow of water in a line or system of pipe at will;
f) Storage cistern – A cistern for storing water;
g) Water line – A line marked inside a cistern to indicate the highest water level at which the supply valve should be adjusted shutoff;
h) Water main (street main) – A pipe laid by the water undertakers for the purpose of giving a general supply of water as distinct from a supply to individual consumers and includes any apparatus used in connection with such a pipe;
i) Water outlet – A water outlet, as used in connection with the water distribution system, is the discharge opening for the water (a) to a fitting, (b) to atmospheric pressure (except into an open tank which is part of the water supply), and (c) to any water-operated device or equipment requiring water to operate;
j) Washout valve – A device located at the bottom of the tank for the purpose of draining a tank for cleaning, maintenance, etc.
k) Water supply system – Water Supply System of a building or premises consists of the water service pipe, the water distribution pipes and necessary connecting pipes, fittings, control valves, and all appurtenances in or adjacent to the building or premises.

Figure 11.43 shows Sketch showing typical Bedding Angle.

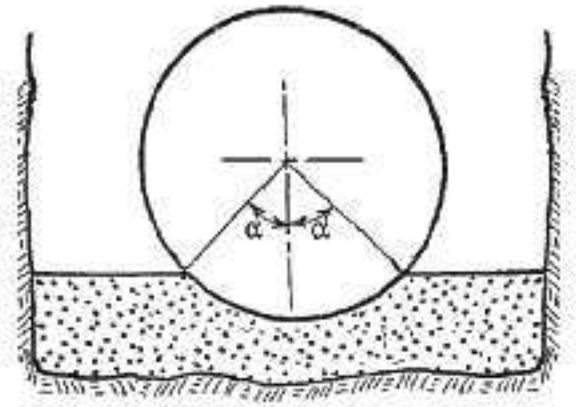


Figure 11.43: Sketch showing typical Bedding Angle

Bedding and bedding angle – The bedding is the material placed in the bottom of the trench on which the pipe is laid. The bedding for both rigid and flexible pipes is an uncompacted layer of select material. This layer of uncompacted select material is placed over the foundation or the replaced foundation. The thickness of this layer depends on the pipe diameter. For pipes with a diameter of 300 to 1350 mm (12 to 54 in), the thickness of the bedding is 100 mm (4 in). For pipe diameters larger than 1350 nun (54 in), the thickness of the bedding is 150 mm (6 in). Pipe is laid directly on the bedding. The pipe bedding factor is very important as this adds a great deal of strength to the pipe when it is in service. Ideal factor can be anywhere between 90% and 120% or more of the total structural strength of the pipe/bedding system. Pipe Bedding Class A (Plain Concrete Cradle) includes an unreinforced concrete cradle encompassing 120° of the bottom of the pipe. Fine grading of the surface of the bedding shall be such that the final grade of the pipe shall not exceed the specified departure from grade, because when the bedding material is uncompacted, there will be some slight settlement of the pipe laid on the uncompacted bedding. The amount of settlement will vary depending on the type of soil, the type of pipe, and the diameter of the pipe. The initial (placement) thickness of the bedding layer will have to be established by trial and error at the beginning of a job or after any change that would affect the settlement. If the bedding becomes compacted by excessive foot traffic, equipment travel or rain before the pipe has been placed, it must be loosened by removal and replacement or by scarifying. For special designs of very large diameter pipe, a thicker bedding may be specified.

Proper design of the water distributing systems in a building is necessary in order that the various fittings may function properly, and there is an adequate supply to meet the needs of the occupants of the building, both with regard to their domestic as well as flushing (of sanitary appliances) requirements. Pipes going underground must have adequate cover. As per the relevant IS code, domestic water metres should be installed as prescribed by the authority to receive potable water. Figure 11.43 shows sketch of a typical bedding angle.

11.13.1 Polypropylene-Random Copolymer Pipes for Hot and Cold Water

The BIS Code IS 15801 (2008, (Reaffirmed Year: 2022)) – Polypropylene-random copolymer pipes for hot and cold water supplies specifies requirements for polypropylene-random copolymer pipes from 16 mm to 200 mm nominal diameter of standard dimension ratio (SDR) 11, 7.4, 6, and 5 for:

a) wall concealed hot and cold water conveyance pipelines for inside and outside buildings (properly UV stabilised), and
b) pipelines for the solar heating system inside and outside the buildings.

Standard dimension ratio (SDR) is a method of rating a pipe's durability against pressure. The standard dimension ratio describes the correlation between the pipe dimension and the thickness of the pipe wall. Common nominations are SDR11, SDR7.4, SDR6, SDR 5. Pipes with a lower SDR can withstand higher pressures.

Polypropylene-random copolymer (PP-R) used for the manufacture of pipes shall conform to the requirement of IS 10951 (2002): Polypropylene Materials for Moulding and Extrusion and IS 10910 1994 (Reaffirmed 2003) IS 10910 (1984): Polypropylene and its copolymers for its safe use in contact with foodstuffs, pharmaceuticals and drinking water. The PP-R pipes, when in permanent or temporary contact with water, which is intended for human consumption, shall not adversely affect the quality of drinking water.

11.14 Pipeline in Colder Region

Selection of pipe material in colder climate shall take into consideration the BIS Code IS 6295: 1986 (Reaffirmed Year: 2022) Code of practice for water supply and drainage in high altitudes and/or sub-zero temperature regions to handle the following issues:

- Freeze-Back Forces: Excessive pore water pressure trapped between the permafrost layer and winter frost layer can deform or collapse pipe.
- Potential Freeze Damage: Pipes should, if freezing risk is high, be capable of being thawed and returned to service without loss of strength.

The general recommended type of pipe materials are HDPE, AC, GI, CI, and uPVC as per "IS 6295: 1986 (Reaffirmed Year: 2022) – Code of practice for water supply and drainage in high altitudes and/or sub-zero temperature regions". Ductile iron can also be used as per the relevant ISO Standards 21051:2020.

Unless piping can be installed below the seasonal frost line, some form of freeze protection/insulation is mandatory. Factory-applied polyurethane is recommended for both buried and over ground pipes.

UPVC pipe becomes brittle in the cold and can shatter when frozen. PVC is not recommended for use where there is a chance of the pipe being exposed to freezing conditions. UPVC pipe shall be buried to depths unlikely to experience freezing temperatures.

HDPE is preferred where there is a high risk of freezing. HDPE can normally be thawed and returned to service without damage to the pipe. It is corrosion-resistant and not affected by extreme cold.

The BIS Code "IS 6295 (1986, Reaffirmed 2022): Code of practice for water supply and drainage in high altitudes and/or sub-zero temperature regions" gives recommendations regarding the factors to be given consideration while planning and designing water supply and sanitation system peculiar to high altitudes and/or sub-zero temperature regions of the country.

In transmission and distribution, freezing of the buried pipe may be avoided primarily by laying the pipe below the level of the frost line; well consolidated bedding of clean earth or sand, under, around or over the pipe should be provided. The level of frost line is generally found to be between 0.9 m and 1.2 m below ground level in the northern regions of India, wherever freezing occurs.

For the efficient operation and design of transmission and distribution work, the available heat in the water shall be economically used and controlled. If heat naturally present in water is inadequate to satisfy heat losses from the system, the water shall be warmed. Where economically feasible, warm water from hot springs or other ground water sources, if potable, shall be mixed with the primary source for this purpose. If found unsuitable for drinking water purposes, such water may be used for heating purposes. Heat losses shall be reduced by insulation, if necessary. Any material that will catch, absorb, or hold moisture shall not be used for insulation purposes. Adequate number of break pressure water tanks and air release valves shall be provided in the distribution system. HDPE pipes with proper break pressure chambers along with the outlets at suitable positions will prove to be a good transmission/distribution system. Where high density polyethylene (HDPE) pipes are used in some cases cylinder of ice is formed inside the pipe near the joints. Extra precaution should be taken near the joints by way of lagging.

Materials for insulation of pipes as per the normal practice in India is to surround the pipe with straw, grass, hessian cloth/strip or jute rapped over with gunny and painting with bitumen; alternatively, other materials like 85 per cent magnesia, glass wool or asbestos coated lagging ropes may also be used.

HSCs shall be kept operative by the use of adequate insulation at exposed places extending below the frost line. A typical arrangement of providing insulation for HSCs is shown in Figure 1 of the BIS code IS 6295 (1986, Reaffirmed 2022), which may be referred to for general guidelines for fire hydrant protection in freezing climate region is also provided.

11.15 Excavation and Preparation of Trench

Excavation may be done by hand or by machine. The trench shall be so dug that the pipe may be laid to the required gradient and at the required depth. When the pipeline is under a roadway, a minimum cover of 0.9 m is recommended for adoption, however cover should be provided as per respective BIS code for different pipe materials and suiting to the local field conditions by taking necessary precautions. However, the structural strength of the pipe, based on dead load and live load over the pipe, should also be analysed. The trench shall be so braced and drained so that the workmen may work therein safely and efficiently. The discharge of the trench dewatering pumps shall be conveyed either to drainage channels or to natural drains and shall not be allowed to be spread in the vicinity of the worksite. The width of the trench at the bottom shall provide not less than 200 mm clearance on both sides of the pipe. Additional width shall be provided at positions of sockets and flanges for jointing. Depths of pits at such places shall also be sufficient to permit the finishing of joints.

Ledge rock, boulders, and large stones shall be removed to provide a clearance of at least 150 mm below and on each side of pipes for valves and fillings for pipes of 600 mm diameter or less and 200 mm for pipes larger than 600 mm in diameter.

11.16 Shoring and Strutting

The shoring shall be adequate to prevent caving in of the trench walls by subsidence of soil adjacent to the trench. In narrow trenches of limited depth, a simple form of shoring shall consist of a pair of 40 to 50 mm thick and 30 cm wide planks set vertically at intervals and firmly fixed with struts. For wider and deeper trenches, a system of wall plates (Wales) and struts of heavy timber section is commonly used. Continuous sheeting shall be provided outside the wall plates to maintain the stability of the trench walls. The number and the size of the wall plates shall be fixed considering the depth of the trench and the type of soil. The cross struts shall be fixed in a manner to maintain pressure against the wall plates, which in turn shall be kept pressed against the timber sheeting by means of timber wedges or dog spikes. In non-cohesive soils combined with considerable groundwater, it may be necessary to use continuous interlocking steel sheet piling to prevent excessive soil movements by groundwater percolation and extend the piling at least 1.5 m below the trench bed. In the case of deep trenches, excavation and shoring may be done in stages.

11.17 Handling of Pipes

While unloading, pipes shall not be thrown down but may be carefully unloaded on inclined timber skids. Pipes shall not be dragged over other pipes and along concrete and similar pavements to avoid damage to pipes.

11.18 Detection of Cracks in Pipes

The pipes and fittings shall be inspected for defects and be rung with a light hammer, preferably while suspended, to detect cracks.

11.19 Lowering of Pipes and Fittings

All pipes, fittings, valves, and hydrants shall be carefully lowered into the trench by means of derrick, ropes, or other suitable tools and equipment to prevent damage to pipe materials and protective coatings and linings. Pipes over 300 mm in diameter shall be handled and lowered into trenches with the help of chain pulley blocks.

11.20 Anchorages

A pipeline need anchorage at dead ends and bends as appreciable thrust occurs, which tends to cause draw and even "blow out" joints. Where thrust is appreciable, concrete blocks/restrained joint system should be installed at all points where movement may occur. Anchorages are necessary to resist the tendency of the pipes to pull apart at bends or other points of unbalanced pressure or when they are laid on steep gradients and the resistance of their joints to longitudinal or shear stresses is either exceeded or inadequate. They are also used to restrain or direct the expansion and contraction of rigidly joined pipes under the influence of temperature changes. Anchor blocks shall be designed in accordance with IS: 5330 (1984, Reaffirmed 2020).

11.21 Thrust Blocks

Water travelling through a piping system under internal pressure exerts a thrust force at all bends, tee junctions, and stop ends. The magnitude of these forces usually is so high that they can easily weaken the joints and even can cause leakage or failure of the piping/pipeline system. With an increase in the piping size, these forces increase further. Installation of a thrust block partially absorbs that pressure thrust force and the remaining is transferred to the surrounding soil. As such, thrust blocks should be designed and cast at all the horizontal bends, vertical bends, tees, wye’s, reducers, and enlargers.

The following are some typical thrust force calculation formulas for ductile iron pipes.

- **Thrust Force on an Elbow or bend**

  To calculate the design thrust force or resultant force for bends the following formula can be used:
  Thrust force, $F = 2 P A \sin(\phi/2)$
  Where: P = design pressure,
  A = cross-sectional area of the pipe, and
  ϕ = angle of the bend.
- **Thrust force on Plugs or Caps**
  The thrust force in a plug or cap is equal to the design pressure (P) times the cross-sectional area (A) of the pipe.
  (Thrust force, $F = P A$).
- **Thrust force for tee connections**
  The thrust force generated in a Tee connection is calculated as
  $F=P A_b$.
  Where P=internal design pressure and
  A_b= cross-sectional area of the branch pipe.
- **Thrust force calculation of pipe reducers**
  The design thrust force for piping reducers/expanders is equal to the design pressure (P) times the difference of the cross-sectional areas of the large (A_1) and small end (A_2) sizes of the reducer.
  Hence, thrust restraint force, $F = P (A_1 - A_2)$

11.22 Bore well / Tube well

A Borewell/Tube well construction and assembly consist of the following pipes mainly:

a) **Casing Pipe:** Pipe that is used to protect the wells and the boreholes from collapsing.
b) **Housing Pipe:** Upper portion of the case section of the well and serves as housing for the pumping equipment and is a vertical conduit through which water flows from the aquifer to the pump. It is watertight and extends downwards from the ground surface to a safe depth below the anticipated pumping water level.
c) **Drive pipe:** Type of casing made of seamless or welded mild steel pipes designed to withstand the driving force and penetrate into the ground to protect against the collapse of the movement of the loose formation which takes place during drilling operations.

11.22.1 Casing/Housing/Drive Pipes

Mainly following two types of pipes are used for tube well casing/housing/drive:

I) Steel: General requirements relating to the supply of steel tubes for water wells shall conform to IS 4270 (2001, Reaffirmed 2022): Steel Tubes Used for Water Wells [MTD 19: Steel Tubes, Pipes and Fittings]

II) uPVC shall conform to IS 12818 (2010, Reaffirmed 2021) Unplasticized Polyvinyl Chloride (PVC-U) screen and Casing Pipes for Bore/tube well

I) **Steel tubes**: Steel tubes can be classified based on the manner in which they are manufactured as follows:

a. Automatic fusion welded pipe: A tube made from steel plates formed into the pipe and welded longitudinally by a submerged arc welding process.
b. Electric resistance welded pipe: Electrically welded tube is made from steel strip which is formed into a tubular shape and welded by passing a heavy current across the longitudinal joint.
c. High-frequency induction welded pipe: The electrically welded tube is made from a steel strip which is formed into a tubular shape and welded by passing a current at a high frequency across the longitudinal joint.
d. Seamless steel tube or pipe: A tube without a longitudinal joint or weld.

Steel tubes shall be one of the following types and grades of steel:

1. Hot finished seamless (HFS),
2. Electric fusion welded (EFW),
3. Electric resistance welded (ERW), and
4. High-frequency induction welded (HFIW).

Grade of steel: Fe 410 and Fe 450 are generally used to manufacture steel pipes for borewell/tube well.

II) **uPVC Pipes:** Follow the latest IS: 12818 (2010, Reaffirmed 2021) Unplasticized Polyvinyl Chloride (PVC-U) screen and Casing Pipes for Borewell/tube well, which cover DN 35 mm to DN 400 mm for borewells/tube wells for water supply. Solid wall plain surface pipes are used as extension pipes to the screen pipe.

Casing pipes are classified into three categories based on well depth that are shallow, medium, and deep described below:

i. CS (Casing for shallow well) pipe: Shallow well casing pipes suitable for wells with depths up to 80 m.
ii. CM (Casing for medium well) pipe: Medium well casing pipes suitable for wells with depths beyond 80 m and up to 250 m.
iii. CD (Casing for deep well) pipe: Deep well casing pipe suitable for wells with depths beyond 250 m and up to 450 m.

11.22.2 Screens and Slotted Pipes:

Borewell/tube well screens and slotted pipes shall conform to IS 8110: 2019 – Water Well Screens and Slotted Pipes — Specification. In this Indian standard, FRP pipes have been covered for the manufacture of screens and slot pipes. Well screen is the most critical element in a tube well, affecting its life, pump maintenance, and efficiency.

Well screens are specially fabricated screen pipes from different materials which can have a wider range of slot opening from much finer to coarse compared to slotted pipes.

Slotted pipes are pipes with slots cut into them in a pattern suitable to the basic material of the pipe.

Following are the types of well screens and slotted pipes:

a) Plain slotted pipes: These are pipes with slots cut by milling;
b) Bridge slotted pipes: The slots in the pipe are not cut but pressed out;
c) Mesh wrapped screens: These are made by wrapping copper mesh over perforated steel pipe using spacers about 3 mm thick in between the copper mesh and perforated pipe;
d) Cage-type wire wound screen: These are a special type of screen where a continuous shaped profile wire is spirally wound around a series of longitudinal support rods of a circular shaped section with each interaction of profile wire and support rod welded by electric fusion welding process. The longitudinal support rods are welded to end rings at both ends to facilitate joining with casing pipes or other screens by butt welding or threading;
e) Pre-packed resin bonded gravel screens: Gravel is pasted on the perforated pipe with the help of resin-type adhesive material. The thickness of the gravel bond varied between 10 mm to 15 mm depending upon the diameter of the base pipe;
f) Brass Screens: Brass screens are made from the brass sheet in which slots of required sizes are cut before rolling;
g) Ribbed Screen pipes: Pipe with external longitudinal ribs and transverse (perpendicular to pipe longitudinal axis) slots. This shall be designated as ribbed medium well screen (RMS) and ribbed deep well screen (RDS) pipes;
h) Plain screen pipes: These are plain surface pipes with transverse slots. This shall be designated as plain medium well screen (PMS) and plain deep well screen (PDS) pipe;
i) FRP strainers and slotted pipes: These are also being manufactured in India and are covered under IS: 8110: 2019. The FRP slotted pipes shall be manufactured by the filament winding process. The slots shall be cut by milling. The slotting patterns shall be such as to ensure the minimum cutting of the glass fibre in the pipe and thereby maintaining maximum strength. Selecting FRP slotted pipes made from FRP base material shall fulfil the requirements given in Annexure A of IS: 8110: 2019, which must be capable to withstand the internal hydrostatic pressure, external collapse pressure test, and water absorption and retention of strength.

Materials for well screens and slotted pipes shall be made of either corrosion-resistant material or steel pipes having sufficient thickness to guard against the effect of corrosion and to ensure reasonable life of the tube well.

The following are the recommended materials for various types of well screens and slotted pipes:

a) Low carbon or mild steel corresponding to IS: 1239 Part 1 (2004)
b) Leaded brass sheet corresponding to IS: 531 (1981, Reaffirmed 2006)
c) Fibre glass reinforced thermosetting plastics corresponding to IS: 12709 (1994, Reaffirmed 2009)
d) UPVC conforming to IS: 10151 (1982, Reaffirmed 1997)
e) Copper wire conforming to IS: 4412 (1981, Reaffirmed 2006)
f) Galvanised steel wire as per IS: 280 (2006)
g) Stainless steel wire as per IS: 6528 (1995, Reaffirmed 2001)

11.22.3 Joints

Casing/Housing/Drive Pipes joints shall be as follows:

a) Screwed and socketed butt joints;
b) Screwed flush butt joints; and
c) Plain bevelled end pipes for butt welded joints.

Well screens shall be threaded and socketed, plain bevel ended, collared or male and female types so that convenient lengths could be added. The slotted pipe screens shall have adequate strength to withstand axial, collapse, and hydrostatic loads to be experienced during development and use. The screen shall be as far as possible of single metal construction to avoid galvanic corrosion.

11.23 Appurtenances

The following appurtenances are used in the piping system:

1) Valves
2) Manholes/Inspection and repair chamber
3) Fire hydrants
4) Water Metres

11.23.1 Valves

Valves are mechanical devices that are operated manually or automatically to facilitate in operation and maintenance of water system or processes by control of flow, pressure, and formation of zones. Valves are also used to isolate and drain pipe sections for test, installation, cleaning and repairs. A number of appurtenances or auxiliaries are generally installed in the line. Various types of valves are used which have specific function within a system or process are described as follows:

11.23.1.1 Line Valves

Main line valves are provided to stop and regulate the flow of water in the course of ordinary operations and in an emergency. There are many types of valves for use in pipeline, the choke of which depends on the duty. The spacing varies principally with the terrain traversed by the line. In urban areas with connections in the distribution system, the main aim is to sectionalise the line in order to maintain reasonable service. Figure 11.44 shows a typical pipeline layout showing the location of gate valve, air valves, and blow-off (drain) valves in a pipeline.

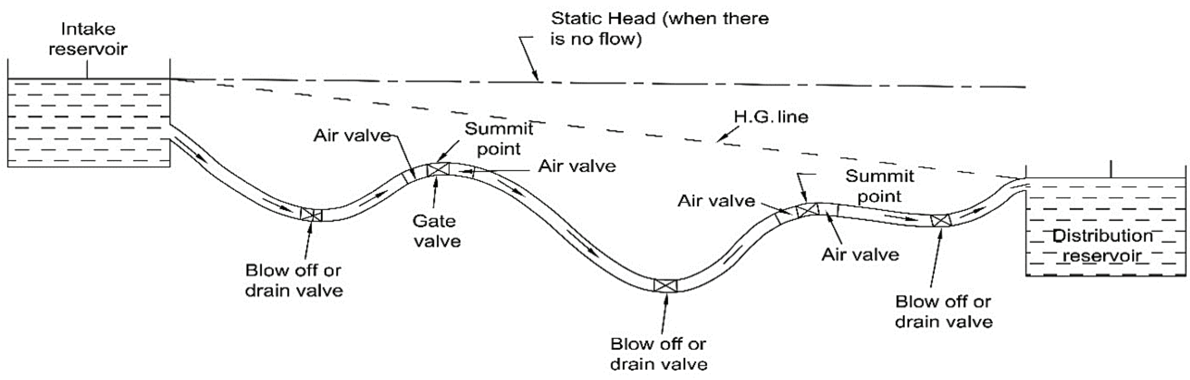


Figure 11.44: Typical Pipeline layout showing location of Gate Valve, Air Valves, blow-off (Drain) Valves in a pipeline

In larger lines, isolating valves are frequently installed at intervals of 1 to 5 Km. The principal considerations in location of the valves are accessibility and proximity to special points such as branches, stream crossings, etc. The spacing of the valves is a function of economics and operating problems. Sections of the pipeline may have to be isolated to repair leaks. The volume of water which would have to be drained to waste would be a function of spacing of isolating valves.

These valves are usually placed at major summits of pressure conduits. Summits identify the sections of the line that can be drained by gravity, and pressures are least at these points permitting cheaper valves and easier operation. Gravity conduits are provided with valves at points strategic for the operation of supply points, at the two ends of sag pipes and wherever it is convenient to drain the given section.

Normally, valves are sized slightly smaller than the pipe diameter and installed with a reducer on either side. In choosing the size, the cost of the valve should be weighed against the cost of head loss through it, although in certain circumstances it may be desirable to maintain the full pipe bore (to prevent erosion or blockage).

It is sometimes advisable to install small diameter bypass valves around large diameter in-line valves to equalise pressures across the gate and thus facilitate opening.

Various types of Line Valves are classified below:

(i) Valve types based on functions

Valves serves various functions within the piping system. Such as

- Stopping and starting a fluid flow. Depending on whether a valve is open or closed, it will let pass the process fluid or halt the fluid.
- Throttling the fluid flow. Some of the valves let you throttle the fluid depending on open % of the total opening. Lesser the opening higher the throttling and otherwise.
- Controlling the direction of fluid flow. A multi-port valve lets you decide the way fluid will go.
- Regulating a flow or pressure within the piping system. Some of the automatic control valves maintain the flow and pressure within the system by adjusting opening and closing.
- Relieving pressure or vacuum from the piping system and equipment. Pressure and vacuum relief valves safeguard the process system from overpressure and during vacuum conditions.

Different types of valves serve these functions. These valves can be classified or categorised based on:

- Function
- End connection
- How it operates
- Types of actuators it used

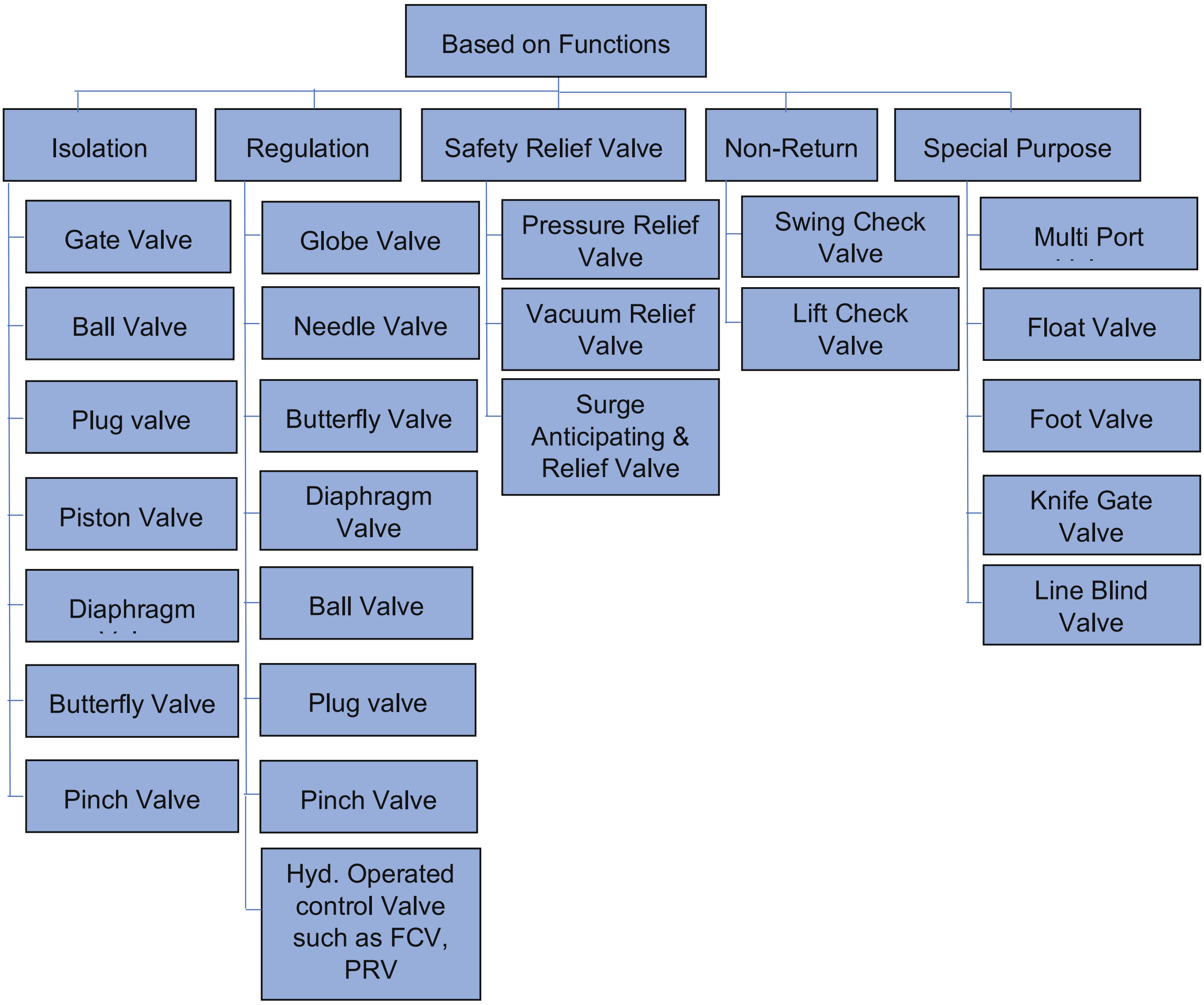


Figure 11.45: Classification of Valves Based on Function

In the above chart, you can see the types of valves and their function.

