CHAPTER 3: Irrigation equipment and jointing techniques

INTRODUCTION

Irrigation system installations consist of various pipes, fittings, valves and other equipment depending on the kind of system and the type of installation. Most installations have the same structure, and thus a relatively small range of equipment can meet the requirements of a whole region.

Irrigation equipment can be divided into:

- pipes;
- pipe connector fittings;
- flow control devices;
- filters;
- fertigation equipment;
- water emitters;
- automation equipment;
- operation equipment;
- water-lifting devices.

The main characteristics of the irrigation equipment are:

- material, e.g. galvanized steel, rigid PVC, etc.;
- size, i.e. the nominal diameter (DN) of the ISO metric range in millimetres (16–160 mm) and/or of the BSP threaded range in inches (¾–4 inches);
- type of joint, e.g. threaded, quick coupling, solvent welded, etc.;
- working pressure PN (nominal pressure) or PR (pressure rating) in bars, e.g. 6.0 bars;
- national and/or international standards conformed to, e.g. DIN, ISO, BS, ASTM, EN.

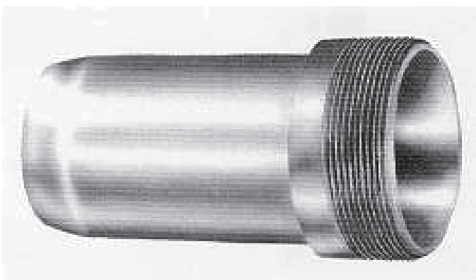
The working pressure of a pipe or a fitting is the maximum internal water pressure to which the pipe or the fitting is subjected continuously in ordinary use, with certainty that failure of the pipe will not occur. It is specified as nominal pressure (PN) or pressure rating (PR).

PIPES

The pipes are the basic component of all irrigation networks. There are various kinds and types available in many pressure ratings and in different sizes (diameters). The pipes in use for farm-level irrigation systems are mainly in rigid PVC and polyethylene (PE). Quick coupling light steel pipes and layflat hoses are used on a smaller scale. Threaded galvanized steel pipes are of limited use. All these pipes are described below.

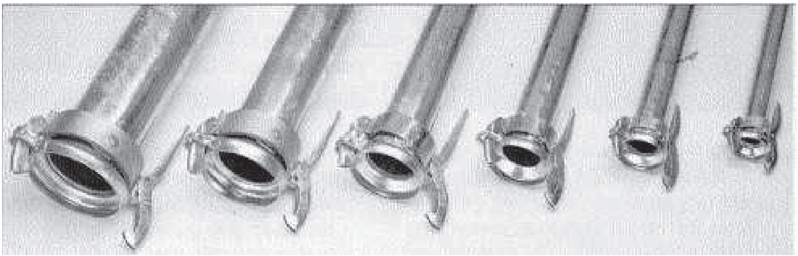
Steel threaded pipes. Galvanized steel pipes have been used widely in every country for all kinds of water works. In the past they were used as mains and submains in pressure piped irrigation solid installations. Due to their excellent properties, they have the ability to withstand stress, to resist high pressures and to maintain their strength for the duration of their service life, unlike plastic pipes which suffer a continuous creep strength with time and temperature fluctuations. They are not often used nowadays for irrigation because they are very expensive. However, they are useful in small pieces needed for risers in the hydrants, connector tubes in the head control units and similar applications. They are available in nominal diameters (DN), usually in inch-based series of ¾, ½, 1, 1¼, 1½, 2 inches, etc., which correspond more or less to the actual bore diameter, and in several high pressure rates (classes) in accordance with various standards and recommendations (ISO R-65, BS 1387, DIN 2440/41/42, or to American Standards, etc.). Supplied in random lengths of 6 m, they are for permanent assembling with screw-type (threaded) joints. Each pipe carries an internal threaded socket. Welded hot-dip galvanized steel pipes have an average life of 15–20 years on the surface ‘in the atmosphere’ and of 10–15 years in soil depending on soil physical properties. There is a large range of pipe connector fittings made of galvanized malleable iron for jointing these pipes (Figure 3.1).

