TRADE OF

Pipefitting

PHASE 2

Module 3

Pipe Processes

UNIT: 2

Piping Components and Fittings

Produced by

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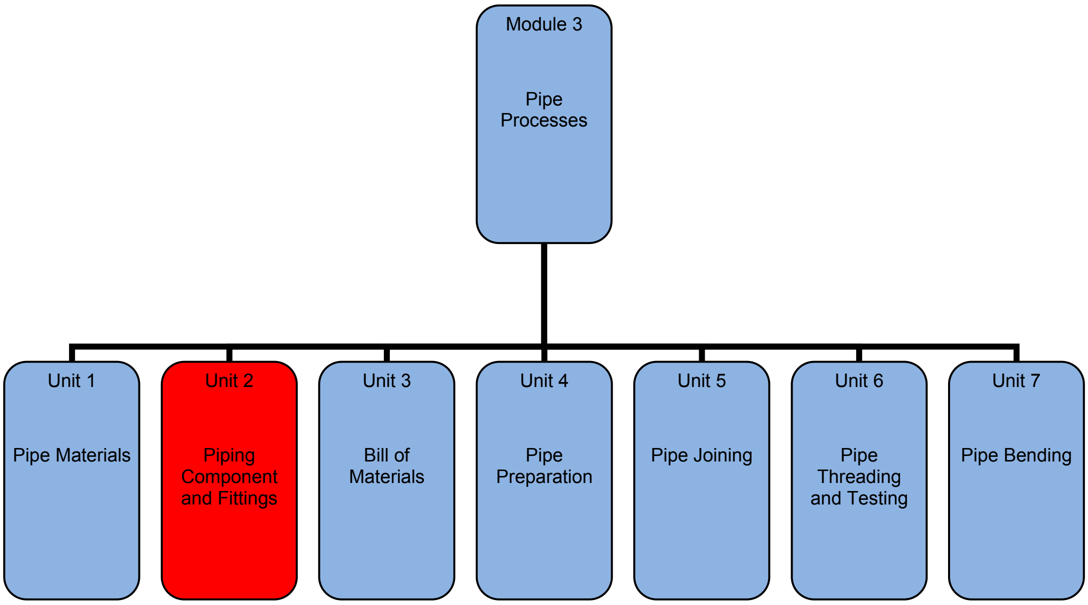
Unit Objective

There are seven Units in Module 3 for Pipe Processes. Unit 1 focuses on Piping Materials, Unit 2; Piping components and fittings, Unit 3; Bill of Materials, Unit 4; Pipe Preparation, Unit 5; Pipe Joining, Unit 6; Pipe threading and testing and Unit 7 Pipe bending.



In this unit you will be introduced to the different components such as fittings, valves pumps and instruments used in piping systems. This unit will look at how they are classified and why they are selected for different applications and services.

Learning Outcome

By the end of this unit each apprentice will be able to:

- Identify the various types of pipe joining fittings used in piping systems.
- flanges
- threaded
- welded
- Explain the purpose of valves and where they are normally positioned in piping systems.
- Identify different types of valves for the following functions:
- Stop valves for flow isolation
- Check valves
- Flow regulating valves
- Control valves
- Safety relief valves
- Identify the common information identified on a valve name plate
- Explain the correct procedure for storing and handling of valves.
- Identify the most common types of pumps and their applications in piping systems.
- Centrifugal pump
- Rotary lobe pump
- Air operated diaphragm pump
- Identify the various types of gauges/meters used in pipe installations
- pressure gauges
- temperature gauges
- flow meters

1.0 Pipe Fittings

Key Learning Points

- Identify the basic pipe fittings used for pipe and tube systems
- Identify the function of each fitting and any special installation techniques if applicable

1.1 Introduction to Pipe Fittings

Fittings are used in pipe and plumbing systems to connect straight pipe or tubing sections, to adapt to different sizes or shapes, to branch or re-direct the piping system and if necessary to provide a jointing method if 2 dissimiliar piping materials are used in the one system. Fittings for pipe and tubing are most often made from the same base material as the pipe or tubing being connected, e.g., stainless steel, steel, copper or plastic. However, any material that is allowed by code may be used, but must be compatible with the other materials in the system, the fluids being transported, and the temperatures and pressures inside and outside of the system. For example, brass-bodied fittings are common in otherwise copper piping and plumbing systems. The photographs below show some common fittings that are used in piping systems.