Isolation valve isolates or cuts the supply of fluid when needed. Gate, ball, plug, piston, diaphragm, butterfly, and pinch valve falls under this category.

A control valve that regulates the flow of fluid falls in the regulation category. Globe, needle, butterfly, diaphragm, ball, plug, and pinch valves are used as a control valves. You can see that some valves serve dual purposes such as the globe and the ball valve, whcih can be used as isolation as well as a control valve. Figure 11.45 shows classification of valves based on function.

Pressure and vacuum relief valve used to prevent overpressure and vacuum with the system that can damage the piping and equipment. Non-return valve such as swing and lift check valve prevents backflow within the system, whereas some valves are designed to serve a special purpose such as multi-port, knife, and line blind valve. Figure 11.46 shows classification of valves based on end connections.

Figure 11.46: Classification of Valves Based on End Connections

(ii) Valve type based on the end connection

Valve ends can be:

- Screwed or threaded that connect with matching thread on the pipe. A small bore valve is used in instrument connection or as a sample point has a threaded end.
- The majority valve used in piping has a flanged-type end.
- Butt welded valves are used in very high pressure and temperature services.
- Socket welded valves are used in low pressure.
- Check valve and butterfly valves are available in wafer and lug end construction. These types of ends are used when space is constrained.

(iii) Valve type based on the way it is opened and closed

Another way to classify the valve is the way it opens and closes. Each valve opens and closes by either linear or rotary motion or by the quarter turn which is nothing but a rotary motion.

a. Linear motion valves

Linear motion valves use a closure member that moves in a straight line and cut the flow to start, stop, or throttle the flow. The closure device could be a disc, or flexible material, such as a diaphragm. Linear motion valves are slower in operation, but they provide a higher level of accuracy and stability in the position of the closure member. Figure 11.47 shows linear motion valve.

b. Rotary motion valves

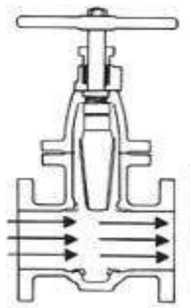


Figure 11.47: Linear Motion Valve

c. Rotary motion valves

These rotate a disc or swing it from the hinge pin that holds the disc. Figure 11.48 shows rotary motion valve.

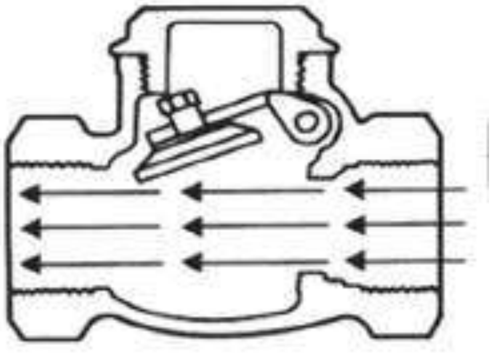


Figure 11.48: Rotary Motion Valve

d. Quarter turn valves

A 90° turn of the stem in quarter turn valves fully open or fully closed the valve. Because of this quick turn, the operation of the quarter turn valve is much faster than linear motion valves. Some rotary motion valves are also known as the quarter turn valve. Figure 11.49 shows a quarter turn valve.

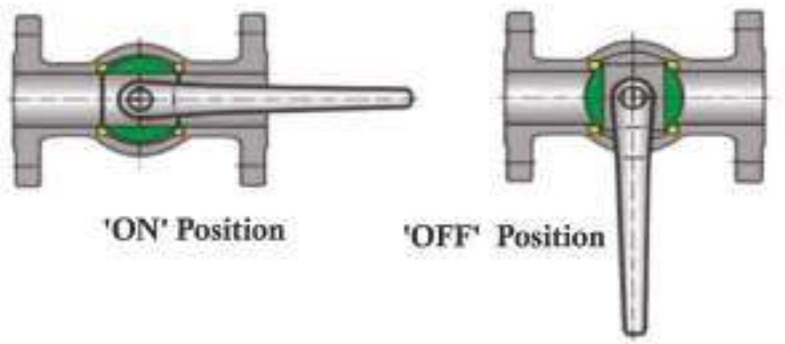


Figure 11.49: Quarter Turn Valve

Table 11.3: Motions of Different Types of Valves

Motion Type to open and close Valve	Valve Type
Linear Motion	Gate Valve
	Globe Valve
	Lift Check Valve
	In-Line Check Valve
	Stop Check Valve
	Pinch Valve
	Diaphragm Valve
	Safety Valve
	Relief Valve
	Swing Check Valve
	Tilting Disc Check Valve
	Folding-disc Check valve

Motion Type to open and close Valve	Valve Type
Rotary Motion	Stop Check Valve
	Ball Valve
	Butterfly Valve
	Plug Valve
Quarter Turn	Ball Valve
	Butterfly Valve
	Plug Valve

The table above shows that the ball valve, butterfly valve, and plug valve are both rotary and quarter turn valves, whereas swing check, tilting disc, and other rotary motion valves are not a quarter turn valve.

(iv) Valve type based on types of actuators are used

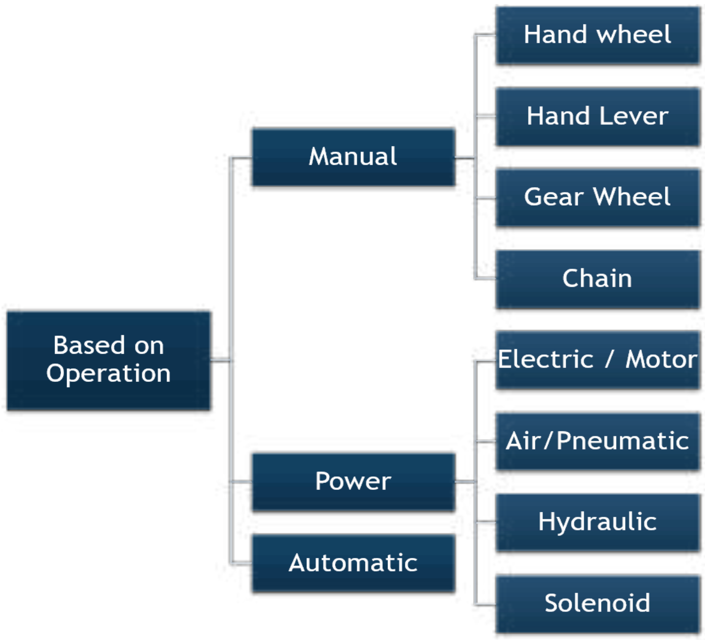


Figure 11.50: Operation Based Valve Type

Valves are classified as per the types of the actuator used to transfer the motion to operate the valve. The valve can be operated manually with the help of a hand wheel, lever, chain, or by a gear wheel. An external power source such as an electric motor, air, hydraulic fluid, or solenoid is used to operate a valve from the control room. The check valve works automatically when subjected to the backflow. Figure 11.50 shows operation based valve type.

11.23.1.2 Sluice or Gate Valves

Sluice valves or gate valves are the normal type of valves used for isolating or scouring. They seal well under high pressures and when fully open, offer little resistance to fluid flow.

IS 14846: 2000 (Reaffirmed Year: 2020) – Sluice Valve for Water Works Purposes (50 to 1200 mm Size) – covers requirements for non-rising stem-type sluice valves used for water supply up to 45 °C and having double flanges.

Sluice valves are designated by nominal pressure (PN) defined as maximum permissible gauge working pressure in MPa for the sizes 50 mm to 600 mm diameter as PN1.0 and PN1.6 and also for sizes from 50 mm to1200 mm diameter as PN1.0. The sluice valves are of nominal sizes 50 mm, 65 mm, 80 mm, 100 mm, 125 mm, 150 mm, 200 mm, 250 mm, 300 mm, 350 mm, 400 mm, 450 mm, 500 mm, 600 mm, 700 mm, 800 mm, 900 mm, 1000 mm, 1100 mm, and 1200 mm diameter. The nominal sizes refer to the nominal bore of the waterway.

(A) Types of sluice or gate valves

There are following three ways to classify the gate valves:

(i) Types of discs

a. Solid taper wedge
b. Flexible wedge
c. Split wedge or parallel disc valve

(ii) Types of body bonnet joint

a. Screwed bonnet
b. Bolted bonnet
c. Welded bonnet
d. Pressure seal bonnet

(iii) Types of stem movement

a. Rising stem or OS and Y-Type (outside stem and screw-type)
b. Non-rising stem-type

(i) Classification by Type of Disc

a) Solid wedge gate valve

Solid wedge is the most common and widely used disc-type because of its simplicity and strength. A valve with a solid wedge may be installed in any position, and it is suitable for almost all fluids. It can be used in turbulent flow also.

However, it does not compensate for changes in seat alignment due to pipe loads or thermal expansion. So, this type of disc design is most susceptible to leakage. Solid wedge is subjected to thermal locking if used in a high-temperature service.

Thermal locking is a phenomenon in which a wedge is stuck between the seats due to the expansion of the metal. Solid wedge gate valves are generally used in moderate to lower pressure temperature applications. Figure 11.51 shows a typical sketch of a sluice valve for size 150 mm diameter with a thrust plate.

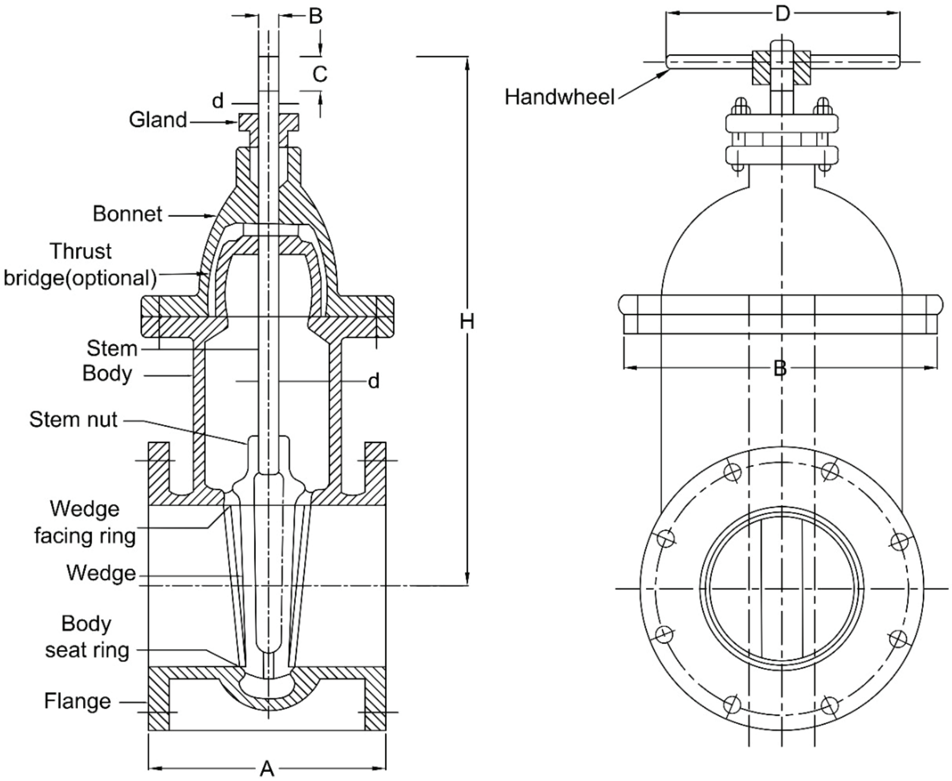


Figure 11.51: Typical sketch of a sluice valve for size 150mm diameter with thrust plate

There are two types of spindles for raising the gate:

a. A rising spindle which is attached to the gate and does not rotate with the hand wheel; and
b. A non-rising spindle which is rotated in a screwed attachment in the gate. The rising spindle is easy to lubricate.

The gate may be parallel sided or wedge shaped. The wedge gate seals best but may be damaged by grit. For low pressure, resilient or gunmetal scaling faces may be used. For high pressure, stainless steel seals are preferred. Sluice valves are not intended to be used for continuous throttling, as erosion of the seats and body cavitation may occur. If small flows are required the bypass, valve is more suitable for this duty. Despite sluice valve's simplicity and positive action, they are sometimes troublesome to operate. They need a big force to unseat them against high unbalanced pressure and large valves take many minutes to turn open or closed, for which power operated or manual operated actuators are also used. Some of these problems can be overcome by installing a valve with a smaller bore than the pipeline diameter.

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.

b) Flexible wedge gate valve

The flexible wedge is a one-piece solid disc with a cut around the perimeter. These cuts vary in size, shape, and depth. A shallow, narrow cut on the wedge perimeter gives less flexibility but retains strength. A cast-in recess or deeper and wider cut on the wedge perimeter gives more flexibility but compromises the strength.

This design improves seat alignment and offers better leak tightness. It also improves performance in situations where thermal binding is possible. Flexible wedges gate valves are used in steam systems.

Thermal expansion of the steam line sometime causes distortion of valve bodies which may lead to thermal blinding. The flexible gate allows the gate to flex as the valve seat compresses due to thermal expansion of the steam pipeline, thus prevents thermal blinding.

The disadvantage of flexible gates is that line fluid tends to collect in the disc. These may result in corrosion and ultimately weaken the disc. Figure 11.52 shows a flexible wedge gate valve.

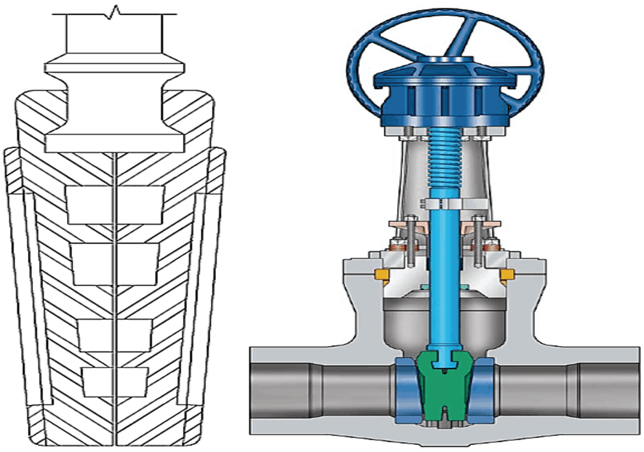


Figure 11.52: Flexible Wedge Gate Valve

c) Split wedge or parallel disc gate valve

Split wedge disc consists of two solid pieces and holds together with the help of a special mechanism. You can see the same in images. In case where one-half of the disc is out of alignment, the disc is free to adjust itself to the seating surface. The split disc can be in a wedge shape or a parallel disc-type.

Parallel discs are spring-loaded, so they are always in contact with seats and give bi-directional sealing. The split wedge is suitable for handling noncondensing gasses and liquids at normal and high temperatures.

Freedom of movement of the disc prevents thermal binding even though the valve may have been closed when a line is cold. This means that when a line is heated by fluid and expands, it does not create thermal blinding. Figure 11.53 shows split wedge parallel disc gate valve.

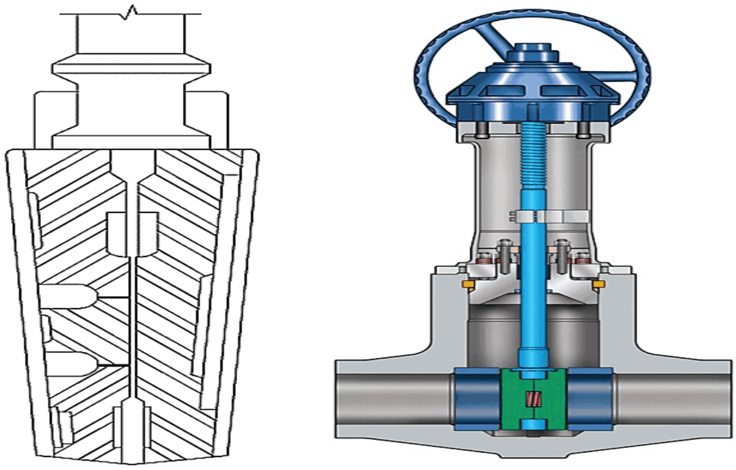


Figure 11.53: Split Wedge parallel discs Gate Valve

(ii) Classification by types of body, bonnet connection

Figure 11.54: Different Valves based on Bonnet Connections

1. **Screwed bonnet:** This is the simplest design available, and it is used for inexpensive valves.

2. **Bolted bonnet:** This is the most popular design and used in a large number of gate valves. This requires a gasket to seal the joint between the body and bonnet.

3. **Welded bonnet:** This is a popular design where disassembly is not required. They are lighter in weight than their bolted bonnet counterparts.

4. **Pressure seal bonnet:** This type is used extensively for high pressure high-temperature applications. The higher the body cavity pressure, the greater the force on the gasket in a pressure seal valve.

(iii) Classification by types of stem movement

a) OS and Y gate valve or rising stem (outside stem and screw-type)

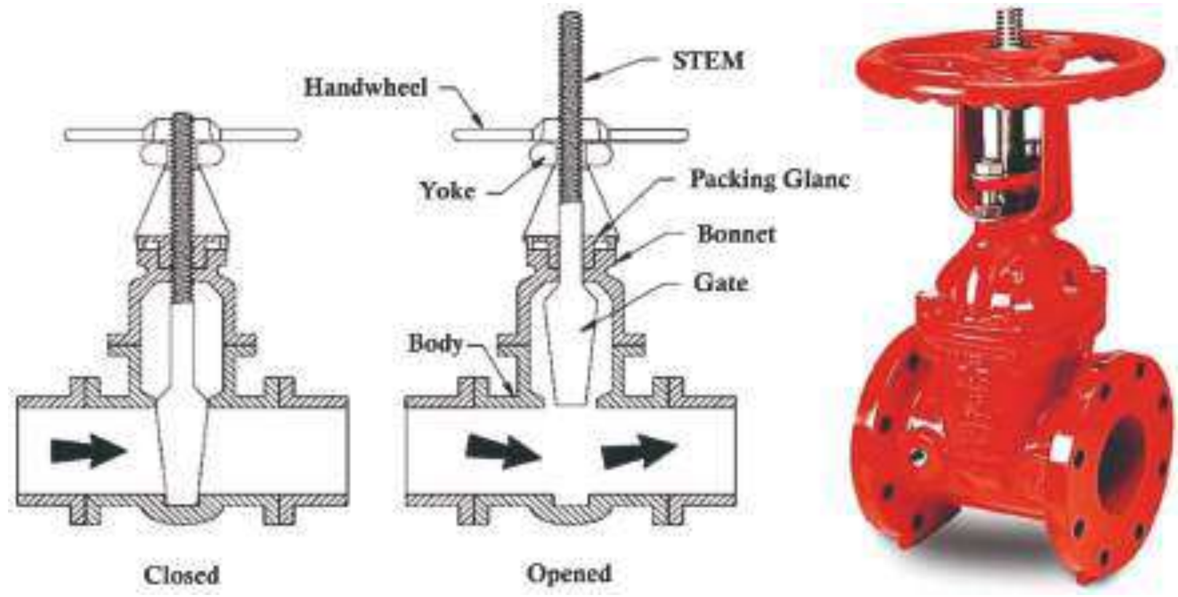


Figure 11.55: OS & Y Gate Valve

For a rising stem valve, the stem will go up while opening the valve and move down when closing the valve. Figure 11.55 shows OS and Y gate valve.

Whereas in the case of the outside screw design, the only smooth portion is exposed to the flow medium and the stem will rise above the hand wheel. This type of valve is also known as OS and Y valve. OS and Y means outside steam and York respectively.

b) Non-rising stem gate valve or insider screw valve

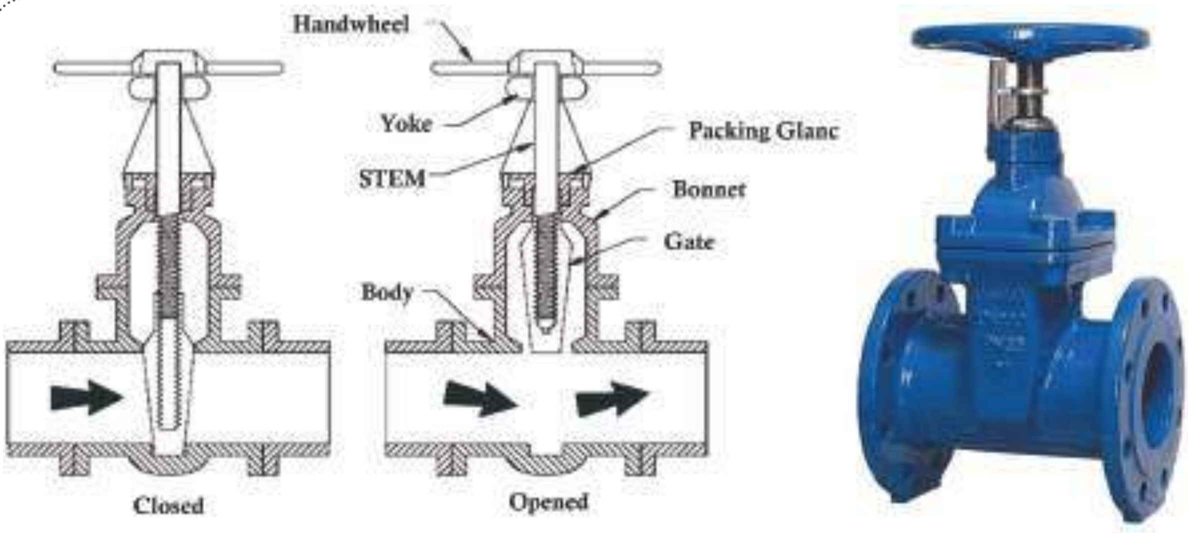


Figure 11.56: Non-rising Stem Gate Valve

There is no upward movement of the stem in a non-rising stem-type. The valve disc is threaded internally. The disc travels along the stem like a nut when the stem is rotated. You can see the image. In this type of valve, stem threads are exposed to the flow medium. Figure 11.56 shows non-rising stem gate valve.

Therefore, this design is used where space is limited to allow linear stem movement, and the flow medium does not cause erosion, corrosion, or wear and tear to stem material. This type of valve is also known as an insider screw valve.

(B) Gate valve applications

- Gate valves are used in almost all fluid services such as air, fuel gas, feedwater, steam, lube oil, hydrocarbon, and all most any other services.
- Some special gate valves are used in slurry and powder product also such as knife gate valve.

(C) Advantages and disadvantages of sluice valve

Advantages	Disadvantages
Pressure drop during operation is very less.	A gate valve is slow in operation. Opening and closing take time which is good also as it reduces the chance of hammering.
Most of the gate valve can be used as bi-directional.	When partially open it creates vibration and noise.
Most suitable for high pressure and temperature application and required less maintenance.	Repairs, such as lapping and grinding of seats are more difficult due to limited access.
---	It cannot be used to control the flow.

11.23.1.3 Butterfly Valves

IS 13095: 2020 – Butterfly Valves for General Purposes (First Revision) covers double flanged and wafer-type of metal-seated, resilient-seated, cast iron, ductile iron, and carbon steel and lined butterfly valves for general purposes. Valves covered under tis standard can be operated manually, pneumatically, hydraulically, or electrically.

Butterfly valves are used to regulate and stop the flow especially in large size conduits. They are sometimes cheaper than sluice valves for larger sizes and occupy less space. Butterfly valves with no sliding parts have the advantages of ease of operation, compact size, reduced chamber or valve house and improved closing and retarding characteristics.

(A) Valve applications:

a. Tight shut-off – A valve having no visible leakage past the disc in closed position under test condition;
b. Regulating – A valve intended for regulating purposes and which may have a clearance between the disc and the body in closed position;
c. Low leakage – A valve which has specified maximum leakage rate past the disc in the closed position.
d. A butterfly valve is used in many different fluid services, and also perform well in slurry applications also. They can be used in liquids, steam, cryogenics, cooling water, air, gasses, firefighting, and vacuum services.
e. Butterfly valves are used for all types of industry applications even in high pressure and temperature services.

These would involve slightly higher head loss than sluice valves and also are not suitable for continuous throttling. The sealing is sometimes not as effective as for sluice valves especially at high pressures. They also offer a fairly high resistance to flow even in the fully open state, because the thickness of the disc obstructs the flow even when it is rotated to fully open position. Butterfly valves as well as sluice valves are not suited for operation in partly open positions as the gates and seatings would erode rapidly. Both types require high torques to open them against high pressure, they often have geared hand wheels or power-driven actuators.

Butterfly valves with loose sealing ring are sometimes not effective, especially at higher pressures. Butterfly valves with fixed liner can overcome this shortcoming. Furthermore, the butterfly valves with fixed liner needs no frequent maintenance for replacement of sealing ring as in the case of butterfly valves with loose sealing ring. The fixed liner design butterfly valves are now available in India and are suitable for working pressures up to 16 kg/sq. cm. Presently, there is no IS for the fixed liner butterfly valves.