FIGURE 3.1 - A threaded steel pipe fitting (male adapter).



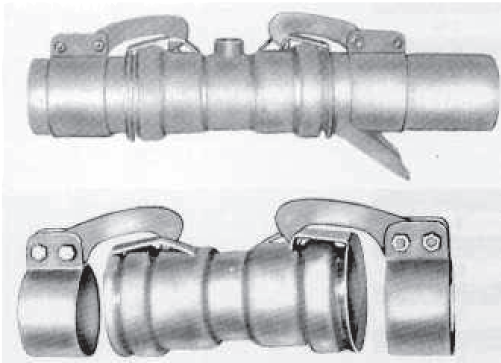
Quick coupling light steel pipes. These pipes are made of light rolled strip steel which has been hot-galvanized inside and outside. Each pipe is equipped with a hand-lever quick coupling welded on one end while the other end is arranged accordingly for water and pressureproof tight closure. The standard pipe length is 6 m and the working pressure (PN) ranges from 12.0 to 20.0 bars. They are light in weight, easy to install and remove, and they are used as mains, submains, manifold feeder lines and laterals with sprinklers. They have a full range of pipe connector fittings of the same type of joints. They are available in many sizes and in diameters (DN) of 70, 76 and 89 mm, which are convenient for farm-level pressure irrigation techniques (Figure 3.2.).

FIGURE 3.2 - Quick coupling light steel galvanized pipes and fittings.



Quick coupling aluminium pipes. They are mostly used, always above ground, as moveable lateral lines in sprinkler irrigation portable installations. Made of aluminium alloy by extrusion or by fusion welding, they are light in weight (about half that of the light steel ones), relatively strong and durable. In accordance with ASAE S263.2, they are manufactured in nominal diameters quoted in inches, corresponding to the outside pipe diameter, of 2, 3, 4, 5 and 6 inches (51, 76, 102, 127 and 159 mm). The minimum working pressure is 7.0 bars. In accordance with ISO 11678, the same sizes in the metric series are 50, 75, 100, 125 mm and so on with working pressures of 4.0, 10.0 and 16.0 bars. They are supplied in standard lengths of 6, 9 and 12 m, complete with aluminium quick couplings. These are either detachable by means of clamps and rings, or permanently fixed on the tubes. With the use of U-shaped rubber gaskets, the couplings seal automatically under high water pressure during operation and drain in pressures below 1.0 bar. There are several types of quick couplings which allow the farmer to couple or uncouple the connections from any location along the pipe. The most widely used are the latch system (single or dual), with a ¾ or 1 inch threaded outlet for sprinkler risers, or hose extensions (Figure 3.3). Quick coupling provides a high degree of flexibility to aluminium pipelines laid on uneven ground. The expected life of these pipes is 15 years under good management. The light portable quick coupling pipes, steel or aluminium, can be used not only as sprinkler lateral lines, but also as water conveyance and distribution lines. In micro-irrigation systems they are often used as manifolds. These pipes maintain their value for a considerable length of time. Indeed, some cases have been reported of farmers selling many of these pipes at a profit even after extensive use.

FIGURE 3.3 - Quick coupling aluminium pipes.



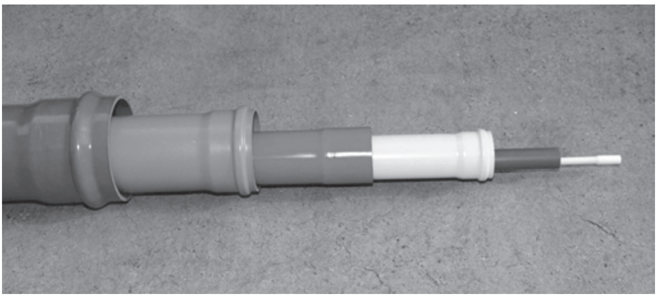
Rigid PVC pipes. Extruded from unplasticized polyvinyl chloride, also called uPVC for unplasticised polyvinyl chloride (or PVC-U), these pipes are ideal for irrigation, (cold) water conveyance and distribution lines as mains and submains. In many cases they can also serve as manifolds and laterals. Very light in weight, they are easy to transport and to handle on site. Their only limitations are that they must always be laid permanently underground, protected from high or very low ambient temperatures and solar radiation. The maximum flow velocity should not exceed 1.5 m/s. They are manufactured in standard lengths of 6 m, and in several series and classes denoting the working pressure, in accordance with various national and international standards applied in Europe, the United States and elsewhere (ISO 161-1/2: 1996, ISO 3606, BS 5556, DIN 8062, ASTM D 2241, ANSI/ASAE S376.1, ANSI/ASTM D 1785).

These standards, although equivalent to each other, vary in the pipe dimensioning, i.e. the pipe's actual diameter, the working pressure (PN), the safety factors, etc. In the United States, thermoplastic pipes are mainly classified in terms of standard dimension ratio (SDR) between the pipe's outside diameter and the pipe wall thickness, and schedules (for higher pressures). In Europe, the hydrostatic design stress (hoop strength) of PVC common material is 100 bars. In the United States, several compounds are used with different stress values, thus a great variety of pipes are produced, all in inch sizes. In accordance with the European standards and ISO 161, rigid PVC pipes are available in nominal diameters (DN), which is the approximate outside diameter, in 50, 63, 75, 90, 110, 125, 140, 160, 200 and 225 mm (Figure 3.4.). The working pressures are 4.0, 6.0, 10.0 and 16.0 bars at 24°C. At higher temperatures, the working pressures decrease accordingly. Usually, small diameter pipes up to 50 mm and inch-sized pipes have one end plain with a preformed socket at the other end for solvent cement welding. Larger diameter pipes have a tapered spigot at one end while the other end consists of a wall-thickened, preformed grooved socket with a rubber sealing ring for a push-fit integral mechanical joint.

There is a complete range of connector fittings for these pipes; some made of uPVC and others of cast iron. The compression-type polypropylene (PP) fittings are also suitable for uPVC pipes up to 110 mm. All the fittings and the valves of underground PVC pipelines should be thrust blocked to prevent them from moving whilst in operation due to the thrusting force of the water pressure. The estimated average life of buried uPVC pipes is 50 years.

Rigid PVC pipes are made for underground installation, where they are protected from temperature changes and hazards imposed by traffic, farming operations, etc. The trench should be as uniform as possible, firm, relatively smooth and free of large stones and other sharp edged material. Where ledge rock or hardpan is encountered, the trench bottom should be filled with embedment material, such as compacted grained soil or sand, to provide a bed depth of about 10 cm between pipe and rock. The minimum depth of cover should be 45 cm for pipes up to 50 mm, 60 cm for pipes up to 100 mm, and 75 cm for pipes over 100 mm DN. Where rigid PVC pipes are installed under roads, the depth of cover should not be less than 1 m; otherwise the pipes must be sleeved in a protective steel tube.

FIGURE 3.4 - Rigid PVC pipes.



Polyethylene (PE) pipes. Flexible black PE pipes are extruded from polyethylene compounds containing certain stabilizers and 2.5 percent carbon black which protect the pipes against ageing and damage from sunlight and temperature fluctuations. LDPE (low-density resin) pipes are also known as soft polyethylene and PE 25, while HDPE pipes (highdensity resin) are more rigid and known as hard polyethylene or PE 50 (the numbers correspond to the pipe material's hydrostatic design stress). They are manufactured in accordance with various standards in inch-based and metric series (ISO 161-2, DIN 8072/8074, etc.) Both sorts have proved successful in pressure piped irrigation techniques and are the predominant kind of pipes in micro-irrigation systems. All laterals with micro-emitters are LDPE pipes (hoses) of 12–32 mm. HDPE pipes of larger diameters are used for main lines, submains and manifolds. They are also often used as water conveyance pipelines. LDPE pipes are less affected by high temperatures than HDPE pipes are. PE pipes are supplied with plain ends in coils of 50–400 m, depending on the diameter (Figure 3.5). Laid on the surface, they have a service life of 12–15 years. Conforming to European and international standards, they are available in the following sizes and working pressures:

DN (external diameter) millimetres:
12, 16, 20, 25, 32, 40, 50, 63, 75, 90 and 110;

PN (working pressure) bars:
2.0, 4.0, 6.0, 10.0 and 16.0.