(B) Butterfly valve types

A butterfly valve is a quarter turn rotary motion valve that is used to stop, regulate, and start the flow. Butterfly valves are a quick open type. A 90° rotation of the handle can completely close or open the valve. Normally, they are used in systems where a positive shut-off is not required and are of the following types:

i. Wafer-type
ii. Lug style-type
iii. Flanged-type
iv. Butt welded end types
v. Zero offset
vi. Double offset
vii. Triple offset

Large butterfly valves are usually equipped with gearbox-type actuator, where the handwheel is connected to the stem via a gearbox. This will reduce the force but at the same time reduce the speed of the operation. This type of valve should be installed in the open position. If the valve is closed during installation, the rubber seat will wedge against the valve disc and make it difficult to open.

Butterfly valve types based on body construction:

Based on the type of ends of the body butterfly valves are available in following types.

(i) Both flanged ends
(ii) Wafer-type ends
(iii) Lug-type ends
(iv) Butt welded-type ends

(i) Wafer types

The wafer body is placed between pipe flanges, and the flange bolts surround the valve body. A wafer type butterfly valve is easy to install but it cannot be used as an isolation valve. Figure 11.63 shows a wafer type butterfly valve.

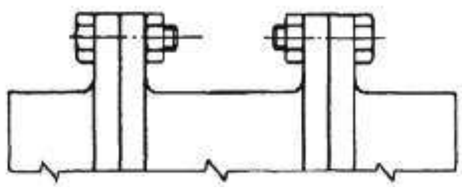


Figure 11.57: Butterfly Valve, Double Flanged Type

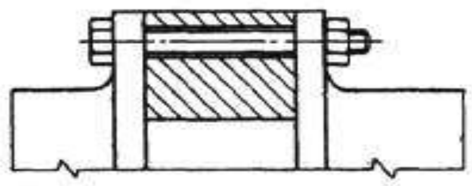


Figure 11.58: Butterfly Valve, Single Flange Wafer Type

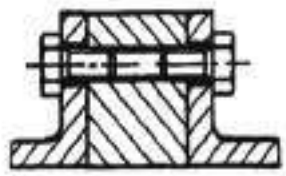


Figure 11.59: Wafer Lugged Screw

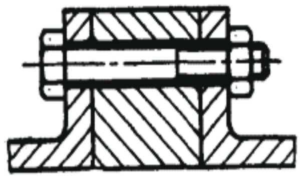


Figure 11.60: Wafer Lugged through bolt

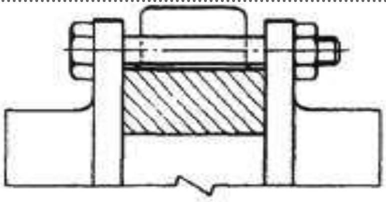


Figure 11.61: Butterfly Valve, Flangeless Wafer Type

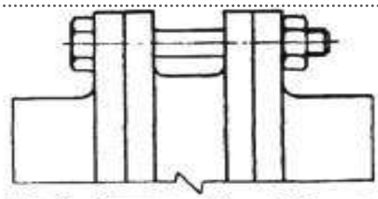


Figure 11.62: Butterfly Valve, U-Section Wafer Type

Figure 11.63: Wafer Type Butterfly Valve

(ii) Lug style

The lug body has protruding lugs in the periphery of a body that provides passage to bolt holes that match with those in the flanges. Figure 11.64 shows a lug type butterfly valve.

Figure 11.64: Lug Type Butterfly Valve

(iii) Flanged type

In these types, the body has flanges that match with pipe flange dimension. Figure 11.57 shows a butterfly valve, double flanged type, Figure 11.58 shows butterfly valve, single flange wafer type, and Figure 11.65 shows a double flanged butterfly valve.

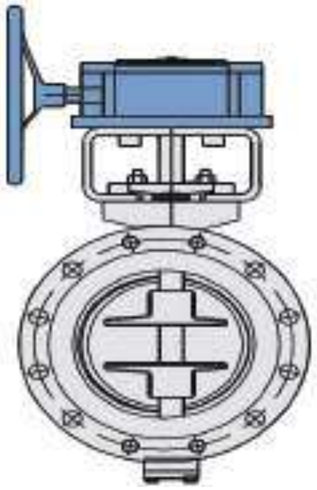


Figure 11.65: Double Flanged Butterfly Valve

(iv) Butt welded end types

These types of ends are used in high-pressure services and are directly welded to the pipe. Figure 11.66 shows a butt welded end type.

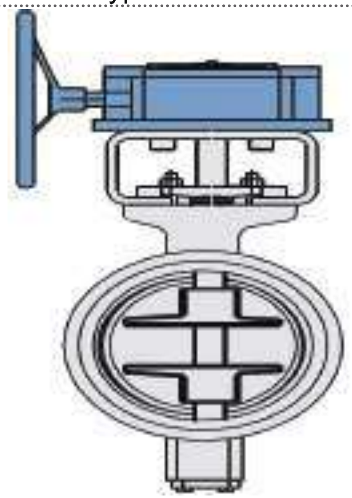


Figure 11.66: Butt Welded End Type

(v) Zero offset butterfly valve

Zero offset design is used for the valve which is utilized in low pressure and temperature services. In this design, the disc and shaft axis are concentric with the valve body. In the open position, the disc divides the flow into two equal halves, with the disc in the middle and parallel to the flow.

This type of valve has a resilient seat. Sealing is achieved when the disc deforms the soft seat. There is friction between the disc and seat during the full operating cycle which is the disadvantage of a zero offset valve. Figure 11.67 shows a zero offset butterfly valve.

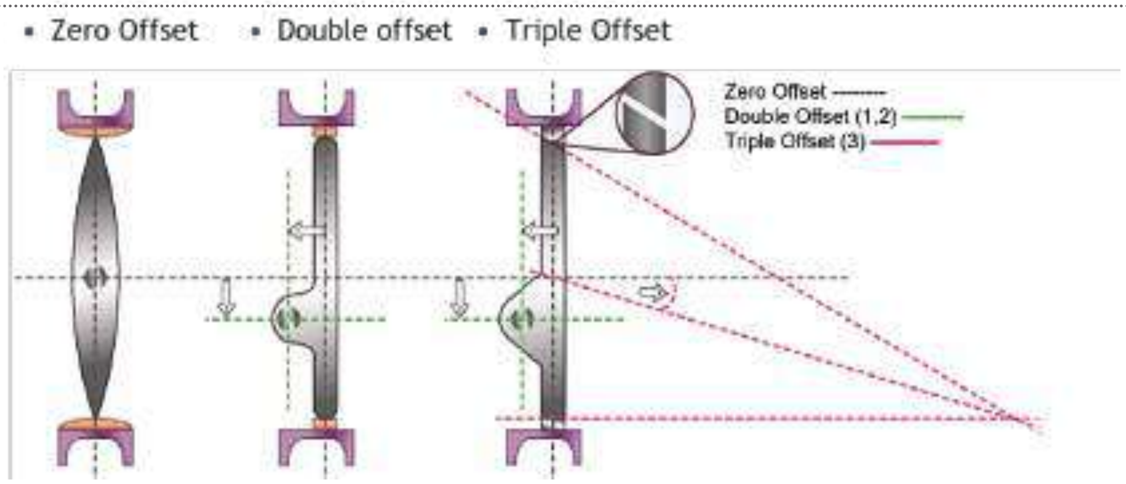


Figure 11.67: Zero offset Butterfly Valve

(vi) Double Offset Butterfly Valve

In double offset, the disc is offset from the valve centre line and also from the valve body centre line. You can see this in the image where one and two are written. This creates a cam action during operation that lifts the seat out of the seal.

Double offset makes opening and closing smooth as friction is applicable only during the first few degrees of opening and final few degrees of closing, approx. 10° of opening and closing. Figure 11.68 shows a double offset butterfly valve.

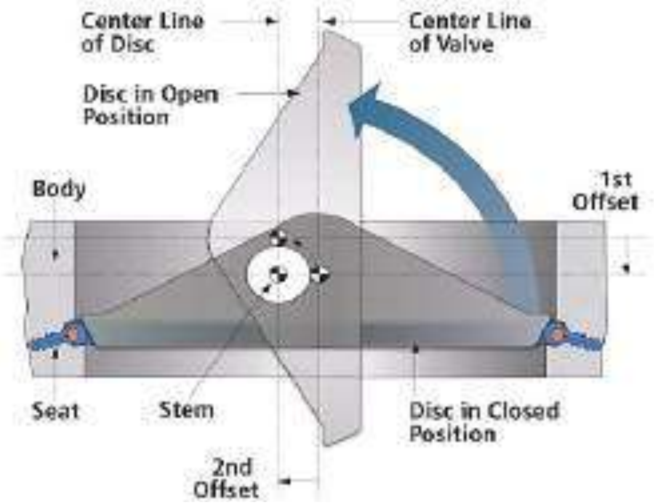


Figure 11.68: Double Offset Butterfly Valve

(vii)Triple offset butterfly valve

In triple offset design, the third offset is created by the geometrical design of the seating surface. The seat is machined into an offset conical profile resulting in a right-angled cone.

This ensures frictionless stroking throughout its operating cycle. Contact is only made at the final point of closure with the 90° angle acting as a mechanical stop; the metal-seated valve uses triple offset design. Figure 11.69 shows butterfly valve body parts and Figure 11.70 shows the typical butterfly valve has a short circular body, a round disc, shaft, and metal or soft seats.

Figure 11.69: Butterfly Valve Body Parts

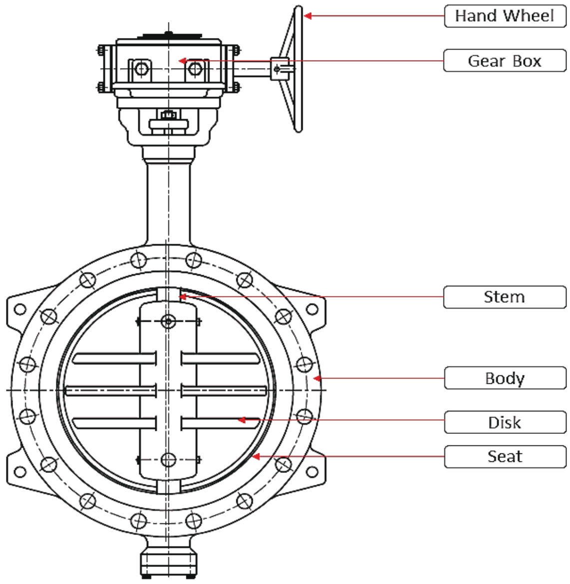


Figure 11.70: The typical butterfly valve has a short circular body, a round disc, shaft, and metal or soft seats

(viii) Seat types

Butterfly valves can be metal-to-metal seated, soft seated, or with a fully lined body and disc. The first image is of a soft seated fully lined body and disc valve. The second image is a soft seat with metal disc and the third image is a metal-to-metal seat type valve.

The disc of butterfly valve can be concentric or eccentric with the valve body.

(C) Advantages and disadvantage

Advantages	Disadvantages
Butterfly valve is suitable for large valve applications due to compact, lightweight design that requires considerably less space, as compared to other valves	Throttling is limited to low differential pressure services and that too with a 30- to 80-degree disc opening.
Due to a quick operation, it needs less time to open or close	There is a chance for cavitation and choke as the disc is always in the flow Turbulence flow can affect the disc movement.
The maintenance costs are usually low compared to other valve types	
A pressure drop across a butterfly valve is small	

Advantages	Disadvantages
Valve with non-metallic seating can be used in chemical or corrosive media	

11.23.1.4 Globe Valves

Globe valves have a circular seal connected axially to a vertical spindle and hand wheel. The seating is a ring perpendicular to the pipe axis. The flow changes direction through 90° twice thus resulting in high head losses. These valves are normally used in small bore pipe work and as taps, although a variation is used as a control valve.

A globe valve is a linear motion valve used to stop, start, and regulate the fluid flow. The globe valve disc can be removed entirely from the flow path, or it can completely close the flow path. During the opening and closing of the valve, the disc moves perpendicularly to the seat.

This movement creates the annular space between the disc and seat ring that gradually closes as the valve closed. This characteristic provides the globe valve good throttling ability required for regulating the flow.

Leakage from a globe valve seat is less as compared to the gate valve, mainly due to right angle contact between the disc and seat ring, which allows tighter seal between the seat and the disc.

IS 13114: 1991 (Reaffirmed Year: 2022) – forged brass gate, globe and check valves for water works purposes refers. In the below globe valve diagram, you can see how the globe valve functions. The image also shows flow direction.

Globe Valve Diagram

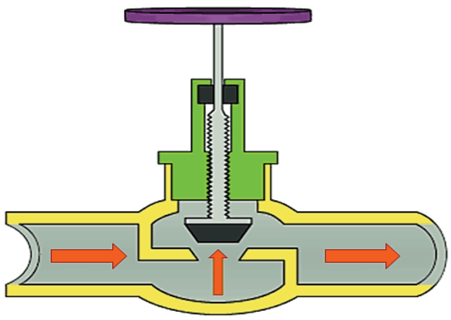


Figure 11.71: Disc Close against the Flow Direction

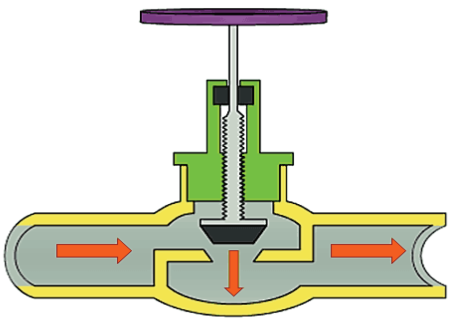


Figure 11.72: Disc Close in Flow Direction

Globe valves can be arranged in such a way that the disc closes against the flow or in the same direction of flow. Figure 11.71 shows a disc closing against the flow direction and Figure 11.72 shows disc closing in flow direction.

When the disc closes in the direction of flow, the kinetic energy of the fluid helps closing but obstructs the opening. This characteristic is preferable when a quick-acting stop is required.

When the disc closes against the direction of flow, the kinetic energy of the fluid obstructs closing but helps to open the valve. This characteristic is preferable when quick-acting start is required. Figure 11.73 is a sketch showing all globe valve parts such as body, bonnet, stem, seat, disc, etc.

Sr No	Globe Valve
1	Body
2	Bonnet
3	Disc
4	Disc nut
5	Body seat ring
6	Stem
7	Back seat
8	Gland follower
9	Gland flange
10	Yoke nut
11	Handwheel
12	Handwheel nut
13	Stud bolts
14	nuts
15	Stud bolts
16	nuts
17	Bonnet gasket
18	Packing

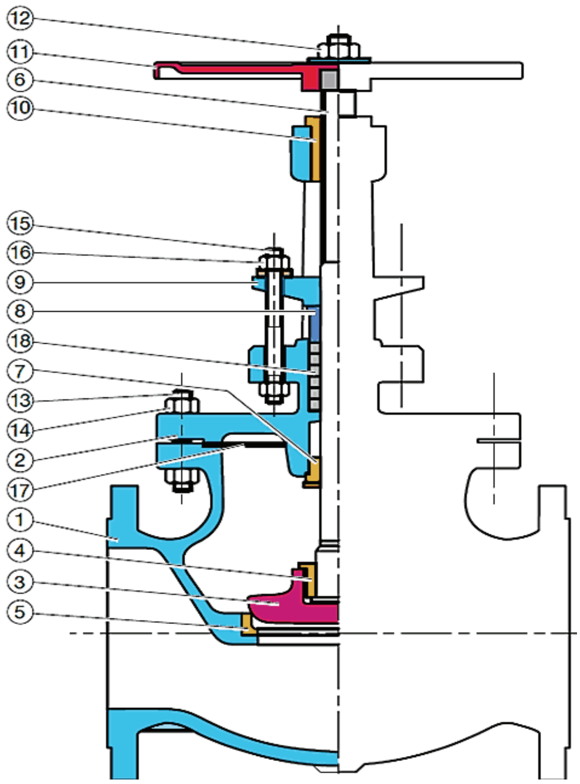


Figure 11.73: Sketch showing globe valve parts such as Body, Bonnet, Stem, Seat, Disc, etc.

(A) Types of globe valve based on disc types

Globe valve is available in many different types of disc arrangement. The most used disc designs are listed below.

1. Ball-type
2. Needle-type
3. Composite-type

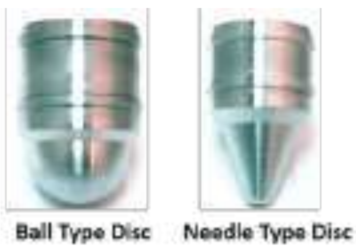


Figure 11.74: Ball-Type Disc and Needle-Type Disc

Ball disc design is used in low pressure and low-temperature systems. It is capable of throttling flow, but in principle, it is used to stop and start the flow.

Needle disc design provides better throttling as compared to ball or composition disc design. A wide verity of long and tapered plug discs is available to suit different flow conditions.

Composition disc is used to achieve better shutoff. A hard, non-metallic insert ring is used in composition disc design.

Figure 11.74 shows ball-type disc and needle-type disc.

(B) Types of globe valve based on body type

Depending on type of body, there are three types of globe valves;

(i) Z types
(ii) Y types
(iii) Angle types

(i) Z types globe valve

The simplest design and most common type is a Z-body. The Z-shaped partition inside the globular body contains the seat. The horizontal seating arrangement of the seat allows the stem and disc to travel at a perpendicular to the pipe axis resulting in a very high-pressure loss.

The valve seat is easily accessible through the bonnet which is attached to a large opening at the top of the valve body. Stem passes through the bonnet like a gate valve.

This design simplifies manufacturing, installation, and repair. This type of valve is used where pressure drop is not a concern and throttling is required. Figure 11.75 shows Z types of globe valves.

Figure 11.75: Z-types Globe Valve

(ii) Y types globe valve

The Y-type design is a solution for the high-pressure drop problem in Z-type valves. In this type, both seat and stem are angled at approximately 45° to the pipe axis. Y-body valves are used in high pressure and other critical services where pressure drop is a concerned. Figure 11.76 shows Y types of globe valvse.

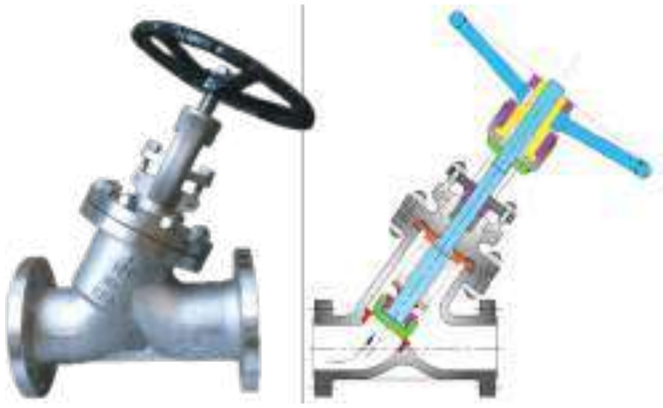


Figure 11.76: Y Types Globe Valve

(iii) Angle types globe valve

Angle globe valve turns the flow direction by 90º without using an elbow and one extra pipe weld. Disc opens against the flow. This type of globe valve can be used in the fluctuating flow conditions also, as they are capable of handling the slugging effect. Figure 11.77 shows angle types of globe valve.

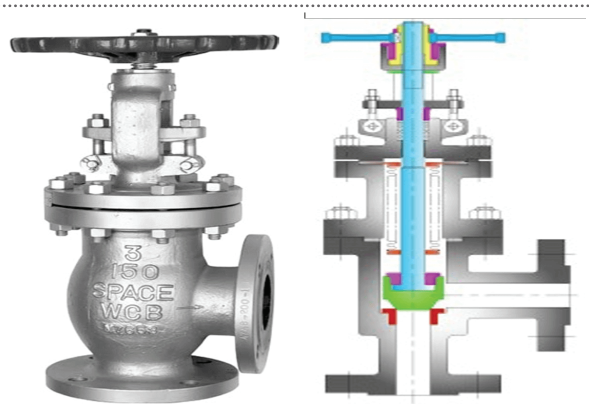


Figure 11.77: Angle types Globe Valve

(C) Types of Globe Valve Based on Body Bonnet Connection

a) **Screwed bonnet:** This is the simplest design available and it is used for inexpensive valves.
b) **Bolted bonnet:** This is the most popular design and used in a large number of globe valves. This requires a gasket to seal the joint between the body and bonnet.
c) **Welded Bonnet:** This is a popular design where disassembly is not required. They are lighter in weight than their bolted bonnet counterparts.
d) **Pressure Seal Bonnet:** This type is used extensively for high pressure high-temperature applications. The higher the body cavity pressure, the greater the force on the gasket in a pressure seal valve.

(D) Application of globe valve

Globe valves are used in systems where flow control is required and leak tightness is also important.

- It is used in high point vents and low point drains when leak tightness and safety are major concerns. Otherwise, you can use a gate valve for drain and vent.
- It can be used in feedwater, chemical, air, lube oil, and almost all services where pressure drop is not an issue.

- This valve is also used as an automatic control valve but, in that case, the stem of the valve is a smooth stem rather than threaded and is opened and closed by lifting action of an actuator assembly.

(E) Advantages and disadvantage of globe valve

Advantages	Disadvantages
Better shut off as compared to gate valve	High head loss from two or more right-angle turns of flowing fluid within the valve body
Good for frequent operation as no fear of wear of seat and disc	Obstructions and discontinuities in the flow path lead to a high head loss
Easy to repair, as seat and disc can be accessed from the valve top	In a large high-pressure line, pulsations and impacts can damage internal trim parts
Fast operation compares to gate valve due to shorter stroke length	A large valve requires considerable power to open and create noise while in operation
Usually operated by an automatic actuator	It is heavier than other valves of the same pressure rating
-----	Costlier compared to the gate valve

11.23.1.5 Needle and Cone Valves

Needle valves are more expensive than sluice and butterfly valves but are well suited for throttling flow. They have a gradual throttling action as they close, whereas sluice valves and butterfly valves offer little flow resistance until practically shut and may suffer cavitation damage.

A needle valve is a manual valve that used where continuous throttling of flow is required for regulation. Needle valves are similar to the globe valve in design with the biggest difference is the sharp needle-like disc.

Needle valves are designed to give very accurate control of flow in small diameter piping systems. They get their name from their sharp-pointed conical disc and matching seat. Figure 11.78 shows needle and cone valves.

Figure 11.78: Needle and Cone Valves

Fluid flowing through the valve turns 90º and passes through an orifice. Due to needle shape disc, a certain portion of the disc will pass through seat opening before disc comes in contact with the seat, which has a matching tapered design as a disc. This arrangement permits a very gradual increase or decrease in the size of the opening.

Needle valve has a forged and machined body. This body can be of forged carbon steel or stainless steel depending on the requirements of the services. A seat can be a soft, metal, or composite, same as a globe valve. Normally, needle valves are used in smaller sizes and are provided with either screwed or socket weld end.

All the aspects of the needle valve are the same as a global valve except its size and pointed needle-like disc. You can refer to a globe valve for more detail.

(A) Needle valve application

- All field analogue instruments are fitted with a needle valve to control flow entry, where sudden surges of fluid under pressure can damage the instruments.
- Needle valves can be used in situations where the flow must stop gradually and, in the application, where precise adjustments of flow are required or where a small flow rate is desired such as sample points in the piping.
- Needle valves can be used as both on/off and throttle valves.
- Used in all types of industries for controlling and metering applications of fluid such as steam, air, gas, oil, water, or other non-viscous liquids.

Needle valves may be used with counterbalance weights, springs, or actuators to maintain constant pressure conditions either upstream or downstream of the valve or to maintain a constant flow. They are resistant to wear even at high flow velocities. The method of sealing is to push an axial needle or spear shaped cone into a seat. There is often a pilot needle which operates first to balance the heads before opening. The cone valve is a variation of the needle valve, but the sealing cone rotates away from the pipe axis instead of being withdrawn axially.

The needle and cone valves are not commonly used in water supply but are occasionally used as water hammer release valves when coupled to an electric or hydraulic actuator.

11.23.1.6 Air Valves

When a pipeline is filled, air could be trapped at peaks along the profile thereby increasing head losses and reducing the capacity of the pipeline. It is also undesirable to have air pockets in the pipe as they may cause water hammer pressure fluctuations during operation of the pipeline. Other problems due to air include corrosion, reduced pump efficiency malfunctioning of valves or vibrations. Air valves 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, that might be accumulated at high points in the pipeline during normal operations.

Without air valves, vacuum may occur at peaks and the pipe could collapse or it may not be possible to drain the pipeline completely.

Air valves require care in selection and even more care in siting and it is good practice to plan the pipeline alignment to avoid air troubles altogether. A special study of the possible air problems is necessary at the design stage itself and provision should be made for suitable corrective measures rather than positioning arbitrary air valves at pipeline peaks.

Location of air valves can be at both sides of gates at summits, the downstream side of other gates and changes in grade to steeper slopes in sections of line not otherwise protected by air valves.

The valve usually takes the form of a rigid buoyant vulcanite or rubber-covered ball seated on a rubber or metal ring. The sealing element, i.e., the ball, is slated against an opening at the top of the valve when the pipe is full and seals the opening. When the pressure inside the pipe falls below external pressure, the ball drops thereby permitting air to be drawn into the pipe. The valves are mainly available in two forms, either single ball or double ball. The single ball-type can have either a large orifice or a small orifice, the former being only suitable for emptying and filling of pipelines, and the latter for discharging small quantities of entrained air. Double air valves are available which can be classified as dual purpose with a large orifice and small orifice in one unit, with a common connection to the main. For large aqueduct pipelines, a triple orifice air valve is available with two large orifices and one small. For high pressures, stainless steel floats are used instead of the vulcanite-covered balls.

Special designs of air valves are also available which operate satisfactorily with high velocity air discharges. If normal air valves are used under these conditions, there is a danger that the ball might be carried on to its seat by the air stream before the accumulated air has been fully released.

Air valves can be provided with an integral stop valve or alternatively, and preferably, a standard sluice valve can be bolted to the inlet flange, which must be of adequate size for its duty. Regular maintenance checks on at least an annual basis should be carried out to ensure that the balls are free to move and that the seals do not leak. If an air valve is isolated for any reason in very cold weather, the body should be drained to prevent frost damage; a plug cock can be fitted at the base of the body for this purpose. Trapped chamber drainage is essential to prevent any possibility of stagnant or polluted water or air entering the pipeline.

Automatic air valves in urban streets present a serious contamination risk, since they must have air vents that could, in some circumstances, admit polluted surface water. Constructing an air valve chamber as watertight as possible and fitting a ball valve interceptor as an outlet to a storm water sewer is a practice to obviate this possibility. Using manually operated air valves in the streets, it being the routine duty of a turncock in the area to air the main in order to minimise the risk of serious contamination, is yet another practice.