Jointing PE pipes is simple. A full range of PP connector fittings is available in all diameters and types suitable for pressures from 2.0 to 10.0 bars.

FIGURE 3.5 - Polyethylene pipe in a coil.

The manufacturers of PVC and PE pipes recommend that the maximum flow velocity in the plastic pipes should not exceed 1.5 m/s. Based on this recommendation, Table 3.1 presents the flow rates in various plastic pipes with a flow velocity of 1.7 m/s, which should be taken as the maximum permissible under normal operating conditions.

TABLE 3.1 - Maximum recommended flow in plastic pipes without outlets

Rigid PVC 6 bars (DIN 8062)	DN mm Inside d. mm m^3/h	63 59.2 17	75 70.6 24	90 84.6 34	110 103.6 51	125 117.6 66	160 150.6 109
HDPE 6 bars (DIN 8074)	DN mm Inside d. mm m^3/h	50 44.2 9	63 55.8 15	75 66.4 21	90 79.8 30	110 97.4 45	
LDPE 4.0 bars DIN(8072)	DN mm Inside d. mm m^3/h	16 12.4 0.75	20 16.4 1.3	25 20.6 2.0	32 27.2 3.5		

V = 1.7 m/s

Selection of PVC and PE pipes's dimensions. Thermoplastic pipes (uPVC, PE etc.) have had widespread application in water conveyance, supply and irrigation in recent years. Many national and international special standards and specifications have been issued and many others are in the course of preparation for these pipes, in which different regulations and recommendations are included regarding the wall thickness of the various pipes as related with the pressure rating and the service time. The wall thickness s of the pipes is calculated by means of the equation given in ISO/R 161:

$$s = p\,\frac{d}{2\sigma + p}$$

Where, ***p*** is the pressure rating, ***d*** the outside diameter of the pipe, and **σ** hydrostatic design stress i.e. the permissible stress of material in calculating the wall thickness ***s***. The value of ***s*** was based on a specific span of time creep rupture stress, making allowance for a safety factor too. For many years the manufacturers offered plastic pipes designed for standard values materials (PVC 100, HDPE 50 and LDPE 25). The hydrostatic design stress (creep strength) values given in kPa were based on a 50-year creep stress (service life) with safety factor 2.5 and maximum working (internal) pressure. These criteria in many cases were beyond the actual installation and operating conditions. Meantime new types of resins are available in the market with better mechanical strengths, higher than what has been required by current standards. The material designations have been updated, the safety factors modified and the wall thickness specifications have been amended to conform to ISO 4065. The pipe nominal pressure (PN) is no longer the basis for specifying the dimensions.

In accordance with DIN 8062 (1988) the un-plasticised uPVC pipes series are as in the previous standards. In the new standards the uPVC pipes are categorized in series (S), nominal pressure (PN) and standard dimension ratio (SDR). The sizes of the pipes (outside diameter) have not changed. There are many series and each one corresponds to a PN and an SDR (Table 3.2). The ISO 4065 gives a universal number of series, which correspond to specific series of other standards (see the following tables).

TABLE 3.2 - uPVC Pipe series

Nominal pressure in Bars (PN)	PN 4	PN 6	PN 8	PN 10	PN 12.5	PN 16
Pipes series to DIN 8062	2	3	–	4	–	5
Pipes series to ISO 4422 (S)**	25	16.7	12.5	10	8	6.25
Standard Dimension Ratio (SDR)	51	34.4	26	21	17	13.5
Pipe size d (out.dia.)	Wall thickness s mm					
75	1.8	2.2	2.9	3.6	4.5	5.6
90	1.8	2.7	3.5	4.3	5.4	6.7
110	2.2	3.2	3.4*	5.3	5.3*	8.2
125	2.5	3.7	3.9*	6	6*	9.3
160	3.2	4.7	4.9*	7.7	7.7*	11.9

Note: Up to the sizes of 90 mm the safety factor 2.5 is taken for designation of the pipes to DIN and ISO. For larger sizes > 90 to ISO the safety factor is 2.0. Then for the pipes PN 10 and PN 16 the wall thickness to ISO is less than the ones to DIN in sizes >90.
** ISO 4422 contains additional series, (S 20–SDR 41–PN 5), (S 16–SDR 33–PN 6.3), (S 4–SDR 9–PN 25).

The pipe dimensions given above are designed for a service life of 50 years at 20º Celsius under the precise PN. The three factors are interrelated and vary accordingly, e.g. at higher temperatures both the service life and the permissible working pressure change accordingly and the same applies when the working pressure differs from the designed one. Informative tables are included in the standard papers and/or in the manufacturers catalogues.

Regarding irrigation pipes made from polyethylene (PE) the worldwide known LDPE pipes to DIN 8072 are still in production, however new types of resins especially for high density (HDPE) are available in the market with better mechanical strengths, higher than what has been required by previous standards. Next to the familiar PE 25 and PE 50, there are the PE 32, PE 63, PE 80 and PE 100. The number corresponds to the σ value for the pipes designation. So the pipes for a specific PN differ in SDR and wall thickness according to the hydrostatic design stress of the row material made from. The selection of the appropriate pipe has become more accurate for the designed application, although more complicated (Table 3.3).

TABLE 3.3 - PE Pipes (50, 63, 80) wall thickness for PN 6 and PN 10

	PN 6			**PN 10**		
	Hydrostatic design stress σ (kPa)					
	PE 50	PE 63	PE 80	PE 50	PE 63	PE 80
	Pipe series (s) to ISO					
	S 8.3	S 10	–	S 5	S 6.3	S 8
	Standard Dimension Ratio (SDR)					
	17.6	21	–	11	13.6	17
Pipe d mm	Pipe wall thickness s mm					
50	2.9	–	–	4.6	–	–
63	3.6	–	–	5.8	4.7	–
75	4.3	–	–	6.8	5.6	4.5
90	5.1	4.3	–	8.2	6.7	5.4
110	6.3	5.3	–	10.0	8.1	6.6
125	7.1	6.0	–	11.4	9.2	7.4

Note: For the same PN with different material hydrostatic stress (σ) values there are different characteristics (SDR, S, wall thickness and weight).

Layflat hose. Layflat tubing has been used in irrigation for a number of years (Figure 3.6). It is an alternative to rigid PVC pipes for surface use as water conveyance lines, mains and manifolds, in drip and other low pressure micro-irrigation installations. It is made of soft PVC reinforced with interwoven polyester yarn. Layflat hoses are flexible, lightweight, and available in various sizes (millimetres or inches) from 1–6 inches and for working pressures (PN) of 4.0–5.5 bars. They are manufactured with plain ends and supplied in coils in standard lengths of 25, 50 and 100 m.

There are no special connector fittings for layflat hoses. The hoses are connected by inserting small pieces of PE piping into the ends of the hoses, or by metallic quick couplings attached to both pipe ends. Small diameter PE tubes are used to connect laterals to the layflat manifolds. In these cases, wire ties are needed to secure the connections. However, several micro-irrigation industries have designed and manufactured special connector fittings for jointing their drip lines with layflat hoses.

FIGURE 3.6 - A layflat hose.