The following ratios of air valves to conduit diameter provide common but rough estimates of needed sizes:

For release of air only	1:12
For admission as well as release of air	1:8

An analysis of air inlet valves for steel pipelines, Parmakian takes the compressibility of air into account and combines equations for safe differential pressures of cylindrical steel pipe, pipe flow, and air flow, in the following approximate relationships:

$$\frac{d_a}{d} = 1.99 \times 10^{-2} \sqrt{\frac{\Delta V}{C}} \left[1 - \frac{P_1}{P_2} \times 0.288\right] - 0.25 \qquad (11.4)$$

For P_2 > 0.53 P_1 , and as

$$\frac{d_a}{d} = 3.91 \times 10^{-2} \sqrt{\frac{\Delta V}{C}} \left(\frac{P_2}{P_1}\right)^{0.356} \qquad (11.5)$$

For $P_2 \leq 0.53 P_1$ because air flow cannot increase beyond a critical differential of 0.488 Kg/cm^2.

In these equations, d_a and d, respectively, are the diameters of the air orifice and pipe, ΔV is the difference in the velocities of flow on each side of the inlet valve, C is the coefficient of discharge of the valve, P_2 and P_1, are the pressures inside and outside the pipe respectively, with $P_1 - P_2$ not exceeding one-half of the collapsing pressure as a matter of safety.

The equations apply strictly only to elevations of 304.8 m above mean sea level at 40 degrees latitude (g = 9.81 mps) temperatures of 25.32 °C, 20% humidity, an adiabatic expansion for which $pv^n = pv^{1.40}$, the air occupying a volume of 0.87 cum/Kg.

(A) Air Release Valves

Air release valves are designed specifically to vent, automatically and when necessary, air accumulations from lines in which water is flowing. Such accumulations of air tend to collect at high points in the pipeline. Air which accumulates at such peaks, reduces the useful cross-sectional area of the pipe, and therefore induces a friction head factor that lowers the pumping capacity of the entire line. The use of air release valves eliminates the possibility of this air binding and permits the flow of water without damage to pipeline. Releasing small burst of air at frequent intervals with the pipeline flowing full, the valve is immensely helpful in purging small bursts of accumulated air in the pipeline thereby enhancing discharge capacity of water mains. The float configuration, the lever arrangement, and the orifice size are decided upon after careful study of the site condition. By changing the orifice size, it can tackle large differential pressures (0.5 to 16 bar). Figure 11.79 shows air release valves.

Figure 11.79: Air Release Valves

Small orifice air valves are designated by their inlet connection size, usually 12 to 50 mm diameter. This has nothing to do with the air release orifice size which may be from 1 to 10 mm diameter. The larger the pressure in the pipeline, the smaller need be the orifice size. The volume of air to be released will be a function of the air entrained which is on the average 2% of the volume of water (at atmospheric pressure).

The small orifice release valves are sealed by a floating ball, or needle which is attached to a float. When a certain amount of air has accumulated in the connection on top of the pipe, the ball will drop or the needle valve will open and release the air. Small orifice release valves are often combined with large orifice air vent valves on a common connection on top of the pipe. The arrangement is called a double air valve. An isolating sluice valve is normally fitted between the pipe and the air valves.

Double air valves should be installed at peaks in the pipeline, both with respect to the horizontal and the maximum hydraulic gradient. They should also be installed at the ends and intermediate points along a length of pipeline which is parallel to the hydraulic grade line. It should be borne in mind that air may be dragged along in the direction of flow in the pipeline and may even accumulate in sections falling slowly in relation to the hydraulic gradient. Double air valves should be fitted every ½ to 1 km along descending sections, especially at points where the pipe dips steeply.

Air release valves should also be installed all along ascending lengths of pipeline where air is likely to be released from solution due to the lowering of the pressure, again especially at points of decrease in gradient. Other places where air valves are required are on the discharge side of pumps and at high points on large mains and upstream of orifice plates and reducing tapers.

Air relief towers are provided at the first summit of the line to remove air that is mechanically entrained as water is drawn into the entrance of the pipeline.

(B) Air Inlet Valves

In the design and operation of large steel pipelines, where gravity flow occurs, considerations must be given to the possibility of collapse in case the internal pressure is reduced below that of atmosphere. Should a break occur in the line at the lower end of a slope, a vacuum will in all probability be formed at some point upstream from the break due to the sudden rush of water from the line. To prevent the pipe from collapsing, air inlet (vacuum breaking) valves are used at critical points.

These valves normally held shut by water pressure, automatically open when this pressure is reduced to slightly below atmosphere, permitting large quantities of air to enter the pipe, thus effectively preventing the formation of any vacuum. In addition to offering positive protection against extensive damage to large pipelines, by prevention of vacuum, they also facilitate the initial filling of the line by the expulsion of air wherever the valves are installed.

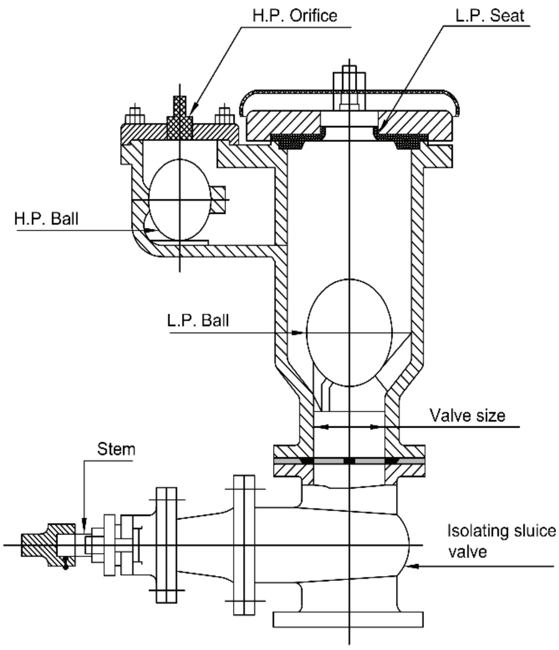
Air inlet valves should be installed at peaks in the pipeline, both relative to the horizontal and relative to the hydraulic gradient. Various possible hydraulic gradients, including reverse gradients during scouring, should be considered. They are normally fitted in combination with an air release valve.

Often, air release valves are used in conjunction with them, the purpose of which is to vent air accumulations that may occur at the peaks after the line has been put into operation.

(C) Kinetic Air Valves

In case of ordinary air valve, single orifice (small or large) type, the air or water from the rising main is admitted in the ball chamber of the air valve from one side of the ball. The disadvantages with this type of valve are that (a) once the ball goes up, it does not come down even when air accumulates in the ball chamber and (b) due to air rushing in, it stirs the ball making it stick to the upper opening which does not fall down unless the pressure in the main drops. The kinetic air valve overcomes these deficiencies since the air or water enters from the bottom side of the ball and the air rushing around ball exerts the pressure and loosens the contact with the top opening and allows the ball to drop down. Figure 11.80 shows a double chamber kinetic air valve (onsite), Figure 11.81 shows a double chamber kinetic air valve (schematic), Figure 11.82 shows single chamber kinetic air valve (large orifice), and Figure 11.83 shows single chamber kinetic air valve (small orifice).

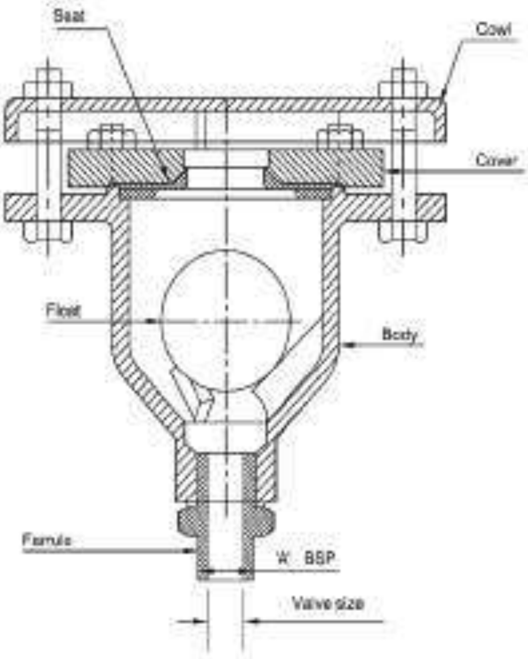
Figure 11.80: Double Chamber Kinetic Air Valve (Onsite)



Major component	Material of construction
Body/Cover/Coal	Cast iron/Ductile iron
L.P./H.P. ball	Vulconite/Rubber covered timber ball
L.P. Seat	Elastomer
H.P. Orifice	Gun metal
Isolating sluice valve	DF Metal seated
Isolating sluice valve stem	Stainless steel: AISI 410/AISI 431/AISI 304/AISI 316

Valve size	50Ø	80Ø	100Ø	150Ø	200Ø

Figure 11.81: Double Chamber Kinetic Air Valve (Schematic)

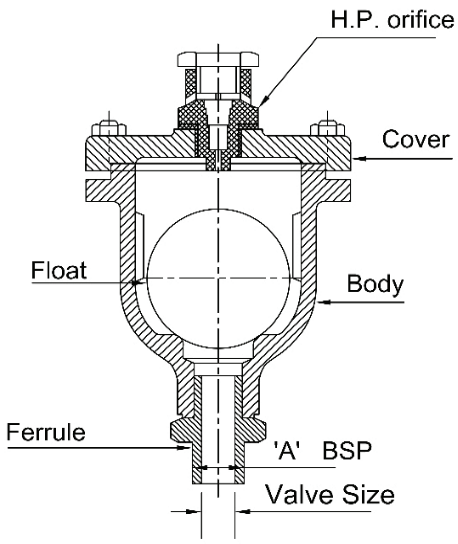


Major component	Material of construction
Body/Cover/Coal	Cast iron
Floot	Vulcanite covered timber ball
Seat	Elastomer
Ferrule	Standard

Valve size	25Ø	50Ø
'A' BSP	1"	2"

Figure 11.82: Single Chamber Kinetic Air Valve (Large Orifice)

Single air valve (small orifice)



Major component	Material of construction
Body/Cover	Cast iron
Floot	Rubber covered timber ball
Orifice	Gun metal
Ferrule	Standard

Valve size	25Ø
'A' BSP	1"

Figure 11.83: Single Chamber Kinetic Air Valve (Small Orifice)

Pipelines must breathe, inhale air when being emptied (to prevent collapse), or exhale when being charged with water. And while the pipeline is running full, the dissolved air in water must be purged from time to time to ensure optimum health of the system.

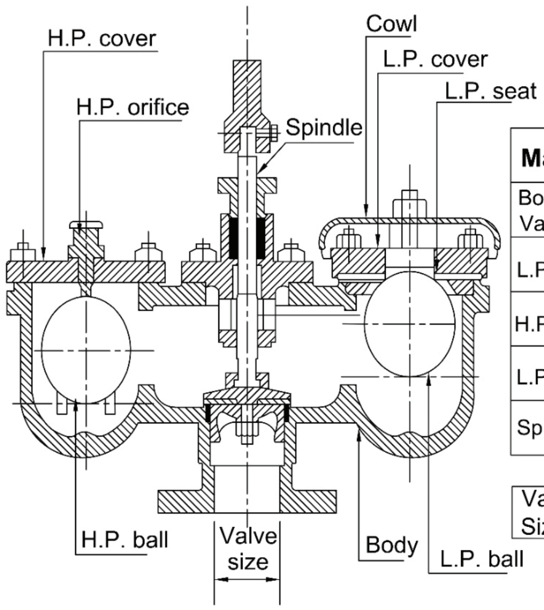
There are four principal types available besides the two small sizes for smaller mains, each having its own positive features. An isolating valve must essentially be provided below the air valve to isolate it for carrying out maintenance in the air valve, with the pipeline below running full.

(D) Guideline for Usage

- For mains size larger than 1200 NB, it is recommended that a cluster of 2 or 3 be used in one location.
- Normally 10 bar rated, 16 bar or higher pressure on request.
- Single air valve of size 1″ as per IS: 14845 can be supplied, suitable for 100 NB mains.
- Other special valves for water application are air vacuum valve (up to 350 NB) and air release valve (150 NB). Table 11.4 below shows valve sizes for different mains sizes. Figure 11.84 shows a double air valve with screwed down isolating valve, Figure 11.85 shows a single chamber triple function air valve, and Figure 11.86 shows a combination of air valves (tamper proof).

Table 11.4: Valve Sizes for Different Main Sizes

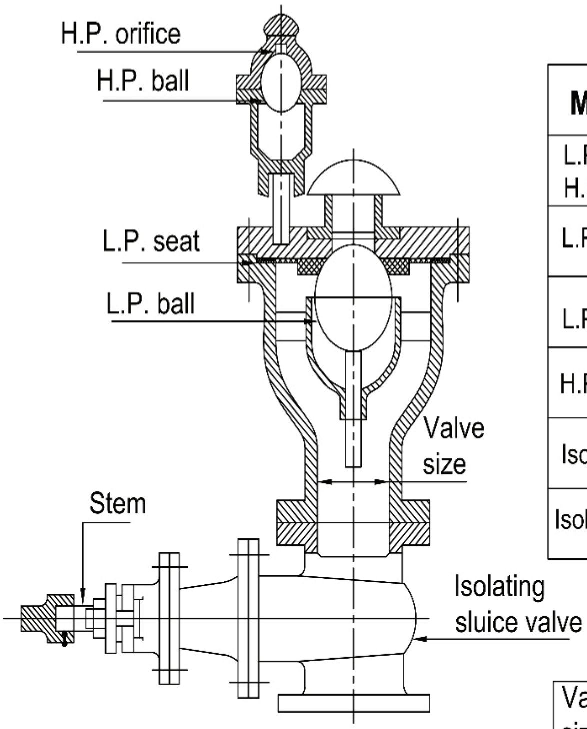
Valve size	For Mains size
50ø	Up to 200ø
80ø	225–350ø
100ø	400–500ø
150ø	600–900ø
200ø	1000–1200ø



Major component	Material of construction
Body/L.P.& H.P.cover/ Valve/Cowl	Cast Iron/Ductile Iron
L.P./Seat ring	Elastomer
H.P. Orifice	Gun metal
L.P. & H.P. ball	Vulconite/Rubber covered timber ball
Spindle	Stainless steel: AISI 410/AISI 304/AISI 316

Valve Size	50Ø	80Ø	100Ø	125Ø	150Ø	200Ø

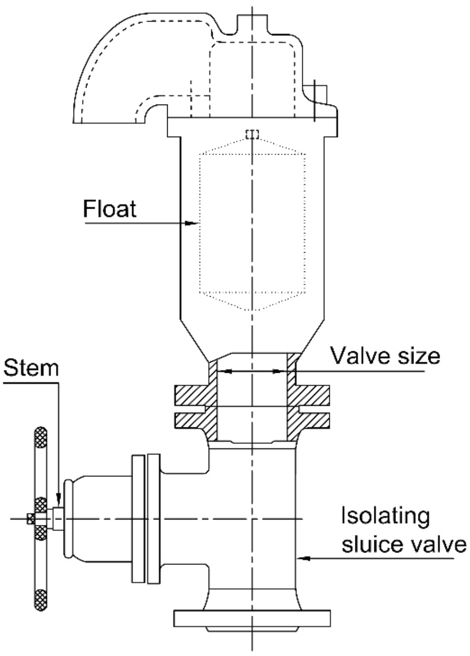
Figure 11.84: Double Air Valve with screwed down isolating valve



Major component	Material of construction
L.P.& H.P. chamber/L.P.& H.P.cover	Cast iron/Ductile iron
L.P. & H.P. ball	Vulconite/Rubber Covered timber ball
L.P./Seat	Elastomer
H.P. orifice	Gun metal
Isolating sluice valve	DF metal seated/Resilient seated
Isolating sluice valve stem	Stainless steel: AISI 410/AISI 304/AISI 316

Valve size	50Ø	80Ø	100Ø	150Ø	200Ø

Figure 11.85: Single Chamber Triple Function Air Valve



Major component	Material of construction
Body/Top cover	Ductile iron
Float assembly	S.S, AISI, 304
Seal	Elastomer
Isolating sluice valve	DIDF with resilient wedge
Isolating sluice valve stem	Stainless steel: AISI 420/AISI 410/AISI 304/AISI 316

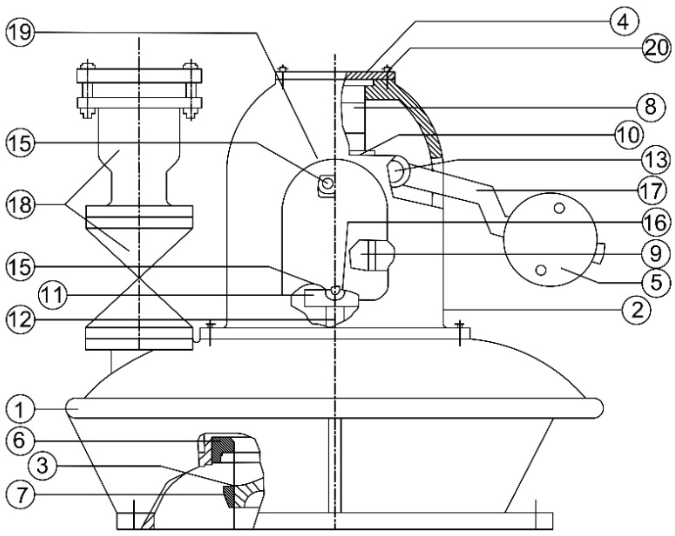
Valve Size	40Ø	50Ø	80Ø	100Ø	150Ø	200Ø

Figure 11.86: Combination of Air Valve (Tamper Proof)

(E) Anti-Vacuum Valve

The anti-vacuum valve is a very special type of air valve. Its primary function is to prevent the formation of vacuum in hydroelectric penstocks or large diameter water mains, which might cause line collapse under such conditions of flow as may result, for example, from too rapid a closure of an upstream head gate or shut down valve, a downstream burst, turbine “runaway” or ordinary emptying of a pipeline.

By virtue of its unique design, the anti-vacuum valve reacts automatically, sensitively, and positively, even after long period of inactivity, to changes of pressure within a pipe, and whenever necessary, permits air to flow in at a sufficiently high velocity, and at a low enough induction pressure, to safeguard the line against collapse. Figure 11.87 shows anti-vacuum valve.



Sr.no	Component	Qty.	Material
1	Body	1	C.I. ASTM A-126 Class B
2	Dome	1	C.I. ASTM A-126 Class B
3	Valve	1	C.I. ASTM A-126 Class B
4	Top cover	1	C.I. ASTM A-126 Class B
5	Weight	4	C.I. ASTM A-126 Class B
6	Body seat	1	Bronze BS:1400 Gr. LG2
7	Valve seat	1	Bronze BS:1400 Gr. LG2
8	Dash pot (top)	1	Bronze BS:1400 Gr. LG2
9	Dash pot (bottom)	2	Bronze BS:1400 Gr. LG2
10	Dash pot cover	1	Bronze BS:1400 Gr. LG2
11	Dash pot base plate	1	Bronze BS:1400 Gr. LG2
12	Stem	1	S.S. ASTM A-276 Type 316
13	HInge pin	1	S.S. ASTM A-276 Type 316
14	Guide pin(not shown)	1	S.S. ASTM A-276 Type 316
15	Set pin	4	S.S. ASTM A-276 Type 316
16	Lever	2	M.S.
17	Bell crank	2	D.I. ASTM A-536
18	BDO K.A.V. with I.S.V.	1	Std.
19	Inspection cover	2	C.I. ASTM A-126 Class B
20	Fasteners		S.S. AISI 304

Figure 11.87: Anti-Vacuum Valve

(F) Cowled Inlet Type

An annular cowl shrouds the orifice, affording protection to the orifice and the seating, air flows through the ports provided around the periphery of the body assembly. Application of this type should be confined to situations where no damage is likely to occur to surrounding structures from sudden intake of air.

(G) Duties

The valve automatically allows induction of large volume of air to prevent vacuum formation and also provides an automatic means of ventilating a line when it is being emptied of water and of exhausting air when it is being recharged.

(H) Operation

The valve element is in the form of a disc which is sensitively balanced by a counterpoising mechanism. The disc guide pin is attached to a crosshead, to which is fitted at either end a cranked lever that rocks about an intermediate pivot pin and carries an adjustable counterweight on its outer arm. The parts are arranged so that by adjusting the position of the counterweights, the valve can be balanced at any desired point in its working travel. Thus, when swinging freely, the valve may be balanced at a partially open position in which case, if it is closed by hand, it is self-opening to the predetermined point of equilibrium and vice versa. Also attached to the crosshead is an oil dashpot which gives free opening, in a downward direction, but offers resistance to closing, in an upward direction and avoids all possibilities of oscillation of the suspended masses. In action, therefore, the valve cannot remain at either extremity of its travel unless it is acted upon by some external force. During normal operation, the disc is held shut by the water pressure in the pipe. Should the pressure on the underside of the disc fall below that of the atmosphere, the valve will immediately open to admit air and break the vacuum. With a very small vacuum, say 1 inch of mercury or about ½ psi below atmosphere, the valve opens fully and offers a wide passage for the free flow of air. On the cessation of air inflow, the valve returns to a position of slightly open, which is sufficient for the escape of air during refilling of the line. When the rising water makes contact with the underside of disc, closure is completed; only a very small water pressure is required to close the valve. Consequently, the quantity of water overflowing through the orifice during final closure is negligible.

(I) Locating Air Valve on Pipeline

The presence of free air in the pipeline can reduce the severity of water hammer considerably. Celerity (speed) of an elastic wave with, say 2% of air at a pressure head of 50 m of water reduces celerity from about 1100 m/s to 160 m/s for a typical pipeline. On the other hand, air in a rising main, whether in solution or in bubble form, can have a number of ill effects.

Cavitation: The formation of vacuous cavities which subsequently rapidly collapse and erode the pump or pipe

Head loss: Accelerating water past air pockets formed in pipes, leading to head losses.

Other forms may include surging, corrosion, reduced pump efficiency, malfunctioning of valves or vibrations.

A pipeline designer therefore has to factor in all the aforesaid, the critical level of permissible vacuum inside a pipeline to prevent collapse I the suction and discharge capacity of an air valve (curves on request) before deciding upon the type, size, spacing, and location of these equipment. Figure 11.88 shows various locations where an air valve may be provided in the alignment.

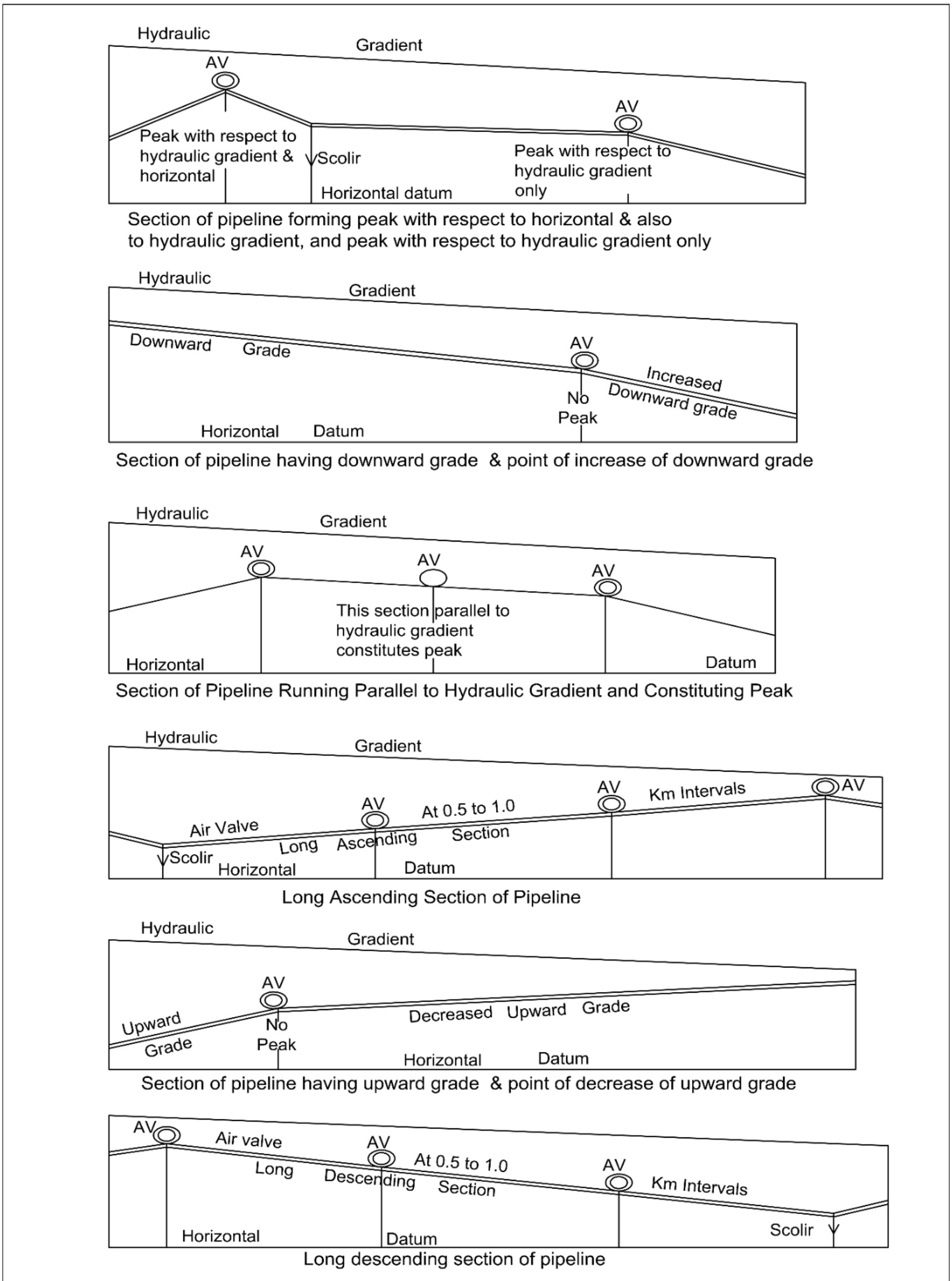


Figure 11.88: Various Locations where Air Valve may be provided in the alignment

11.23.1.7 Pressure Relief Valves

These, also called as overflow towers, are provided in one or more summits of the conveyance main to keep the pressure in the line below given value by causing water to flow to waste when the pressure builds up beyond the design value. Usually, they are spring or weight loaded and are not sufficiently responsive to rapid fluctuations of pressure to be used as surge protection devices. The conventional pressure relief valve is characterised by a rapid pop action or by opening proportionally to the increase in pressure with respect to the opening pressure of the valve.