PIPE CONNECTOR FITTINGS

Malleable iron threaded. These fittings are made for use with galvanized steel threaded pipes and they are available in a wide range as elbows, bends, reducers, tees, plugs, nipples and other (Figure 3.7). They are characterized by toughness and ductility and they provide a sound joint able to withstand pipeline expansion and contraction and other stresses. They are manufactured with screw type joints male and female (taper threads) in accordance with BS 21, DIN 2999, ISO R 7 and American standards in nominal sizes (inside diameters) as in the galvanized steel pipes. The sizes, usually quoted in inches, may be converted to millimeters i.e. ½ inch for DN 15 mm, ¾ inch for 20 mm, 1 inch for 25 mm, 1¼ inch for 32 mm, 2 inches for 50 mm, etc. Mostly they comply to BS 143&1256, DIN 2950, ISO R 49 for working pressures of minimum 14.0 bars.

Polypropylene (PP) pipe connector fittings. PP connector plastic pipe fittings (joints) are primary suitable for use with PE plastic pipes. There is a full range of all kinds, sizes and types of these pipe fittings worldwide.

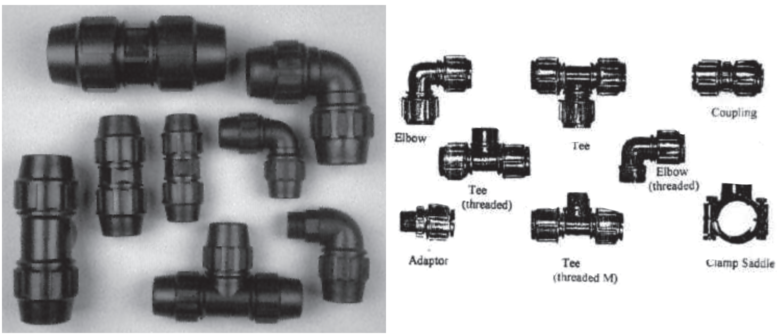
FIGURE 3.7 - Threaded galvanized steel pipe fittings.

There are three main types with several modifications. These are:

- lock connector fittings, inserted into the pipe, with a locking ring which securely fastens the hose pipe to the fitting and can withstand high pressures;
- barbed type fittings, also inserted into the pipe, available only in small diameters up to 20 mm, and for pressures up to 2.0 bars only;
- compression type, which are available in all diameters and are for high pressures, 10.0 bars. The compression fittings are also suitable for larger size rigid PVC pipes. They are easily mounted and dismantled without cutting the pipe. They are more expensive than the other fittings but last longer and can be used in several installations.

All PP connector fittings are also available with one or both ends threaded (Figure 3.8).

FIGURE 3.8 - Polypropylene fittings compression type.



PVC fittings. Pipe fittings made of PVC are available in the inch system following the same dimensioning with the metal pipes and fittings and in the metric system (mm) conforming the ISO and DIN dimensioning. They are manufactured for solvent welding, threaded jointing and for push-fit integral mechanical jointing (Figures 3.9 and 3.10).

FIGURE 3.9 - PVC solvent welding pipe fitting.

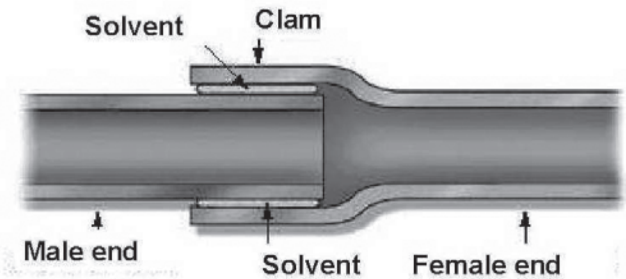
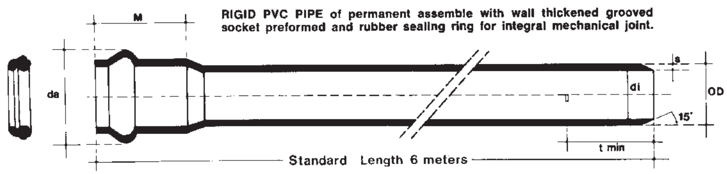


FIGURE 3.10 - PVC pipe with grooved ring socket push/fit joint



FLOW CONTROL DEVICES

Any device installed in a fluid supply system, in order to ensure that the fluid reaches the desired destination, at the proper time, in the required amount (the flow rate), and under the right pressure, is called a control appliance.

As such an appliance controls proper operation of a fluid system, selecting its type, size and placement is of uppermost importance and ought to be done with the full knowledge of the various features of the device and with complete understanding of the way it performs. Equally important is proper maintenance in order to ensure faultless and sound performance of the appliance. Made of metal base material or reinforced high engineering plastics, the common flow control devices used in irrigation systems can withstand high pressures (PN 10.0–16.0 bars) with screw-type end connections with internal or external threads for in-line installation.

Fluid control devices can be divided into three main classes (Table 3.4):

- Directional devices or valves. These serve to directly regulate the fluid flow. Installed in the pipeline, they enable starting or stopping the flow, and setting its rate, pressure and direction. Examples of such devices are the stop valves, the check valves and the regulating valves.
- Measuring devices or valves. In order to ensure the appropriate flow regime, just regulating the flow is not enough. It is also necessary to obtain accurate information about flow parameters, so that adjustments can be made, as required, to achieve the desired flow conditions. Water and flow meters and pressure gauges belong to this group.
- Auxiliary devices. These do not directly influence fluid flow, but ensure an undisturbed functioning of a system. To this group belong air valves and safety valves.

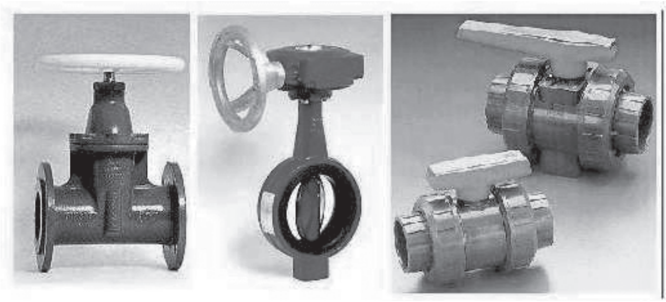
TABLE 3.4 - Scheme for flow control devices.

Directional devices or valves	Shut-off valves (stop valves)	• ball valves • butterfly valves • gate valves • disk* valves (globe, angle and oblique or Y valves) • radial valves
	Check valves (non-return valves)	• swing check valve • parallel check valve
	Regulating valves**	• disk* valves (globe, angle and oblique or Y valves) • radial valves
Measuring devices	Meters	• water meters • flow meters
	Gauges	• pressure gauges
Auxiliary devices	Air valves Safety valves	

Shut-off valves or stop valves. They are most widely used valves, manually operated (Figure 3.11). Usually installed between the ends of two pipes they serve to start or stop the flow of fluid in the pipeline. Stop valves are primarily designed for just two extreme situations: either to be completely open, to freely pass the full flow of fluid, or to be completely closed, to prevent any flow. The most common are the gate, ball, butterfly,

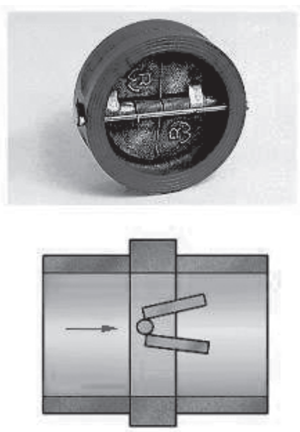
***:** *The sealing of a disk valves can be either a piston or a diaphragm.*
****:** *Regulating valves regulate pressure, flow or water level in either a direct acting or pilot operated way.*

FIGURE 3.11 - Various shut-off valves. From left to right a gate, a butterfly and ball valves.



radial and disk valves. In gate valves, the water moves in a straight line without resistance when fully open. Gate valves are not recommended for regulating or throttling flow, they must be either fully open or full closed. Ball valves are used on a large scale in small sizes of ¾ to 2 inches due to their many advantages. They feature quick on-off operation, quarter-turn and they can balance or throttle the flow. Of the disk valves, the most widely used model in irrigation networks is the oblique (Y-valve), ideal for throttling and regulating the flow. All types are made of brass in sizes of ½ to 4 inches, screw type with internal and/or external threads, at a PN of 16.0 bars. Oblique disk valves are also made of PP plastic material.