The main parts of the conventional pressure relief valve include the body, bonnet, disc, disc holder, seat, and spring. Based on the seating material, conventional pressure relief valves are classified as metal-seated valves and soft seated valves. See the image belowcfor clarity.

There are three types of pressure relief devices:

1. Reclosing-type pressure relief devices
2. Non-reclosing type pressure relief devices
3. Vacuum relief devices

(A) Safety Relief Valves

- A safety relief valve has a combined characteristic of a safety valve and a relief valve. It performs as a safety valve, open by pop-up action when used in a compressible gas system and performs like a relief valve, opens in proportion to the overpressure when used in liquid systems.
- Different types of safety relief valves are used in process piping.
- These valves are classified as conventional type, pilot-operated, balanced bellows type, power actuated, and temperature actuated type. Figure 11.89 shows pressure relief valve diagram.

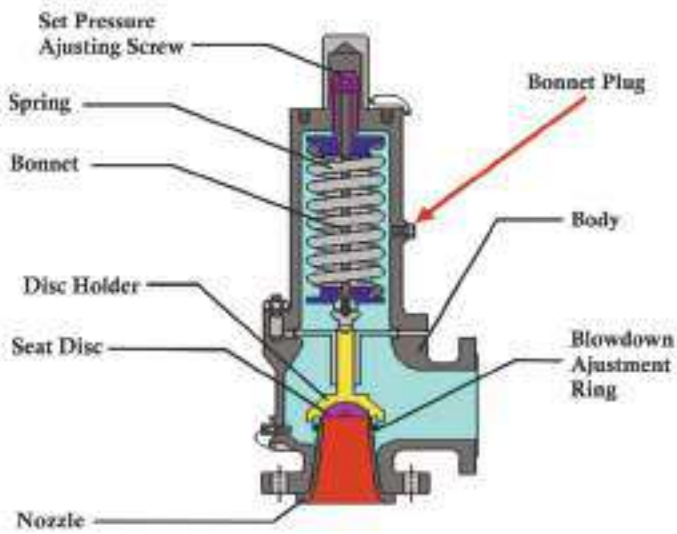


Figure 11.89: Pressure Relief Valve Diagram

During normal operating conditions, the pressure at the inlet is below the set pressure, and the disc remains seated on the nozzle, preventing flow through the nozzle.

The working principle of a conventional spring-loaded pressure relief valve is based on the balance of force. That means the spring load will keep the disc on the seat till the system pressure is less than the spring force.

This pressure is known as set pressure. The disc remains seated on the seat in the closed position till the inlet pressure exceeds set pressure and overcome the spring force. When the inlet pressure is reduced to a level below the set pressure spring force, close the valve.

Conventional pressure relief valves are used for applications where an excessive variable or built-up back pressure is not present. Back pressure will directly affect the valve performance. A pressure built-up on the outlet side of PSV is known as back pressure. More details on back pressure in the section on bellows-type PSV.

(B) Advantages and Disadvantage of Conventional PRV

Advantage	Disadvantage
It can be used in all kinds of gas and liquid services	Backpressure can affect the functioning of the valve
Suitable for high pressure and temperature services	Spring is subjected to corrosion if service material is corrosive

(C) Vacuum Relief Valve

A simple vent can provide protection against vacuum. Our home water storage tanks are fitted with this kind of simple vent. But in a industrial tank which stores various chemical sand hydrocarbon, this simple vent may release vapour of these products in an atmosphere, which can be odorous, toxic, and potentially hazardous. To avoid such release, special vacuum relief valves are used.

(D) Pressure Vacuum Relief Valve -PVRV

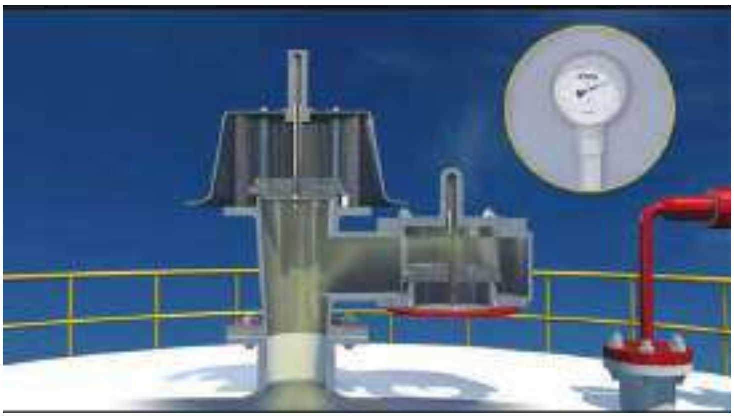


Figure 11.90: Pressure Vacuum Relief Valve -PVRV

The pressure vacuum relief valve or pressure vacuum vent is designed to maintain a tight seal until the system pressure or vacuum exceeds the set pressure of the valve. When overpressure occurs, the pressure lifts the disc just like a safety valve, allowing vapours to pass. Figure 11.90 shows a pressure vacuum relief valve (PVRV).

When a vacuum occurs, vacuum lifts the disc and lets the air inside to break the vacuum. It is like the breathing of a tank. This PVRV arrangement prevents continuous vapour loss to the atmosphere as it opens only when the set pressure is reached. You can see the image for a better understanding.

11.23.1.8 Diaphragm Valve

(A) The History of the Diaphragm Valve

The diaphragm valve traces its origins back to the ancient Roman and Greek times, where it was used to control the water and temperature of the hot baths. With a crude leather diaphragm that was manually closed over a weir, it was a primitive but effective control valve.

In the early 1900s, a South African mining engineer by the name of P. K. Saunders was charged with the project to cut the costly power losses due to faulty, leaking seats and stuffing boxes of the valves used to supply air and water in the underground mines. Saunders was interested in ancient history and archaeology as a hobby and stumbled upon the use of control valves used in the baths. He utilised this concept to develop the first modern diaphragm valve. Many patents were filed in his name for this valve and in 1931, the Hills McCanna Company became the first licensee to manufacture the Saunders patent diaphragm valve in the United States. Soon after that, others entered the business such as Grinell (ITT Diameter Flow), Dow Chemical, and Arco Winn.

With the advent of a variety of advanced plastics and elastomeric materials that could be used in the internal construction of this valve, its sales growth was remarkable; however, it soon became apparent that a reliable actuator to automate it efficiently was urgently required.

Diaphragm valves (or membrane valves) consist of a valve body with two or more ports, an elastomeric diaphragm“, and a "weir saddle" or seat upon which the diaphragm closes the valve. The valve body may be constructed from plastic, metal, wood or other materials depending on the intended use. Figure 11.91 shows diaphragm valve – rubber lined.

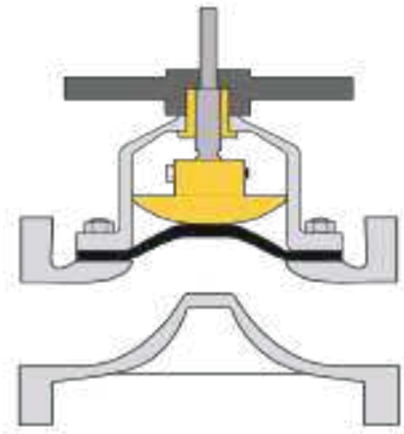


Figure 11.91: Diaphragm Valve – Rubber lined

(B) Categories

There are two main categories of diaphragm valves:

1. Weir-type (saddle) seals over a weir; and
2. Full bore or straight-through valve seals over a seat.

In general, straight-through diaphragm valves are used in on-off applications and weir-type diaphragm valves are used for control or throttling applications.

While diaphragm valves usually come in two-port forms (2/2-way diaphragm valve), they can also come with three ports (3/2-way diaphragm valves also called T-valves) and more (so-called block-valves). When more than three ports are included, they generally require more than one diaphragm seat; however, special dual actuators can handle more ports with one membrane.

Diaphragm valves can be manual or automated. Automated diaphragm valves may use pneumatic, hydraulic, or electric actuators along with accessories such as solenoid valves, limit switches and positioners.

In addition to the well-known, two-way shut-off or throttling diaphragm valve, other types include: three-way zero dead leg valve, sterile access port, block and bleed, valbow and tank bottom valve.

(C) Valve body

Many diaphragm valve body dimensions follow the Manufacturers Standardisation Society MSS SP-88. However, most non-diaphragm valves used in industrial applications are built to the ANSI/ASME B16.10 Standard. The different standards make it difficult to use diaphragm valves as an alternative to most other industrial valves. Some manufacturers offer diaphragm valves that conform to ANSI B16.10 standards thereby making these diaphragm valves interchangeable with most solid wedge, double-disc, and resilient wedge gate valves as well as short pattern plug and ball valves.

(D) Actuators

Diaphragm valves can be controlled by various types of actuators, e.g., manual, pneumatic, hydraulic, electric, etc. The most common diaphragm valves use pneumatic actuators; in this type of valve, air pressure is applied through a pilot valve into the actuator which in turn raises the diaphragm and opens the valve. This type of valve is one of the more common valves used in operations where valve speed is a necessity.

Hydraulic diaphragm valves also exist for higher pressure and lower speed operations. Many diaphragm valves are also controlled manually.

(E) Body Materials

a. Wood
b. Brass
c. Steel type:
    i. Cast Iron
    ii. Ductile iron
    iii. Carbon steel
    iv. Stainless steel
    v. Alloy 20
d. Plastic type:
    i. ABS (Acrylonitrile butadiene styrene)
    ii. PVC-U (Polyvinyl chloride, un-plasticised) also known as PVCu or uPVC
    iii. PVC-C (Polyvinyl chloride, post chlorinated) also known as PVCc or cPVC
    iv. PP (Polypropylene)
    v. PE (Polyethylene) also known as LDPE, MDPE and HDPE (see note)
    vi. PVDF (Polyvinylidene fluoride)
    vii. PTFE
    viii. PFA

(F) Body lining materials

Depending on temperature, pressure, and chemical resistance, one of the following is used:

- Unlined type
- Rubber lined type:
    - NR/Hard Rubber/Ebonite
    - BR/Soft rubber
    - EPDM
    - BUNA-N
    - Neoprene
- Fluorine plastic lined type

  - FEP
  - PFA
  - PO
  - PP
  - Tefzel
  - KYNAR
  - XYLON
  - HALAR
- Glass lined (green glass or blue glass)

(G) Diaphragm materials

- Unlined or rubber lined type:
  - NR/Natural rubber
  - NBR/Nitrile/Buna-N
  - EPDM
  - FKM/Viton
  - BUNA-N
  - SI/Silicone rubber
  - Leather
  - Fluorine Plastic Type:
  - FEP, with EPDM backing
  - PTFE, with EPDM backing
  - PFA, with EPDM backing

(H) Applications

Diaphragm valves are ideally suited for:

- Corrosive applications, where the body and diaphragm materials can be chosen for chemical compatibility (e.g., acids, bases, etc.)
- Abrasive applications, where the body lining can be designed to withstand abrasion and the diaphragm can be easily replaced once worn out
- Solids entrained liquids, since the diaphragm can seal around any entrained solids and provide positive seal
- Slurries, since the diaphragm can seal around entrained solids and provide positive seal
- Water and wastewater
- Power
- Pulp and Paper
- Chemical
- Cement
- Mining and m
- Pharmaceutical and bioprocessing

11.23.1.9 Scour Valve (Drain Valve)

Scour valves shall be installed at low points or to facilitate draining of a water main where required by the water supply operations manager. In areas where the scouring of mains is needed as a frequent operation, a connection to the storm water curb outlets, open channels or catch it shall be provided. The connection of a scour valve to storm water pipes or manholes is not permitted. Figure 11.92 shows scour valve (drain valve).

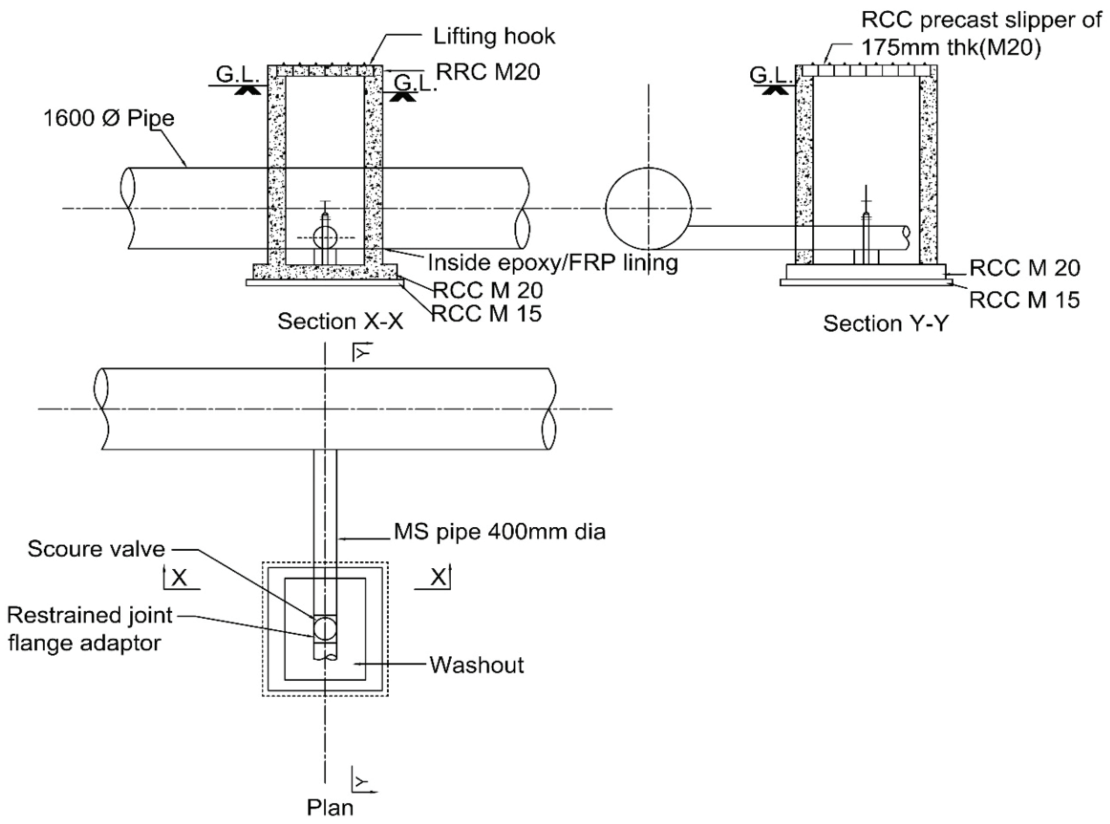


Figure 11.92: Scour Valve (Drain Valve)

11.23.1.10 Check Valves (OR) Non-Return Valves (NRV)

Check valves, also called non-return valves or reflux valves, automatically prevent reversal of flow in a pipeline. They are particularly useful in pumping mains when positioned near pumping stations to prevent backflow when pumps shut down. The closure of the valve should be such that it will not set up excessive shock conditions within the system. For more details of swing check reflux valves, reference may be made to IS 5312 – Pt I - 1984 and Pt II - 1986. The valve that used to prevent backflow in a piping system is known as a check–valve. It is also known as a non-return valve or NRV. The pressure of the fluid passing through a pipeline opens the valve, while any reversal of flow will close the valve.

It allows full unobstructed flow and automatically shuts as pressure decreases. The exact operation will vary depending on the mechanism of the valve.

11.23.1.11 Pump bypass reflux valve

One of the simplest arrangements for protecting a pumping main against water hammer is a reflux valve installed in parallel with the pump. The reflux or non-return valve would discharge only in the same direction as the pumps.

Under normal pumping conditions, the pumping head would be higher than the suction head and the pressure difference would maintain the reflux valve in a closed position. On stopping the pumps, the head in the delivery pipe would tend to drop below the suction head, in which case water would be drawn through the bypass valve. The pressure would therefore only drop to the suction pressure less any friction loss in the bypass. The return wave over pressure would be reduced correspondingly.

This method of water hammer protection cannot be used in all cases, as the delivery pressure will almost never drop below the suction pressure. In other cases, there may still be an appreciable water hammer overpressure (equal in value to the initial drop in pressure).

This method is used only when the pumping head is considerably less. In addition, the initial drop in pressure along the entire pipeline length should be tolerable. The suction reservoir level should also be relatively high or there may still be column separation in the delivery line. Figure 11.93 shows pump with bypass reflux valve.

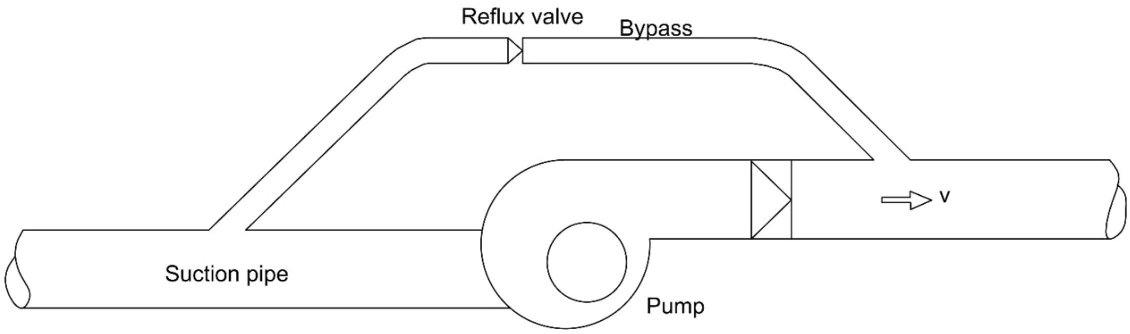


Figure 11.93: Pump with Bypass Reflux Valve

(A) Parts of non-return valve

It consists of a body, cover, disc, hinge pin, and seat ring. In the image below, you can see the parts of the valve. Figure 11.94 shows parts of NRV.

Sr No	Check Valve
1	Body
2	Cover plate
3	Disc
4	Body seats
5	Hinge
6	Hinge pin
7	Nut
8	Cotter pin
9	nuts
10	Stud bolts
11	gasket
12	Washer

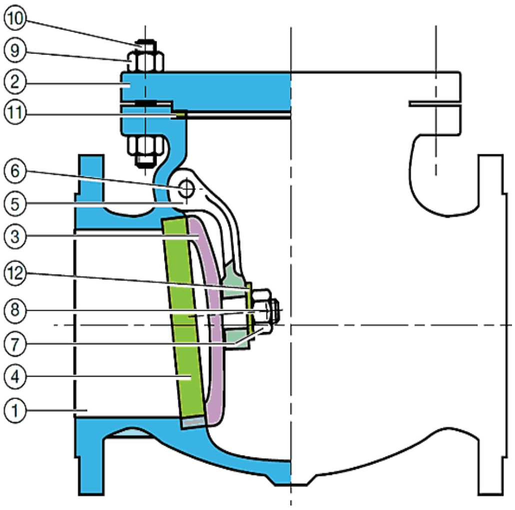


Figure 11.94: Parts of NRV

Source –f Image - TROUVAY & CAUVIN

(B) Types of check valves (non-return valve)

The type of disc will decide the type of valve. Most common types of check valves are

- Swing Type
  - Top hinged
  - Tilting disc
- Lift type
  - Piston type

- Ball-type
- Dual plate type
- Stop check valve

(C) Swing check valve

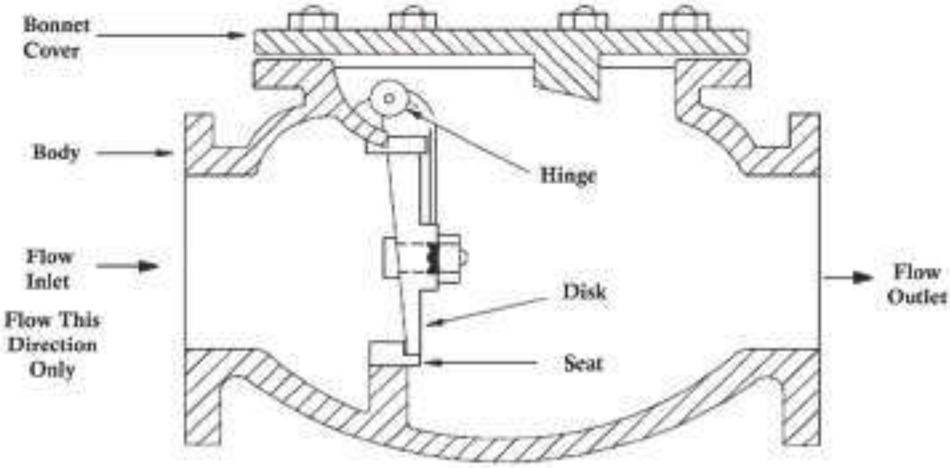


Figure 11.95: Swing Check Valve
Source of Image - DOE Handbook

The disc in a swing type valve is unguided as it fully opens or closes. This valve operates when there is flow in the line and get fully closed when there is no flow. Turbulence and pressure drop in the valve is very low. Disc and seat designs can be of metal-to-metal or metal-to-composite. Figure 11.95 shows swing check valve.

The angle between the seat and the vertical plane is known as the seating angle and varies from 0 to 45 degrees. Usually, the seat angles are in the range of 5 to 7 degrees. Larger seat angles reduce the disc travel, resulting in quick closing, thus minimising the possibility of water hammer. A vertical seat has a 0-degree angle.

The swing type valve allows full, unobstructed flow and automatically closes as pressure decreases, usually installed in combination with gate valves because they provide relatively free flow combinations.

A basic swing type valve consists of a valve body, a bonnet, and a disc that is connected to a hinge.

(D) Tilting disc check valve

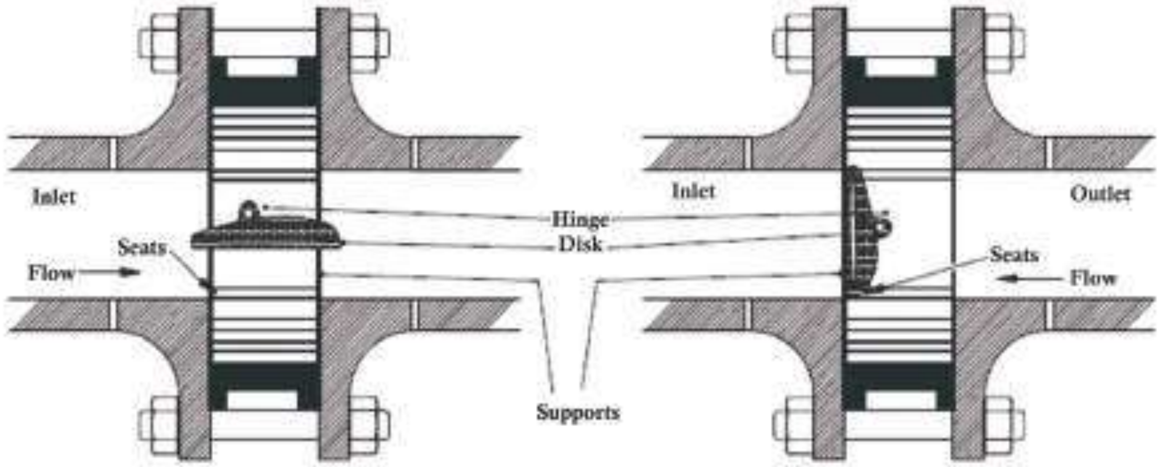


Figure 11.96: Tilting Disc Check Valve
Source of Image – DOE Handbook

The tilting disc type valve is designed to overcome some of the weaknesses of conventional swing type valves. The design of the tilting disc enables the valve to open fully and remain steady at lower flow rates and close quickly when the forwarding flow stop. Figure 11.96 shows tilting disc check valve.

The dome-shaped disc floats in the flow and fluid flow on both the bottom and top of the disc surfaces. As the disc is spring loaded, when forward flow pressure decrases, the spring force helps the valve to close fast. In the image above, you can see the flow from the valve.

Tilting disc type valve is available in wafer type and lug type design.

(E) Ball Type and plug type lift NRV

The seat design of a lift check valve is similar to a globe valve. A piston or a ball are often used as a disc.

Lift check valves are particularly suitable for high-pressure service where the velocity of flow is high. The disc is perfectly set on the seat with full contact. They are suitable for installation in horizontal or vertical pipelines with upward flow.

When the flow enters below the seat, a disc is raised from the seat by the pressure of the upward flow. When the flow stops or reverses, the backflow and gravity forced the disc downward to set on the seat. Commonly used in piping systems that used globe valves as a flow control valve. Figure 11.97 shows a plug type check valve and Figure 11.98 shows a ball-type check valve.

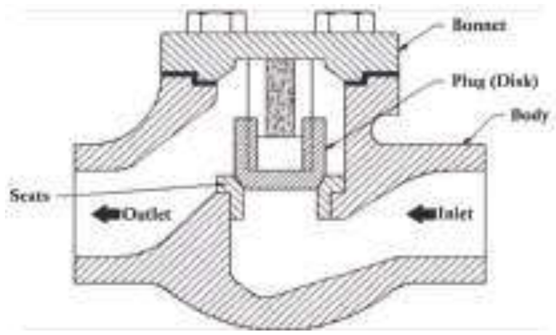


Figure 11.97: Plug Type Check Valve

Figure 11.98: Ball-Type Check Valve

The figures above show a plug or piston type and a ball-type check valve. These valves provide superior leak-tight characteristics to those of swing check valves.

Some designs in plug type valves use spring to retain the disc in a closed position. This will ensure that the valve allows fluid flow only when there is enough pressure in the flow direction.

A ball-type valve is very simple as it simply works on the principle of gravity. When there is enough pressure in the flow, it lifts the ball upward but when pressure is reduced, the ball rolls down and closes the opening.

(F) Stop check valve

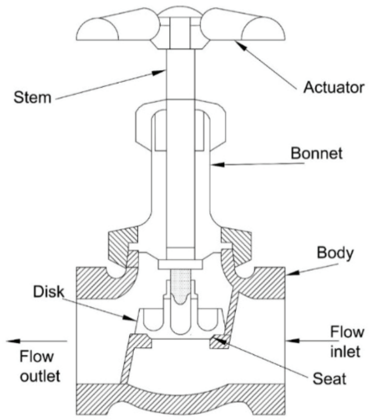


Figure 11.99: Stop Check Valve
Source of Image- DOE Handbook

Stop check valve is a combination of a lift check valve and a globe valve. It can either be used as a check valve or as an isolation (stop) valve like a globe valve. These valves can be closed with the help of a stem that is not connected to the valve disc during normal operation and make it possible to use these valves as a regular NRV. Figure 11.99 shows a stop check valve.