FIGURE 3.12 - Scheme and photograph of a check valve.



Check valves. Check valves, also called non-return valves, permit flow in one direction only and prevent reversal flow in piping by means of an automatic check mechanism (Figure 3.12). They come in two basic types: the swing check, which can be installed in horizontal or vertical piping; and the lift check, for use in horizontal lines only. Water flow keeps the check valves open, and gravity and reversal of flow close them automatically. They are placed in-line at the head control unit immediately after the pump. Swing checks are used with gate valves, lift checks with disk valves. Check valves are made of several metal materials and brass, and are screw type (female joints) quoted in inches from ¾ to 4 inches, at a PN of 16.0 bars.

Regulating valves. Regulating valves are directional, semi-automatic devices, which allow controlling pressure and flow in a water supply system. These valves operate without any intervention from the operator, but the parameters of their performance must be preset by hand or by remote control, according to the requirements of the water supply system.

Regulating valves can be divided basically in three categories:

- For reducing the downstream pressure.
- For sustaining or relieving the upstream pressure.
- As flow regulators.

A pressure reducing valve will throttle flow and maintain downstream pressure at the required level, but only if the upstream pressure is higher than the preset level. Hence, it is controlled only by the downstream pressure (Figure 3.13).

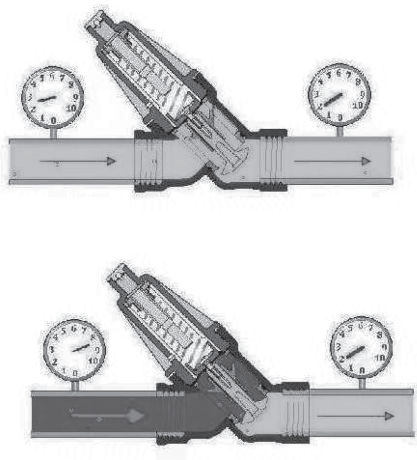
A pressure sustaining valve will maintain upstream pressure either at its maximum permitted level, by relieving the superfluous flow, or at its minimum required level, by throttling the flow. Hence, it is controlled by the upstream pressure level.

Flow regulators are in-line valves that maintain a constant predetermined flow rate, regardless of pressure changes in the system.

All the types of regulating valves work on the principle of flow throttling, being based on the principle of inverse relationship between the cross-sectional area of a flexible orifice and the line pressure. In most cases the valves are of the disk (globe, angle and oblique or Y) or the radial type. Radial valves are often preferred to disk valves. Gate, ball, butterfly and other types are unsuitable for automatic regulation.

Regulating valves are either direct acting or pilot operated. Pressure regulating valves are often installed at the entrance of the manifolds to ensure a constant operating pressure for the laterals. They are made of brass, bronze or plastic in sizes of 1 to 3 inches with threaded connections.

FIGURE 3.13 - A pressure reducing valve maintains downstream pressure constant when pressure upstream increases.



Meters. A distinction must be made between water meters and flow meters. Water meters measure and record the volumes of water passing through them, without considering the time element. Reading the output of a water meter gives information about the volume of water that passed through the appliance in a period, beginning with the last reading or zeroing of the meter. The most common type used for irrigation water is the Woltmann type with an impeller for axial flow. The velocity of flow activates the impeller and the turns are translated into total volume of water transmitted to the display dial through a series of reducing gears. They are manufactured in various designs, with the body made of cast iron, and constructed either as compact units or with an interchangeable inner mechanism. Sizes up to 2 in are available with threaded joints; larger sizes having flanges (Figure 3.14).

The flow meter measures the velocity of flow or, less often, the rate of flow or discharge. The most common type is the rotameter where a specially shaped float moves freely in a tube so that the flow velocity or rate is directly indicated by the float rim.