However, when needed, the stem is used to hold the free-floating disc against the valve seat, just as a globe valve. These valves are available in tee, wye, and angle patterns. Swing type and piston lift type valves are commonly used as stop check valves.

(G) Dual plate check valves

Dual plate check valves employ two spring-loaded plates hinged on a central hinge pin. When the flow decreases, the plates close by torsion spring action without requiring reverse flow. As compared to conventional swing check valves which operates on mass movement, the dual plate check valve are provided with accurately designed and tested torsion springs to suit the varying flow conditions. The dual plate check valves are of non-slamming type and arrest the tendency of reversal of flow. Presently, there is no IS for the dual plate check valves. Figure 11.100 shows dual plate check valve.

Figure 11.100: Dual Plate check valve

A dual plate check valve also known as a butterfly check valve, folding disc check valve, double-disc, or split disc check valve. As the name suggests, the two halves of the disc move towards centreline with the forward flow and with reverse flow, the two halves open and rest on the seat to close the flow (flapping action).

(H) Application of check valve (NRV)

Check valves (non-return valve) are used in a piping system to prevent backflow. The discharge line of rotary equipment such as pump and compressor is always fitted with a check valve to prevent backflow. Use of a dual plate check valve is popular in low-pressure liquid and gaseous services. Its light weight and compact construction make it a preferable choice when space and convenience are important. It is 80% to 90% lighter than the conventional full body check valve. It is frequently used in systems that used butterfly valves. The cost of installation and maintenance is very low compared to other types.

Properties of a dual plate check valve:

a. Compact, light, self-supporting, rugged design, and economical.
b. Low-pressure drops, thus, lower energy loss.
c. Total flexibility in installation – horizontal to vertical.
d. Valve closer at zero velocity – hence no valve induced water hammer.
e. Inherently non-slamming design without any external fitments.
f. Technically superior to swing check valve including multi door swing check valve.
g. Streamlined flow path.

Property of a swing check valve

a. Bulky and voluminous thus cumbersome handling and heavier supporting system.
b. Large and difficult to analyse from stress concentration point in critical application due to intricate body shape.
c. Suitable primarily for horizontal application.
d. Not possible significant pressure loss and energy loss, which is still higher for higher pressure ratings.
e. Swing restricted flow-path.
f. Always require reverse flow for closure and back pressure for effective sealing.
g. External attachments required to counteract slamming.

h. Water hammer tendency persists.
i. Seat and hinge pin require regular maintenance due to impact loads and wear by rubbing.

11.23.1.12 Ball Valves or Ball Float Valves

Ball valves or ball float valves are used to maintain a constant level in a service reservoir or elevated tank or standpipe. The equilibrium type of valve is the most effective as it is designed to ensure that the forces on each side of the piston are nearly balanced. For severe operating conditions, a more expensive needle-type valve will give better service.

In both cases, the float follows the water level in the reservoir and permits the valve to admit additional water on a falling level and less water on a rising level and to close entirely when the overflow level is reached. The disadvantage of this system is that the valve may operate for long periods in a throttled condition, but this can be avoided by arranging for the float to function in a small auxiliary cylinder or a tank. When the water reaches the top of the auxiliary tank, the ball will rise fairly quickly from the fully open position to the closed position without shock. The valve will not open again until the water level in the reservoir reaches the base of the auxiliary tank, at which point the water will drain away and the ball valve will move to the fully open position. With this method the valve is not in a state of almost continuous movement and throttling and erosion of the seats are avoided.

Automatic Shut-Off Valves

These are used on the mains to close automatically when the velocity in the mains exceeds a predetermined valve in case of accident to the line.

Automatic Burst Control

With large steel mains suitably protected against corrosion and laid properly, particularly at change of direction and the ground is not liable to subsidence, the possibility of a major burst is ruled out.

The simplest arrangement as explained in 11.25.1.7(c) is to insert an interrupter timer in the motor circuit so arranged that the final quarter travel of a sluice valve occurs in slow steps to the point of closure. The costlier arrangement will be insertion of a smaller power operated bypass valve alongside the main valve and provision of automatic control arrangements for the main valve to close first at a fairly rapid rate, followed by the smaller bypass valve at a much lower speed.

Plug Valve

Plug valve is a quarter turn rotary motion Valve that uses a tapered or cylindrical plug to stop or start the flow. The disc is in plug shape, which has a passage to pass the flow.

In the open position, this bored passage is in line with the flow. When the plug is turned 90° from the open position, the solid part of the plug blocks the flow.

It is used in place of a gate valve where quick operation is required. It can be used in high-pressure temperature services.

(A) Types of Plug Valves

These valves are available in either a lubricated or non-lubricated design and with different styles of port openings through the plug.

a) Lubricated plug valve

The plug inside a lubricated plug valve has a cavity in the middle along its axis. You can see this in the image below. Lubricant chamber at the bottom and the sealant injection fitting at the top ensure the supply of lubricant.

The small check valve below the injection fitting prevents the sealant from flowing in the reverse direction once the sealant is injected into the cavity.

Plug surface gets constantly lubricated by the sealant that moves from the centre cavity through radial holes into lubricant grooves on the plug surface.

The narrow gap around the plug may allow leakage, and if the gap is reduced further, it will increase the friction and the plug may get stuck inside the valve body. Figure 11.101 shows a plug valve.

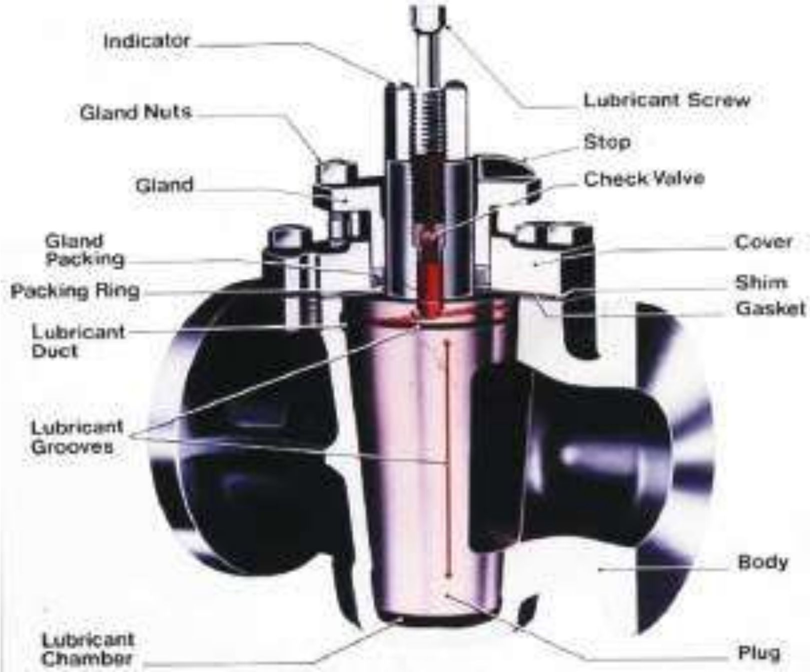


Figure 11.101: Plug Valve
Source of Image - Serck Audco, Newport

The lubricant reduces the force required to open or close the valve and allows smooth movement of the plug. It also prevents corrosion of the plug.

The lubricant material must be compatible with the fluid of the pipeline. It should not dissolve or wash away by the flow medium as this could contaminate the fluid and damage the seal between the plug and the body, resulting in leakage. Also, the sealant used must be able to withstand the temperature of the flow medium.

Lubricated plug valves are available in the large size range, and they are fit to work in high-pressure temperature services. These valves are subject to less wear and provide better corrosion resistance in some service environments.

b) Non-lubricated plug valves

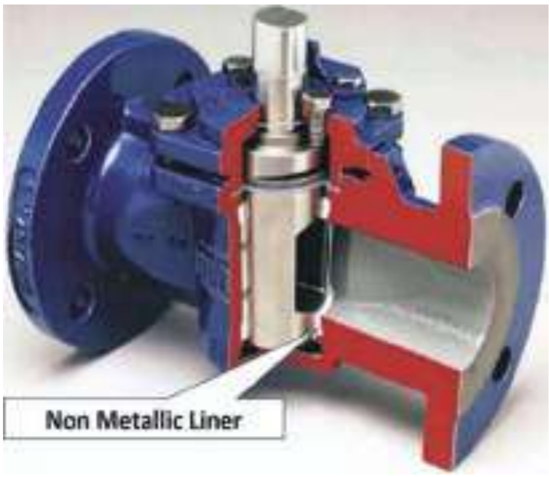


Figure 11.102: Typical non-lubricated plug valve

A non-metallic elastomeric sleeve or liner is used in this type of valve. This sleeve is installed in the body cavity of the valve. The polished tapered plug acts as a wedge and presses the sleeve against the body. Figure 11.102 shows **a** typical non-lubricated plug valve.

This non-metallic sleeve reduces the friction between the plug and the valve body. Non-lubricating plug valves required minimum maintenance. Due to the non-metallic seat, these valves are not used in high-temperature services.

Lubricating and non-lubricating valves are capable of providing a bubble-tight shutoff and are of compact size.

c) Multi-port plug valves

Below is the figure of a three-way multi-port plug valve. The top image is of three-way three-port design and the bottom is a three-way two-port design. Figure 11.103 shows a four-way design of multi-port plug valves.

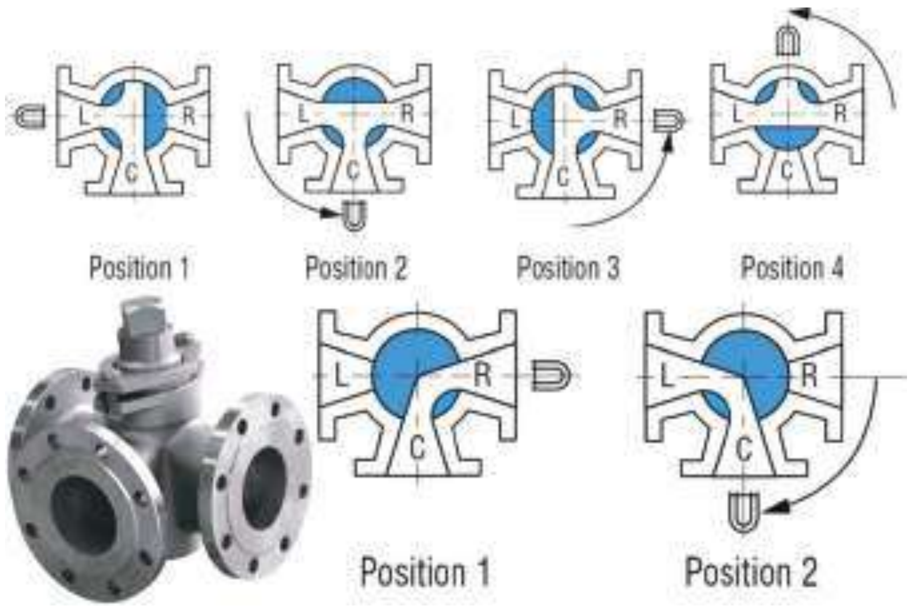


Figure 11.103: Four-way design of Multi-Port Plug Valves

Multi-port valves are used in transfer lines and for diverting services. A single multi-port valve may serve the purpose of three or four gate valves or other types of the shutoff valve.

However, sometimes the multi-port valve does not completely shut off flow. Great care should be taken in specifying the particular port arrangement for proper operation.

(B) Plug Valve Parts

The typical plug valve consists of a body, bonnet, stem, and plug. The seat is an integral part of the body in the case of a lubricated type. For a non-lubricated type, a non-metallic seat is used to improve leak tightness of the valve. Figure 11.104 shows a plug valve parts.

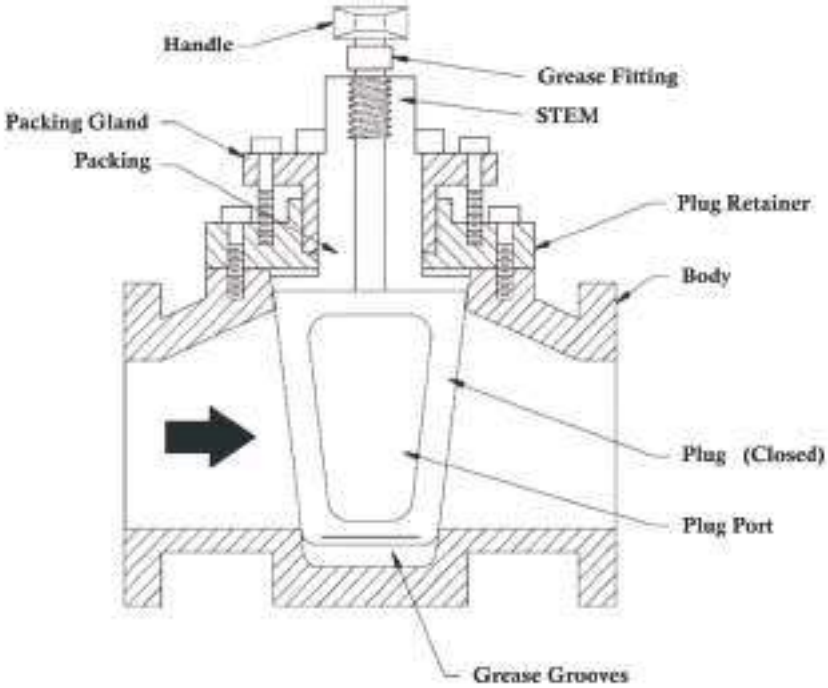


Figure 11.104: Plug Valve Parts

Source of Image – DOE Handbook Plug Valve Disc Types

Plugs are either round or taper cylinder. They may have various types of port openings, each with a varying degree of the opening area.

Plugs are available with

- Rectangular Port

- Round Port and
- Diamond Port

Rectangular Port is the most common for a plug valve. The rectangular port represents at least 70% of the corresponding pipe's cross-sectional area.

Round port plug has a round opening through the plug. It is available in full bore and reduced bore design. Valves with reduced ports are used only where restriction of flow is not important.

Diamond Port plug has a diamond-shaped port through the plug. All diamond port valves are venturi restricted flow type. This design is for throttling service.

(C) Application of valve

- This valve is used as on-off stop valves and capable of providing bubble-tight shut-off.
- It can be used in different types of fluid services such as air, gaseous, vapour, hydrocarbon, slurries, mud, and sewage applications.
- Also used in a vacuum to high pressure and temperature applications.

(D) Advantages and disadvantage

Advantages	Disadvantages
Simple design with few parts	It requires greater force to operate, due to high friction
Quick to open or close	Larger valves cannot be operated manually and required an actuator
In-line maintenance possible	Pressure drop due to reducing port
Offers minimal resistance to flow	Cost of plug valves may be more than ball valves for given size and class
Provides reliable leak-tight service	
Multiple port design helps reduce the number of valves needed and permits a change in a flow direction	

11.23.1.13 Smart Valves

(A) General

The Hydraulic Engineers were using sluice valves, gate valves, or butterfly valves from years together, not only for isolation but also for regulating the flow of water on ground. It was a regular practice to throttle the valves by adjusting the threads to control the flow. This adjustment was completely dependent on the years of experience of the valve person. Even though regulation of flow to some extent could be achieved, still, the lacuna of accuracy existed.

With the advent of modern technology, the manual adjustment by means of throttling was replaced by electrical actuators. Although human intervention got reduced, but the operation cost due to power consumption increased. Also, the valves were unable to function in case of power failure.

To isolate and drain pipe sections for testing, installation, cleaning and repairs, a number of appurtenances or auxiliaries are generally installed in the line like line valves, scour valves, air valves, kinetic air valves, pressure relief valves, check valves, etc.

To overcome all the difficulties faced due to the aforesaid valves, the concept of control valves was introduced. Precision in controlling flow, pressure and other hydraulic parameters could now be achieved. Human intervention has been reduced and the hydraulic engineer got an option to select between hydraulically and electrically operated valves or electronic valves depending on the geographic conditions of the service area in the cities/towns.

Control valves are smart valves used to control the hydraulic parameter (flow/pressure) at varying degrees between minimal flow and full capacity in response to command from a control device. The hydraulic parameter is controlled by varying the size of flow passage as regulated by the control device. This also enables consequential steering of combination of hydraulic parameters.

Problems are inevitably faced by field engineers related to management of water in highly elevated areas, distant service reservoirs, untimely filling of reservoirs, uncontrolled water supply (pressure, flow, and level management in distribution network) and reduction in non-revenue water (NRW). These aforesaid problems result in unequal distribution of water in the service areas. If control valves are used smartly, it shall resolve most of the hydraulic issues as mentioned above. Sizing of these types of valves should be decided on the basis of required hydraulic applications.

In order to procure the optimal size and to ensure no cavitation, the following information must be provided for each main valve size required in the project:

a) Upstream pressure available,
b) Maximum flow rate,
c) Minimum flow rate,
d) Residual pressure at the control valve,
e) Maximum level of reservoir (in case of elevated service reservoir management).

(B) Functions of Control Valves and its Types

Depending on the purpose of its service, control valves may be classified as under:

1. **Flow control valve (FCV):** This valve sets a fixed flow at the downstream. An adjustable differential pilot valve, sensing the pressures across the orifice plate, is set to maintain a preset differential, hence the flow rate. The pilot opens the main valve if the flow is below the required value or closes it when the flow exceeds the desired rate. Figure 11.105 shows a typical FCV.

Figure 11.105: Typical FCV

2. **Pressure reducing valve (PRV):** This valve sets a fixed pressure at the downstream when opened. An adjustable pilot valve, sensing the pressures downstream of the valve, is set to maintain a preset pressure regardless of fluctuations upstream. (Note: The calculated cavitation factor of a valve should be higher than that claimed by the manufacturer. Otherwise, an anti-cavitation kit or step reduction of pressure by installing multiple pressure reducing valves should be deployed). Figure 11.106 shows a typical PRV.

Figure 11.106: Typical PRV

3. **Pressure reducing valve with flow control:** This valve sets a combination of fixed pressure at the downstream when opened or the fixed flow rate at the downstream when opened regardless of fluctuations in the values of upstream pressure and demand. Figure 11.107 shows a PRV with flow control.

Figure 11.107: PRV with Flow Control

4. **Level control valve (float type or altitude type):** The altitude pilot is located at the valve and the float pilot is located in the tank at the intended maximal level. It is connected to the main valve by control tubes, which convey the inlet pressure of the valve to the control chamber when the level reaches the maximal point, thus, closing the valve and preventing overflow. When the water level drops, due to demand from the tank, the altitude/float pilot opens the top of the control tube that connects to the control chamber, allowing the water in it to drain and the main valve to open. Figure 11.108 shows a level control valve.

[Cavitation factor sc = $(P_1 – P_v)/(P_1-P_2)$ where P_1 = upstream pressure, P_2 = downstream pressure, P_v = Vapour Pressure]

Figure 11.108: Level Control Valve

5. **Flow control valve with timer:** This is a flow control valve with timer controller to set the times of operation without any external energy. The valve opens and shut as per the programmed

time. The valve can be actuated with a 9V battery as well if a latching solenoid (NC) is placed before the rate of flow control pilot. Figure 11.109 shows an FCV with timer.

Figure 11.109: FCV with timer

6. **Flow control valve with level control:** This is a flow control valve with the capability to control level. When the level is high, the valve closes and when level reaches the set point, it opens. The valve sets a fixed flow at the downstream when opened, the valve can be installed at the ERS/OHT inlet as well. The valve will maintain the tank level and prevent overflowing as well as feed the tank at a preset and a relatively fixed flow rate. The valve can help in equitable filling up of the water towers connected to common feeders. Figure 11.110 shows an FCV with level control.

Figure 11.110: FCV with level control

7. **Pressure sustaining and relief valve:** This valve maintains upstream pressure, regardless of flow-rate variations. The valve will be in the “closed” position if the upstream pressure drops below the set point and will fully open when the upstream pressure exceeds the set point. This valve helps in sustaining the HGL as well as pressure to a critical user. Figure 11.111 shows a pressure sustaining and relief valve.

Figure 11.111: Pressure Sustaining and Relief Valve

8. **Surge anticipation valve:** This valve is installed on a tee junction on the discharge manifold or the main pipeline, downstream of the check valves of the pumping station. The valve opens instantly when the pressure at the site drops below the static value due to initial low-pressure wave generated by the pump stoppage. The valve stays in "opened" position until the returning flow arrives to the station and will be sized to allow draining of part of it. The velocity changes of the returning flow, when stopped by the already closed check valves, will not generate excessive transient pressures. When the pressure rises above the opening point, the valve starts closing gradually at an adjustable pace. In case of too-fast closure, that may cause pressure surge, the valve will function as a relief valve, re-opening slightly to increase the released flow rate thus preventing overpressure in the pump site.

The above listed functions are controlled by hydromechanical pilot valves – a low pressure pilot that opens the valve through the low-pressure wave, and high-pressure pilot which opens the valve in case the pressure exceeds the allowed maximum. Both pilots are adjustable by the operator. A simulating assembly, containing a pressure gauge, should be a part of the control circuit. It allows adjustment of the low-pressure pilot to the designed opening point, without stopping the pumps.

A drainpipe should be assembled at the outlet of the surge anticipation valve to transport the drained water back to the pumps suction pit or to another location, where the high velocity flow will not cause flood damage. To cease high hydraulic resistance and excessive side-stress in the elbows, the drainage pipe should be sized to avoid excessive velocity. In most of the cases, the drainage pipes are larger than the control valves. The valve can also be electrically timed as well where the static head is low. In such case, the low-pressure sensing pilot is replaced with a solenoid and a special surge anticipating panel and a UPS for energising the solenoid valve. Figure 11.112 shows surge anticipating valve with solenoid and Figure 11.113 shows dual pilot surge anticipating valve.

Figure 11.112: Surge Anticipating Valve with Solenoid

Figure 11.113: Dual Pilot Surge Anticipating Valve

9. **Pump control valve:** A pump control valve automatically regulates the pump start-up and shutdown in a time controlled to minimise system hydraulic surges. The pump control valve is electrically interfaced with the pump motor, the pump control valve "opens" and "closes" at an adjustable speed, providing a smooth, predictable transition of pump discharge flow into the system. The valve is installed at the outlet of pump discharge. The valve is controlled by an electric solenoid valve. The pump control valve automatically adjusts to provide constant pressure at different flows and works with any pump. (Note: However, the utilisation of these valves is neither mandatory nor limited to the applications cited. The engineer can use the control valves as per his discretion after verification of the hydraulic conditions of the site). Pump control valve needs to be operated by a special panel for opening, closing sequencing co-ordinated with the main pump panel. Figure 11.114 shows a pump control valve.

Figure 11.114: Pump Control Valve

(C) Design

All the control valves mentioned above from a) to h) are available in two types of design which are the diaphragm actuated control valve and the plunger type control valve. These are explained in following sections.

(D) Diaphragm Actuated Control Valve

This type of valve can further be classified into following categories:

I) Globe-type control valve

All the functions, viz., opening, closing, and regulation are done by stem assembly actuated by diaphragm. It contains manyparts like stem, seat, diaphragm, centring guide, etc. When the ratio of upstream and downstream pressure is more than 3:1, globe- type valve can be used with anti-cavitation kit. This is a robust valve and can handle high-pressure differentials in the water network. Such valve can also be used as a check valve. Although the diaphragm in this type of valve requires replacement once in seven years. The dynamic O-ring can get worn off if there is problem in water quality and thus leading to internal leakage. Since it involves so many parts, this valve is comparatively heavy.

II) Weir-type control valve

All the functions, viz., opening, closing and regulation are performed by a diaphragm. The diaphragm and the spring are the only moving parts, thereby making it lighter and easier to repair. The diaphragm needs replacement once in five years. When the ratio of upstream and downstream pressure is more than 3:1, weir-type valve can be used in a step-down manner implying utilisation of two or more valves and thereby leading to an increase in capital cost.

Both the globe-type and weir-type valves are available in the following three types such as:

(a) **Hydraulically pilot-operated control valve –** This is a pilot-operated valve. The number of pilots is dependent on the application, such that the control parameters are not hydraulically contradictory. This pilot will be a direct acting adjustable spring device, maintaining any set point as the prescribed value, regardless of flow or upstream pressure variations. If thevalve has to perform the function of both level and flow control, there would be two pilots – one for the flow and the other for the level. The pilot governing the closure would be considered as master pilot. For example, in case of pressure reducing cum flow control valve, if the fixed and set pressure of 45 m is attained prior to attaining the set flow rate of 50 cum/hr., the pilot designated for pressure would dictate the closure of the valve and would be called the master pilot. This type of valve does not require electricity and should be preferred where the set points are fixed.

(b) **Hydraulically pilot-operated control valve with single solenoid.** This is a hydraulically controlled valve by SCADA or local PLC with the provision of an additional solenoid in the control loop to enable On/Off functionality. It is suitable for situations where it is necessary to control valve operations through the SCADA system with fixed set-point control.

(c) **Electronic (dual solenoid) control valve** – There is no pilot required inthis type of valve. This is a dual solenoid operated valve, and the performance is governed by a controlling device that can be PLC, RTU, or preferably, inbuilt controller. The controller should be able to receive either a pulse/volume contact-input or a 4-20mA analogue signal. The flow/pressure set value may be modified automatically on time basis, or by a predefined relation to pressure or another measured parameter. This should also be operated by smart android phone or local HMI screen for change of parameters and to avoid compatibility with the systems. (Note: The performance of the electronic (dual solenoid) control valve for flow controlapplication depends on the performance of flowmeter. Hence, the selection of a flow meter should be done as per flowmeter manufacturers' guidelines.)

Technical comparison of all aforesaid three types of valves has been represented below in Table 11.5.

Table 11.5: Technical comparison of all aforesaid three types of valves

S. No.	Features	Hydraulically Pilot-Operated Control Valve	Hydraulically Pilot-Operated Control valve with Single Solenoid	Electronic (dual solenoid) Control Valve
1	Material	Ductile Iron one-piececast body	Ductile Ironone-piece cast body	Ductile Iron one-piece castbody
2	Flow/Pressure control	Yes	Yes	Yes
3	Level Control	Yes	Yes	Yes
4	Manual on/off	Yes	Yes	Yes

S. No.	Features	Hydraulically Pilot-Operated Control Valve	Hydraulically Pilot-Operated Control valve with Single Solenoid	Electronic (dual solenoid) Control Valve
5	Flowmeter	Not required	Not required	Yes
6	Level Transmitter	Not required	Not required	Yes
7	Power Required	No	Battery operated	Solar/Grid energy
8	SCADA operation	Not possible	Yes, for on/off purpose	Yes
9	O&M Cost	Minimal	Only to change AAA batteries	Maintenance of solar panels, battery replacement
10	Requirement of external devices	None	None	Flowmeter/level transmitter/pressure transmitter to control flow/level and pressure respectively
11	Failure	Low	Low	Failure in case of no power supply or failure of flowmeter or level transmitter
12	Set Points	Fixed set point	Fixed set point	Variable set points
13	Controller/RTU/PLC and Communication	Not required	Required	Required
14	Suitability	Urban, Rural.	Urban, Rural.	More suitable to urban given the power dependency and more sophisticated instruments involved
15	Manpower	Not required	Not required	Not required
16	Vertical operation	Any Position	Any Position	Any position
17	Programming	NA	Minimal	Programming knowledge is required for third party controller. Not required forinbuilt controller.
18	Recurring cost	None	None	SIM card charges for communication
19	Main line strainer	Not required	Not required	Not required

Thus, both globe-type and weir- type are diaphragm- operated valves, performing the same function, differing only in their design.

11.23.1.14 Plunger Type Valve

This type of valve can also perform the functions of regulating hydraulic parameters (flow, pressure, and level) like a diaphragm actuated control valve. This type of valve requires a gear box and actuators for its operation. Since it requires continuous power consumption, the same is not preferred. Although this valve can perform all functions of valves mentioned in Section 3, at present, this type of valve is not much in vogue.

The hydraulic engineers have to first define the purpose of installation of valves before its selection. After which, depending on the geographical/site situation, these may be chosen among the options available in the diaphragm and plunger type valves.

(A) Specifications

I) General requirements

The control valve shall be designed and hydro-tested for the 1.6 times the rated pressure of the control valve, i.e., PN16 rated valve should be tested for pressure of 25 kg/cm^2. The control valves shall be designed to cause minimum head loss in fully opened condition. Flange ends should be as per IS-1538/ISO16/ ANSI B-16.5, Class150 and Class 300/EN-1092-2 or any other National/International Standards. The material of all components of valve/internal working parts shall be corrosion-resistant in case of chlorinated water. The epoxy coating (both external and internal) should be fusion-bonded, food grade of minimum 250 microns (NSF / FDA / WRAS approved).

According to the water network technology's advancement and evolution, the valve may be upgraded on site, i.e., hydraulic valve to electronic (dual solenoid) control valve or flow control valve to pressure reducing valve, by just changing the control trim. The internal parts of the valve body, stem, seating material, package, disc, plug, back rings, etc., are collectively referred to as the trim. In other words, all wetted parts which can be removable and replaceable in the valve body are part of the control valve trim.

More specifically, the function of the valve may evolve towards other standards of control in terms of hydraulic or electronic modulation.

A control valve must demonstrate the following main features:

- **Sensitivity** (ability to respond to the smallest change of the controlled variables);
- **Accuracy** over time within the prescribed operating range.
- **Stability** within the prescribed operating range, for the low demand conditions, must be specified for the lower limits/worst conditions below which the valve may beunable to operate at full stability.

The manufacturer may indicate a simple rate of flow, or a formula allowing for its calculation, and accounting for the pressure differential through the valve. The accuracy of control valve is very important. The regulating valve shall warranty the highest ranges of accuracy when required and same must be checked before approving the control valves during inspection of the project, which should be indicated in absolute value, according to the following Table 11.6.

Table 11.6: Regulating Valve Accuracy Ranges

Downstream Pressure Control	Downstream pressure not more (or less) than ±1 m of water column of set value
Upstream Pressure Control	Upstream pressure not more (or less) than ±1 m of water column of set value
ON-OFF altitude level control	Maximum reservoir level not more than ±0.10 m of water column of set value

Flow control	Downstream flow not more (or less) than ±5% of defined flow rate.

The manufacturer may specify and describe:

- the recommended operating range of the regulating valve by clearly indicating its extreme limits;
- the design features allowing for a precise and stable operation of the valve within this range; and
- the way of setting the operating speed of the valve.

(B) Detailed specifications

I. Hydraulically operated diaphragm-type control valve with globe pattern

The detailed specification of a hydraulically operated diaphragm-type control valve with globe pattern is as under:

a) Main valve

The valve should be preferably single chamber/double chamber, straight/oblique pattern hydraulically operated, direct diaphragm actuated stem guided globe-type. The main valve consists of three major parts: body, cover, internal trim assembly. The only moving part is the internal trim, which is guided in two ends. The stem should be fully guided at both ends by a dismountable stainless steel bearing in the main valve cover. It is bottom -guided, allowing it to slide within the valve-seat in order to be in balance along its full lift for limiting excessive friction, thus increasing its ability to react when performing a correction. This is the recommended solution; however, a slotted disc guide is acceptable.

The main valve should be suitable for low flow conditions and capable of operating in unsteady flow conditions. No supplementary mechanical device may be allowed for achieving stable operation at near zero flows. The diaphragm assembly should be the only moving part and should form a sealed chamber in the upper portion of the valve, separating the operating pressure from line pressure. Packing glands and/or stuffing boxes technology should not be permitted and there should be no piston operating the main valve.

b) Material of Construction for PN10, PN16 and PN25 rated Control Valves with Globe Pattern is given in Table 11.7 below:

Table 11.7: Material of Construction for PN10, PN16 and PN25 rated Control Valves with Globe Pattern

Body and cover	Ductile iron ASTM A536, ENGJS GGG50 or equivalent
Circuit fittings	Brass EN12164/SST316/SS304 (corrosion proof)
Diaphragm	Nylon reinforced rubber/EPDM/Buna-N (FDA/WRAS approved)
Control tubes	High-pressure polypropylene/Copper/SST316/SST304
Pilot and relay	Brass EN12164/SST316/SS AISI-304/CF8 or bronze
Surface protection	Epoxy coating min. 250 microns fusion-bonded, food grade (NSF/FDA/WRAS approved)
Operation	Automatic, manual override enabled with bonnet exhaust barrel to cater any emergency of water supply. By exhausting bonnet, the valve becomes fully open with no water on top of the diaphragm.
Seat ring	Stainless steel AISI – 304/316, raised (if applicable), bronze replaceable in-line or onsite, ASTM-A351 GR CF8M

Stem	Stainless steel AISI-304/316 (replaceable in-line and onsite)
Spring and bearing bush	Stainless steel AISI-302/304/316
Disc guide, disc retainer and diaphragmwasher	Cast steel, stainless steel AISI – 304/316, bronze and coated steel, DI EN GJS GGG50 or equivalent
Seal	Synthetic rubber-Buna-N /EPDM (if applicable) (FDA/ WRAS approved)
Self-cleaning filter	Stainless Steel 316/CF8/SST304/transparent heavy duty with flushing mechanism.
Solenoid valve (if applicable)	IP68 for underground condition and IP65 if vertical installationon ESR (brass, SST 316 base). IP68 solenoids must be warranted for infinite time under 1m submerged condition.
Throttling plug	To have the linear flow (non-turbulent flow), if required, V-shaped or U-shaped throttling plug may be provided
Nut-bolts and studs	Stainless steel AISI-304/ASTM A 193 B7/A2
Air vent valve with isolating valve Provision	The cover of the valve shall have the provision to fix the small air vent valve so as to release the trapper air in the diaphragm and to maintain the sensitivity and ensure required performance of the diaphragm.

Manufacturer must provide the Kv value of each diameter of the valve for selection of valves. The standard valve model fits all control operations (pressure reducing, level control, flow control, or combination of parameters). Disassembly and reassembly of all the valve's components shall be made possible on site, without having to remove the valve from the line. The valve's pilot control loop should include a low maintenance, in-line self-cleaning control filter. The valve should also be suitable for vertical assembly wherever required. Oblique/Y-shaped valves over 200 mm diameter should not be preferred due to dismantling difficulties. Double chamber valve should be selected where external pressure is required to open the valve. The valve shall include a low friction trim. No O-ring sealing is permitted on the valve stem. The valve should require low maintenance.

c) Maintenance

- The bidder should propose a recommended five year set of spare parts per a batch of five valves of the same diameter.
- The valve should be built in a way that enables all future maintenance actions to be performed in situ without having to take the valve body of the line.
- The typical weight of internal assembly, regardless of valve diameter, should not exceed the permitted lifting weight for a single person as defined in the regulations.
- Disassembly should not require usage of sophisticated, heavy lifting devices such as cranes of any type. These are to be provided and installed at the assembly site by the supplier.

II. Hydraulically operated, diaphragm-type control valve with weir pattern

The detailed specification of a hydraulically operated, diaphragm-type control valve with weir pattern is as under.

a) Main valve

Valve should be a single chamber hydraulically operated weir-type control valve. Manufacturer must provide the Kv value of each diameter of the valve. The valve should consist of three major components: the body, cover, and the diaphragm assembly. The diaphragm trim with a stainless steel spring should be the only moving part. The diaphragm should form a sealed chamber in the upper portion of the valve, separating operating pressure from line pressure. The standard valve model fits all control operations (pressure reducing, level, flow control or combination of parameters). The diaphragm of the weir-type valve should not be guided by any shafts or bearings and should not be in close contact with other valve parts except for its sealing surface. A compressing spring at the top side of the diaphragm is essential to a reliable closure.

Disassembly and reassembly of all valve's components should be made possible on site, without having to remove the valve from the line. The valve should also be suitable for vertical assembly wherever required. The main valve should be suitable for low flow conditions and capable of operating in unsteady flow conditions. No supplementary mechanical device may be allowed for achieving stable operation at near zero flows. The selection of valve may ensure a positive drip-tight shut-off. The valves must pass a hydro-test or 1.6 times the rated pressure of the control valve.

b) Material of construction for PN10, PN16, and PN25 rated control valves with weir pattern is given in Table 11.8 below:

Table 11.8: Material of Construction for PN10, PN16 and PN25 Rated Control Valves with Weir Pattern

Body& cover	Ductile iron ASTM A536 or equivalent
Circuit fittings	Brass EN12164/SST316/SST304
Diaphragm	Nylon reinforced rubber/EPDM/Buna-N (FDA /WRAS approved)
Control tubes	High-pressure polypropylene/Copper/SST316/SST 304
Pilot and relay	Brass EN12164/SST316/CF8/SST304
Surface Protection	Epoxy coating min. 250 microns, colour RAL 5005 Blue
Operation	Automatic, manual override enabled
Spring and BearingBush	Stainless Steel AISI – 302/304/316 (if applicable)
Seal	Synthetic rubber-Buna-N /EPDM (if applicable)
Self-Cleaning filter	Stainless steel 316/ CF8/SST304/transparent heavy duty with flushing mechanism.
Solenoid Valve (if applicable)	IP68 solenoid for underground condition and IP65 solenoid if vertical installation on ESR (Brass, SST 316 base). IP68 solenoids must be warranted for infinite time under 1 m submerged condition.

c) Maintenance

- The bidder should propose a recommended five year set of spare parts per a batch of five valves of the same diameter.
- The valve should require low maintenance. No set periodic packing or parts replacement should be required.
- The valve's pilot control loop should include a low maintenance, in-line "self-cleaning" control filter.
- The typical weight of internal assembly, regardless of valve diameter, shall not exceed the permitted lifting weight for a single person as defined in the regulations. Disassembly should not require usage of sophisticated, heavy lifting devices such as cranes of any type. These are to be provided and installed at the assembly site

by the supplier. Figure 11.115 shows weir-type valve design and Figure 11.116 shows valve with stem and seat ring globe straight pattern.

Figure 11.115: Weir-Type Valve Design

Figure 11.116: Valve with Stem and Seat Ring Globe Straight Pattern

III. Hydraulically operated diaphragm-type control valve with single solenoid:

This is also hydraulically operated control valve with an additional solenoid for on/off purpose through SCADA or local PLC/RTU. Solenoid should be IP 68 for underground condition and IP 65 for vertical installation on ESR (brass, SST AISI 316 base). IP 68 solenoids must be warranted for 10 years under 1 m submerged condition. It is highly recommended to provide a bypass tubing for solenoid valve for any emergency manual operation. Preferably, a rigid type SS 304 control tubing and fittings should be used. The valve must have provision for a small air vent valve on top of the cover to ensure the proper functioning of the diaphragm. Figure 11.117 shows a hydraulically operated diaphragm-type control valve with single solenoid.

Figure 11.117: Hydraulically Operated Diaphragm-Type Control Valve with Single Solenoid

IV. Dual solenoid operated diaphragm-type control valve

There are no pilots for this type of valve. This is a dual solenoid operated valve, performance of which should be governed by a controlling device through PLC, RTU or preferably inbuilt controller. In other words, an electronic (dual solenoid) control valve should be controlled by an electronic controller, which enables control of the requested flow rate or pressure as per need and demand. This is a very smart valve and can perform multi-functions through a command from the RTU/PLC. Multiple logics can be formulated and this smart valve can manage pressure, level, leakages, and flow operations.

A controller designed for the control of hydraulic control valves with the support of two continuous operation solenoid valves and/or two latching-type solenoid valves. The configuration should enable high regulation accuracy as well as energy efficient operation. The controller must have an inbuilt battery to run the controller for a minimum of one week during no-power condition. Accordingly, it should also log the data during no-power condition. The controller should enable selection among the solenoid valve types: normally open and/or normally closed. It should allow user to set the variable set points in a timetable as required during supply hours (peak, normal hours). Set values are modifiable with the help of remote communication or an analogue signal. In case of a disconnected control signal, the controller would be able to continue to regulate per preset internal values. The controller must have four digital inputs, four analogue inputs and one RS-485 connection. The user should be able to allocate control inputs and outputs, as per the used control functions so that each input can be used for one or more control functions. The control function should be user-configurable and/or pre-configurable by the manufacturer/supplier. The function should include, but not be limited to, 'Pressure Reducing','Pressure Sustaining', 'Flow control', 'Water Level control', 'Pressure Relief' and a combination of these parameters. It is highly recommended to provision for bypass tubing for each solenoid valve for any emergency manual operation. Preferably, rigid type SS 304 control tubing and fittings should be used. The valve must have provision for a small air vent valve on top of the cover to ensure the proper functioning of the diaphragm. Figure 11.118 shows dual solenoid operated diaphragm-type control valve.

Figure 11.118: Dual Solenoid Operated Diaphragm-Type Control Valve

The change in requirement (pressure to flow control) should not require change in any hardware or software of the systems. Combination of two or more of these control function should be possible without any restriction, as long as this combination is not logically contradicting and sufficient number of inputs are free. The user may not be required to have preliminary programmingknowledge or have other special expertise. To avoid issues in compatibility, the controller and the control valve should be preferred of the same manufacturers/suppliers. The size of the controller should be compact in order to avoid operational difficulties. It should be ensured that the programming language of the RTU/PLC is easy to understand, modifiable, and should not be monopoly driven by the interest of the valve suppliers. Knowledge transfer should be seamless and non-dependent on any specific software that is controlled by the valve suppliers. The transition between the various operators shall be easy in the interest of the projects. The reputed PLCs that are easily available and sustainable should be preferred in the larger interest of the O&M of the project.

I. Electrically operated plunger type valves

a) Main valve

Plunger valve should be provided with electrical actuators having the control facility for intermediate valve positioning by connecting external signal. The electric actuators should be designed to provide the required torque for operations in the flow and pressure conditions of the water transfer system. Gear assembly should be provided as necessary. The flow path with annual flow cross-section in any open position should be rotationally symmetric. The movement of plunger/piston by means of crank/shaft/spindle drives should be axial/linear. A handle wheel should be provided for plunger valves so that operations of the valve can be carried out when the power supply of valve is failed. The torque requirements at the hand wheel should be such that one person can operate the valve. Hand wheel should be positioned to give access for operational personnel. It should be provided with an integral locking device to prevent operation by unauthorised persons. A selector switch should be provided on the actuator for remote/local/hand operation of the valve. Valve/profile sealing seat should be preferably in the no-flow zone. The O-ring seal should envisage the double sealing effect between the body and the plunger. There should not be any obstruction in the main flow passage except the plunger and attached control cylinders.

b) Material of construction of the electrically operated plunger type valves is given in Table 11.9 below:

Table 11.9: Material of Construction Electrically Operated Plunger Type Valves

Body	Ductile iron ASTM A536/DI (GJS 500-7)
Plunger/Piston	Stainless steel AISI -304/Gr 1.4301
Piston Guide	Bronze welded overlay/SS
Shaft Crank/Spindle	Stainless Steel AISI-420/Gr 1.4021
Seat Ring	Stainless Steel AISI-316/Bronze
Seal (O-ring)	Synthetic rubber-Buna-N/EPDM (FDA/WRAS approved)
Bearing Bush	Bronze
Bolts	Stainless steel (A4)
Eye Bolt for Lifting	Galvanised steel
Slotted cylinder/Strainer	Stainless steel
Coating (both inside and outside)	Epoxy coating min. 250 microns, fusion-bonded, food grade (NSF/FDA/WRAS approved)

The hydraulic engineer, when opting for diaphragm actuated control valves, can include both the specifications of globe pattern and weir pattern for procurement purpose. The Bureau of Indian Standards (BIS) may also be followed, if available for these types of valves.

(C) Advantages

The degree of perfection, precision and accuracy which can be attained with respect to regulation by using control valves can hardly be achieved manually or by using actuators. The valves can reduce utilisation of manpower without demanding extra maintenance cost. They can also help in controlling non-revenue water (NRW). As a result, the benefits of these valves are too many to be analysed based on cost benefit ratio. Yet one can find out the savings in workforce and other indirect expenditures as given in Table 11.10 below:

Table 11.10: Format for Finding Savings in workforce and Other Indirect Expenditures

S. No.	Particulars	Amount (Rs.)	Remarks
Total Cost incurred prior to installation of Control Valves			
1	Expenditure incurred towards establishment of employees who are needed for operation of valves		
2	Indirect Losses – Cost of NRW		Total Water Lost(MLD) × Cost of treated water Rs/MLD × 365
Total Cost:			**(A)**
Total cost to be incurred after installation of control valves			
1	Expenditure to be incurred towards establishment of employees who are needed for operation of valves		
2	Indirect Losses – Cost of NRW		NRW will not be nil
Total Cost:			**(B)**
Saving: (A) – (B)			

However, it is suggested that procurement of valves like flow control, pressure reducing, pressure sustaining, and surge anticipation should not be decided on the basis of savings in cost alone. It should also be decided on cost benefit ratio and life cycle cost assessment.

(D) Limitations

Control valves are viewed as a threat by the ground level staff because of the opinion of ground staff that the workforce shall be curtailed. Control valves may also control the tampering of the valves because of its availability for different hydraulic conditions. In absence of technical knowledge of the working of the control valves, it is not utilised to the best of its potential thereby leading to unfruitful expenditure. Hence, prior to installation of valves, the staff of Urban Local Bodies should be given technical training and build the capacity to implement the same at ground level.

The hydraulic diaphragm-type control valves require minimum hydraulic pressure between 5 m and 12 m (varying from manufacturer to manufacturer) for its operation in water supply systems. It is the duty of the hydraulic/environmental engineer to ensure that there is some residual head as specified by the manufacturer for flow control and pressure reducing applications. From the maintenance point of view, it is recommended to install isolation valves as per the requirements.

(E) Applications of Control Valves

The hydraulic/environmental engineer can use the abovementioned control valves in the following scenarios:

I. Case 1: The entire demand of the city is catered through only one ESR (Please refer Figure 11.119)
   Depending on the requirement, the hydraulic/environmental engineer can effectivelyuse either one or all the valves suggested in the sketch or in combination. If the supply is through pumping, surge anticipation valve can be installed for surge protection and water hammer. The level control valve at the inlet of ESR can be used for reducing human intervention and NRW. For intermittent supply, hydraulic/environmental engineer can install a flow control valve with timer whereas the same can be replaced by an electronic (dual solenoid) control valve in case of continuous supply. The workforce saved by adopting this method can be used for other activities.

II. Case 2: There are two or more ESRs in the system (Please refer Figure 11.120).
Same as above. Depending on the difference in ground levels of the ESRs, the level control valves at the inlets of ESRs can be replaced by a flow with level control valve for equitable distribution of water.

III. Case 3: Water is supplied to the ESRs through a master balancing reservoir (MBR) (Please refer Figure 11.121).
Same as Case 2.

IV. Case 4: The city is big and there are multiple district metering areas (DMAs) under each ESR (Please refer Figure 11.122).
Same as Case 3. For equitable distribution of water beyond ESR, flow control valve should be installed at the entrance of each DMA.

V. Case 5: The city is huge and there are multiple sub-zones in each DMA (please refer Figure 11.123)
Same as Case 4. In addition, there is flow control valve at the entrance of each sub-zone. This will exert better control, reduce human intervention considerably and also NRW.

VI. Case 6: In hilly areas (Please refer Figure 11.124)
In hilly areas, bursting of pipelines due to high pressure is very common. To counter such type of problems like the name suggests, pressure reducing valves should be installed.

VII. Case 7: When it is mandatory to maintain certain minimum pressure in the pipeline (Please refer Figure 11.125).
When it is mandatory to maintain a certain minimum pressure on the upstream side of a particular location, pressure sustaining valve should be installed at such location.

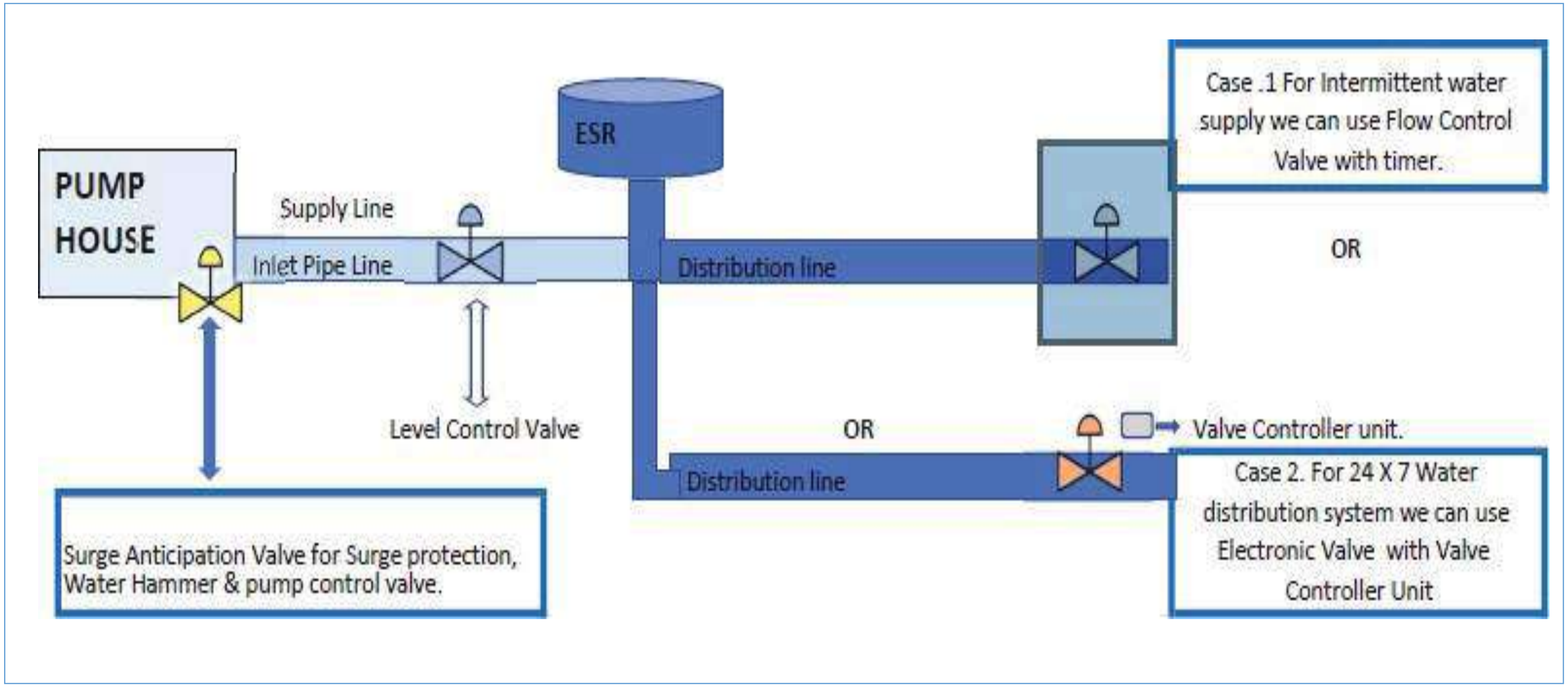


Figure 11.119: Demand of the City Catered Through Only One ESR

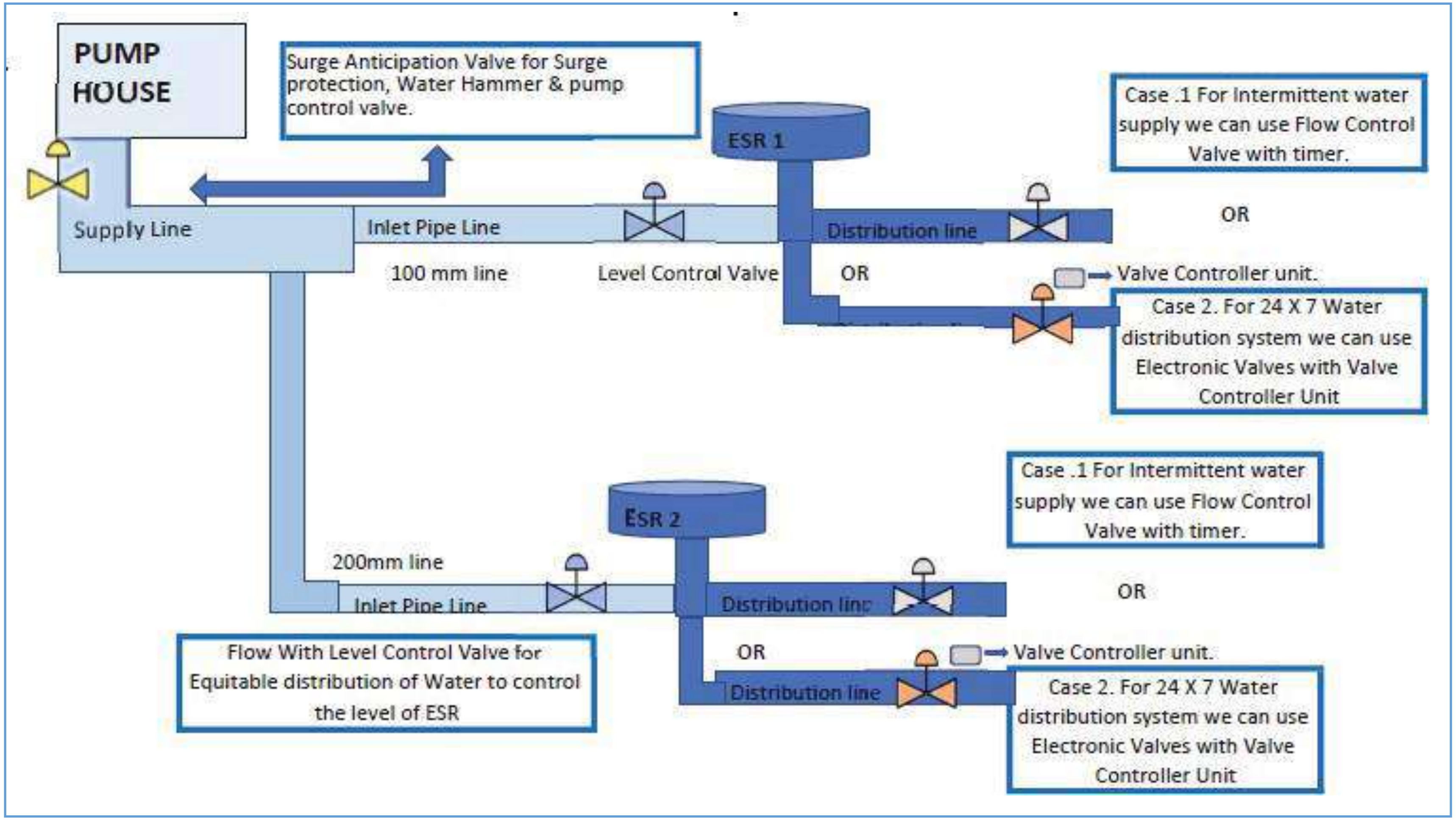


Figure 11.120: Demand of the City Catered Through Two or More ESRs

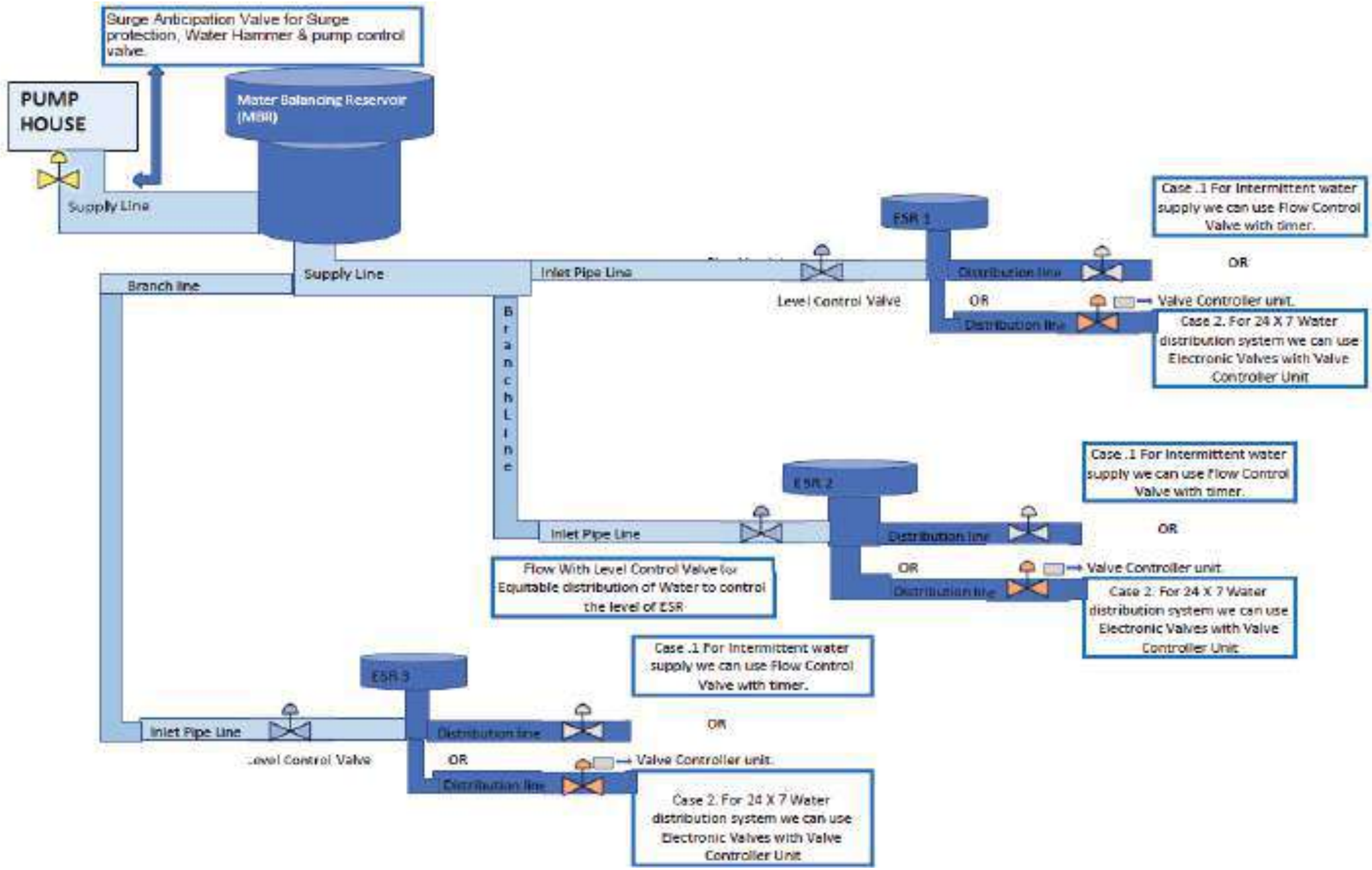


Figure 11.121: When Water is supplied to the ESRs through a Master Balancing Reservoir (MBR)

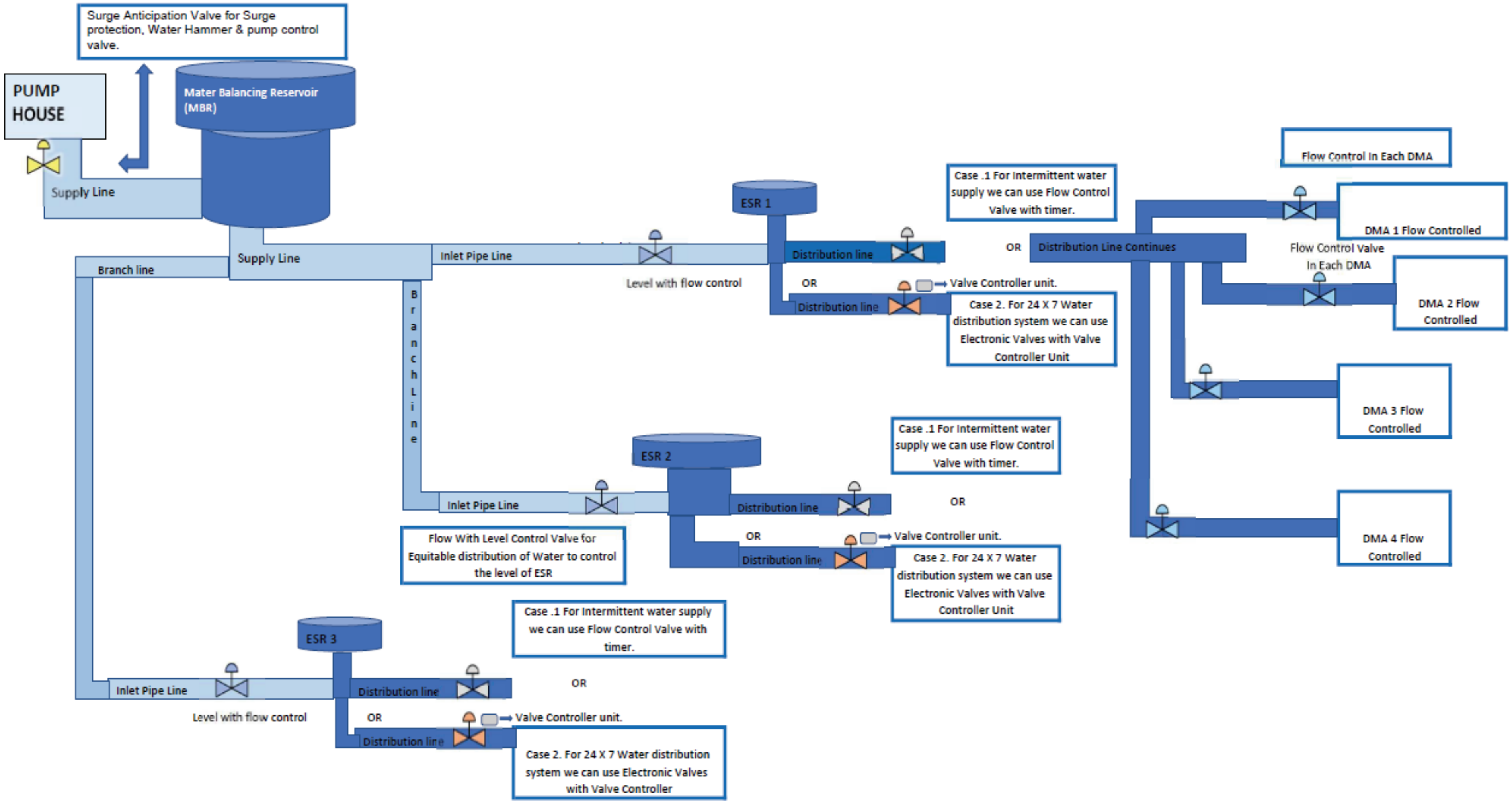


Figure 11.122: City is big and there are multiple District Metering Areas (DMAs) under each ESR

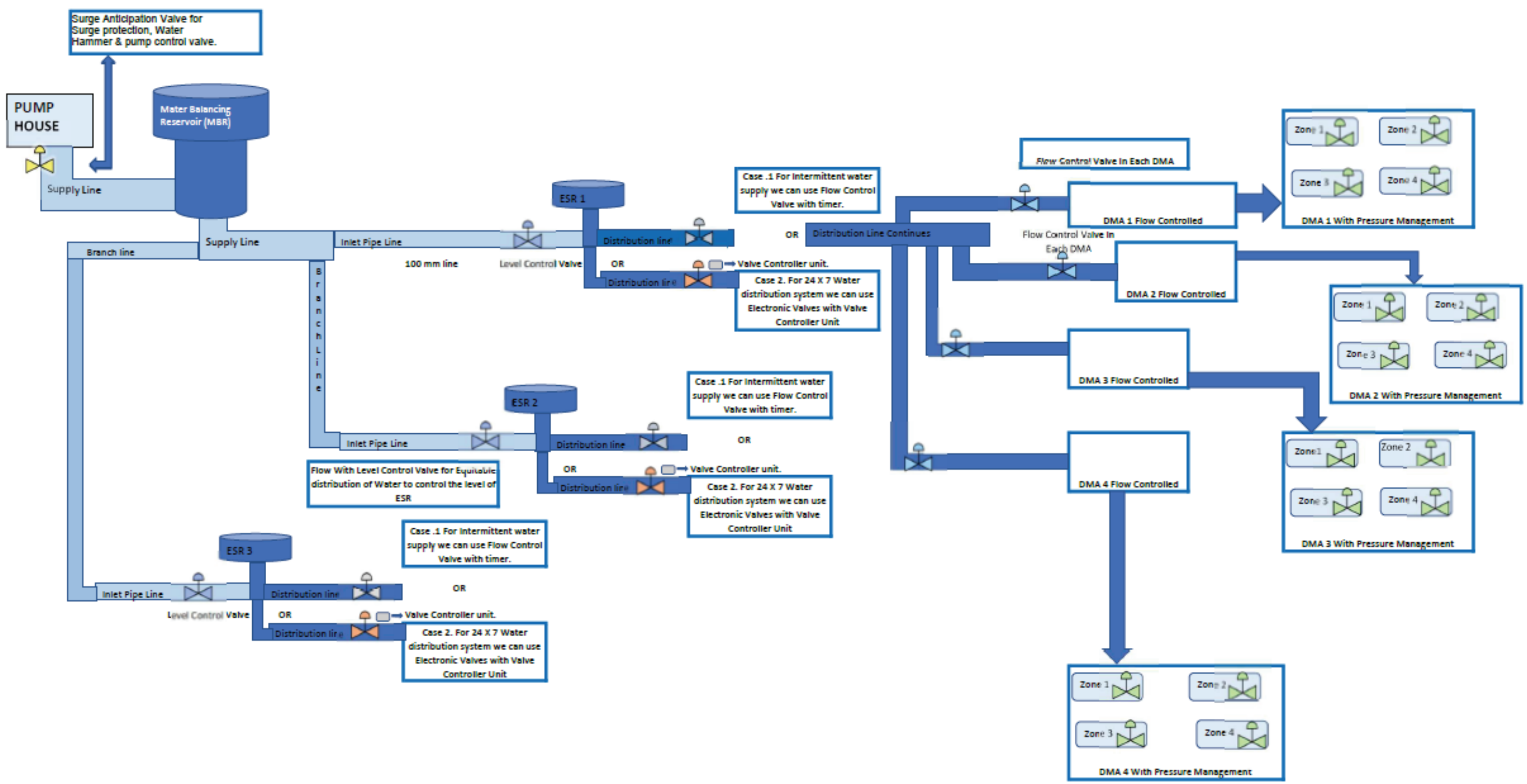


Figure 11.123: City is Huge and there are Multiple Sub-Zones in Each DMA

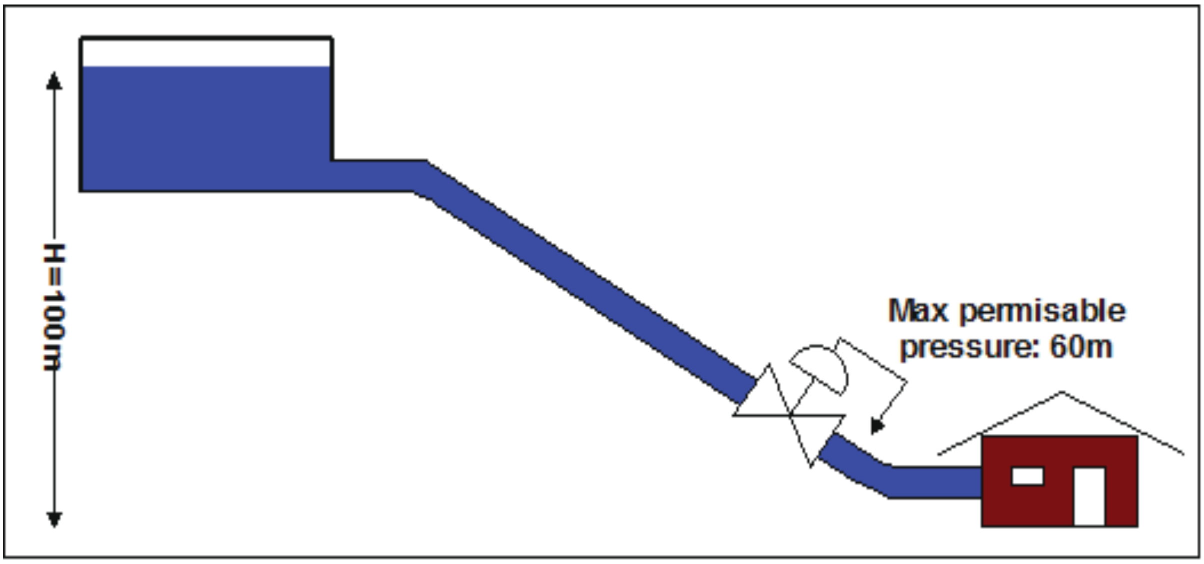


Figure 11.124: Demand Catered in Hilly Areas

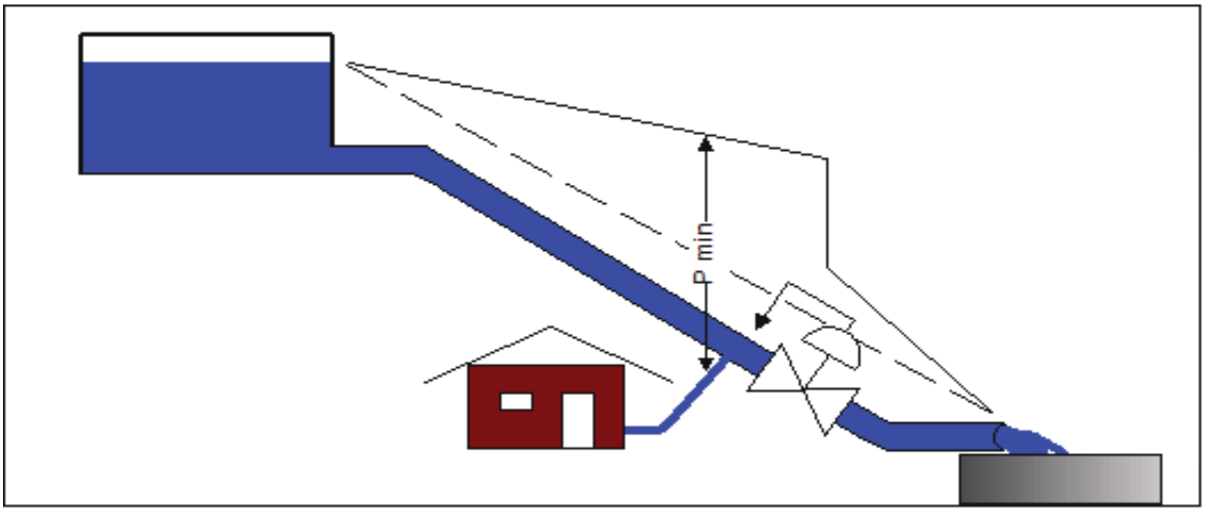


Figure 11.125: Maintenance of Certain Minimum Pressure in the Pipeline

11.23.1.15 Foot Valve

Foot valves for water works purposes are covered under IS 4038 (1986), Reaffirmed 2020: Foot valves for water works purposes [CED3: Sanitary Appliances and Water Fittings]. This standard covers the requirement for flanged and screwed end foot valves of both swing and lift type for use with centrifugal pumps for water works purposes. It covers screwed end valves from 25 mm to 150 mm nominal size and flanged end valves from 50 mm to 450 mm nominal sizes.

11.23.1.16 Pressure Reducing Valves

These are used to automatically maintain a reduced pressure within reasonable limits in the downstream side of the pipeline. This type of valve is always in movement and requires scheduled maintenance on a regular basis. This work is facilitated if the valve is fitted on a bypass with isolating valves to permit work to proceed without taking the main out of service. If the pressure reducing valve is fitted on the main pipeline, a bypass can be provided for emergency use. Needle-type valves which can be hydraulically controlled or motor operated with a pressure regulator are used for large aqueduct mains.

11.23.1.17 Pressure Sustaining Valves

Pressure sustaining valves are similar in design and construction to pressure reducing valves and are used to maintain automatically the pressure on the upstream side of the pipeline.

Spacing of Valves and Interconnections

The pipeline should be divided into sections by valves to avoid the necessity of emptying the whole pipeline in case of repair, each section being provided with an air valve and scouring facilities. The need for scour should be particularly borne in mind when the layout of the pipeline and siting of the valves are finalised, as they cannot always be arranged in the best position due to likely difficulty in disposing of the discharge. They are necessary for scouring the mains and, hence, should be in proportion to the size of the main.

It is desirable to have valves close together in more densely built-up areas. Ease of access to the valves is also important as the time taken in shutting of a valve in an emergency may be mostly spent in reaching it. In gravity mains, automatic valves, self-closing if a pipe bursts, may also be provided for protection to property as well as to prevent excessive wastage of water.

Where there is more than one pipeline, they should be interconnected at each site of main valves, so that only the shortest possible length of one pipeline need be put out of commission at a time. The interconnection will entail only negligible loss of head if its area is not less than two-thirds that of the largest main.

Also, when two or more mains are connected in parallel, the scours may be interconnected so that either main can be refilled from the other while the master valve is shut. Charging through a scour can be done speedily with less risk than charging over a summit, as the danger of surging from trapped air is being much reduced.

Integrated Valves (Modulated Valve)

Integrated or modulated valves combine the functionality of a flow control valve (FCV), flowmeters and a pressure reducing valve (PRV). They help maintain a constant flow rate and pressure, which is essential for the system's proper functioning. These valves are commonly used in flow metering applications where a constant flow rate needs to be maintained despite changes in upstream pressure.

The FCV component of the integrated valve regulates the flow rate, while the PRV component maintains a constant downstream pressure by reducing the pressure as required. This allows for accurate flow rate measurement even in situations where the upstream pressure fluctuates.

Proper selection, installation, and maintenance of these valves are essential for the reliable and efficient functioning of the system. Some guidelines for the use of integrated valves in water supply systems are as follows:

1. Determine the required flow rate and pressure: Before selecting an integrated valve, it is important to determine the required flow rate and pressure of the system. This will ensure that the selected valve can handle the required flow rate and pressure range.

2. Consider the valve size: The valve size should be selected based on the size of the pipe in the system. A valve that is too small will cause pressure drops and flow restrictions, while a valve that is too large will be inefficient and expensive.

3. Select the appropriate valve type: There are different types of integrated valves, such as globe valves, butterfly valves, and ball valves. The valve type should be selected based on the application and the required level of flow control and pressure regulation.

4. Install the valve correctly: The valve should be installed in the correct orientation and with the appropriate fittings and gaskets. The installation should be done in accordance with the manufacturer's instructions to ensure proper functioning of the valve.

11.23.2 Manholes/Inspection and Repair Chamber

Manholes are provided at suitable intervals along the pipeline. They are helpful during construction and later on serve for inspection and repairs. These are usually spaced 300 to 600 m apart on large pipelines. Their most useful positions are at summits and downstream of main valves. They are commonly provided in the case of steel and concrete pipelines and are less common in the case of cast iron and asbestos cement pipelines.

Surface boxes, Guards and underground chambers for the purpose of utilities such as Inlet chamber of DMA etc. shall be as per BS 5834-2-2011 (91.140.60 Water Supply Systems). The surface box for sluice valves shall be as per BIS code IS 3950:1979.

11.23.3 Fire Hydrants

Indian Standard Provision and Maintenance of Water Supplies for Fire Fighting – Code of Practice to be followed.

The following BIS codes are to be followed with regard to selection and installation, etc. for fire hydrants:

(a) IS 908 (1975, Reaffirmed 2020) Fire Hydrant stand post type

(b) IS 884 (1985, Reaffirmed 2020) First-aid hose reel for fire hydrant

(c) IS 8442 (2008, Reaffirmed 2018) Stand post type water and foam monitor for fire fighting

(d) IS 13039: (2014, Reaffirmed 2019) Indian Standard External Hydrant Systems – Provision and Maintenance – Code of Practice

(e) IS 3844 (1989, Reaffirmed 2020): Code of Practice for Installation and Maintenance of Internal Fire Hydrants and Hose Reels on Premises – Fire Safe World

(f) IS 2190 (2010, Reaffirmed 2020): 'Code of practice for selection, installation and maintenance of portable first-aid fire extinguishers (second revision).' This standard covers requirement in respect of installation and maintenance of internal fire hydrants and hose reel systems with or without sprinkler installation for different types of buildings. Internal fire hydrants are intended for use by fire brigade or other trained personnel and provide means of delivering considerable quantities of water to extinguish or to prevent the spread of fire. A fire hydrant is an outlet provided in a pipeline for tapping water mainly for the purpose of firefighting (or fire extinguishing). However, sometimes these may also be used for withdrawing water for certain other purposes such as sprinkling on roads, flushing streets, etc. When a fire breaks out, water is obtained for firefighting from a nearby fire hydrant through a fire hose. For firefighting, usually a large quantity of water at high pressure is required in order to make it to reach to the place of occurrence of fire. Thus, if water at the required pressure is available from a fire hydrant, it can be directly used for firefighting through a fire hose connected to the outlet of the fire hydrant. However, if water at much higher pressure is required, the same is developed by attaching a fire engine or a pump to the fire hydrant outlet. The fire engine or the pump draws water from the fire hydrant, boosts its pressure, and the high pressure water coming out from the outlet of the fire engine, or pump is used for firefighting through a fire hose connected to the outlet of the fire engine or the pump. At the end of the fire hose, a nozzle is provided to develop a powerful jet of water. The number of fire hydrants in a distribution system and their location depends on various factors such as chances of fire occurrence, requirement of water for firefighting, utility of buildings, population of area, etc. Generally, fire hydrants are placed at all important road junctions and at intervals not exceeding about 300 m.

In case of industries of high hazard category (Gr G-3, H, and J), the hydrants should be installed at every 30 m apart along the building line and the hydrant outlet should be single or double hydrant with provision of landing valves.

11.23.4 Water Metres

Water metres are the devices which are installed in pipelines to measure the quantity of water flowing through them. The water flowing through pipelines is supplied to various consumers for domestic, industrial, and commercial uses and its measurement is necessary to charge consumers according to the quantity of water supplied to them. A separate chapter on water metres has been included in this Manual Part A, Chapter 13 - Water Metres.

11.24 24×7 Water Supply and Selection of Pipe Materials and Pipe Appurtenances

Continuous pressurised water supply is a solution for improving the deteriorating quality problem in the country. Through the leaks in intermittent water supply, outside contaminants enter pipeline during non-peak hours due to the vacuum that is developed inside pipeline. Thus, water becomes non-potable. On the contrary, in 24×7 system due to pressure inside pipeline, outside impurities can't enter in and quality of water remains intact. Life of distribution networks increases as steady pressure in the pipes causes less damage to the pipes. A better demand management is possible due to elaborate metering and effective leakage control. It also results in less storage of water or none at all, which in turn reduces wastage of water. Continuous supply of clear water (contamination free) boosts the economy and attracts more industries and businesses.

It is now well established that intermittent water supply leads to health risks for users due to the higher likelihood of contamination of water pipelines through joints and damaged segments during periods when the system is not pressurised. The absence of sound technical and managerial systems associated with intermittent supply makes supply and demand management extremely difficult. This prevents effective estimation or control of the amount of water produced, transmitted, and distributed. Intermittent supply of water also causes great inconvenience to households, especially to women and children who most often bear the brunt of the hardship associated with inadequate and unreliable water supply. To cope with these shortcomings, customers revert to expensive coping strategies such as building expensive underground sumps and overhead tanks, and installing booster pumps, treatment devices, etc. In all ULB's, the NRW level is high due to improper laying, jointing, and O&M of the distribution system. Thus, the engineer should put a lot of emphasis on selection of pipe and compatible specials and fittings, while designing and planning the water supply system.