Screwed stainless steel and butt weld mild steel fittings

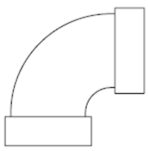
1.2 Identifying Basic Pipe Fittings

Fittings for piping systems can be expensive and require a proportionally large labour element to install, therefore correct selection and use is of vital importance to a well installed piping system. Every type of piping material has a range of fittings that can be used with it and some piping materials can have multiple different ranges of fittings that can be used. For example copper piping systems can be installed by bending the pipe and therefore using no elbows, using soldered copper fittings or compression brass fittings depending on the type of service being transferred in the copper pipe. Fittings are available with ends to match the piping installation therefore the following information will not differentiate between welded, threaded or compression but will concentrate on the orientation and the use of the fitting. The most common type of pipe fittings are:

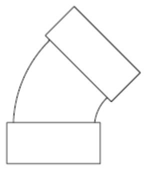
- Elbow
- Tee
- Cross
- Reducer
- Cap
- Union

1.3 Elbow

A pipe fitting installed between two lengths of pipe or tube allowing a change of direction, usually 90° or 45°. The ends may be machined for butt welding, threaded (usually female), or socketed, etc. When the two ends differ in size, it is called a reducing or reducer elbow. Most elbows are available in short radius or long radius of types. The short radius elbows have a center to end distance equal to the nominal diameter, while the long radius is 1.5 times the nominal diameter. Elbows used on powder transfer systems have a much longer radius (radius of bend can be 10 times the nominal diameter of the pipe) to ensure smooth flow, reduce wear to both product and piping and to reduce the chance of getting blockages.



90° Elbow

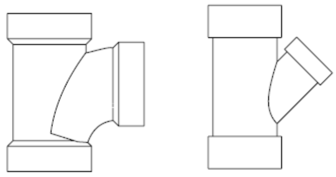


45° Elbow

1.4 Tee

A tee is used to either combine or split a fluid flow. Most common are equal tees which have the same body and branch diameter but there is also a wide range of reducing tees where either the branch or the body is a different diameter relative to each other.

A swept tee is where the branch enters the body at an arc and is used to minimise the frictional losses and promote flow in the system. A wye tee is where the branch is stabbed into the body at an angle and is usually used where the branch is a smaller diameter than the main pipe.



Difference between a swept tee and a wye tee

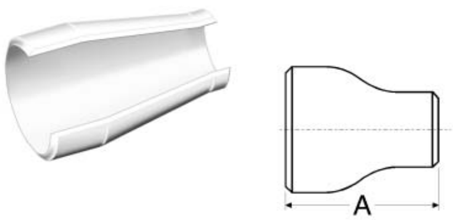
1.5 Cross

A cross has one inlet and three outlets, or vice versa and like tees come in equal and reducing forms. A cross is more expensive than two tees but has the advantage of reduced space and requires less labour to install.

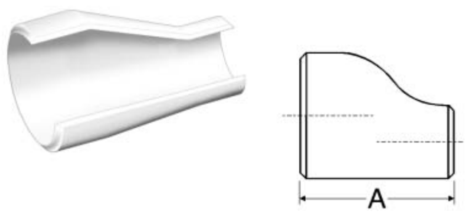
Equal cross with compression fittings

1.6 Reducer

Reducers are used to join 2 different pipe sizes together. They can be either concentric or eccentric which refers to the relative position of the center lines of the outlet and inlet. Special attention must be given when using reducers in a horizontal orientation as the slope will prevent free draining of a system if not installed correctly.



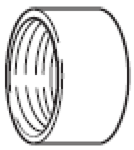
Concentric Reducer



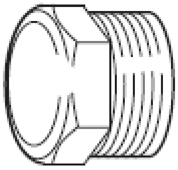
Eccentric (bottom flat) reducer

1.6 Cap or Plug

A type of pipe fitting which is liquid or gas tight, and is used to cover the end of a pipe. A cap has a similar function to a plug. For screwed systems the cap would have female threads where a plug would have male threads.



Cap



Hex Plug

2.0 Fittings for Pipe Joints

Key Learning Points

- Identify how fittings are connected to pipes
- Identify different types of pipe joints

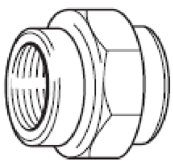
2.1 How Fittings are Connected to Pipes

BSP fittings are a family of fittings used to connect up threaded pipe and equipment. They are manufactured from pipe, bar, hollow bar, castings or forgings. The fittings are used in non-critical, low pressure applications where welding is not possible or required. They therefore provide a relatively low cost method of connection. BSP fittings are usually fitted with a sealant (paste or tape such as PTFE) and are considered to be permanent pipe-work.

Butt weld or socket weld fittings are a type of fittings used for forming circumferential butt weld joints in pipework systems. They are used for critical systems and in areas where pipe-work is permanent and are designed to provide good flow characteristics.

2.2 Screwed Unions

A union is similar to a coupling, except it is designed to allow quick and convenient disconnection of pipes for maintenance or fixture replacement. While a coupling is usually a permanent joint or requires the ability of being able to rotate all the pipe to one side of it to unscrew it, a union provides a simple nut transition, allowing easy release at any time. When using unions with dissimilar metals (such as copper and galvanized steel) a dielectric union should be used. This breaks the electric current with a plastic liner between two halves of the union, thus limiting galvanic corrosion.



BSP union

2.3 Flanges

There are many different flange standards to be found worldwide. To allow easy functionality and inter-changeability, these are designed to have standardised dimensions. Common world standards include ANSI (USA), PN/DIN (European) and BS10, (British/Australian).

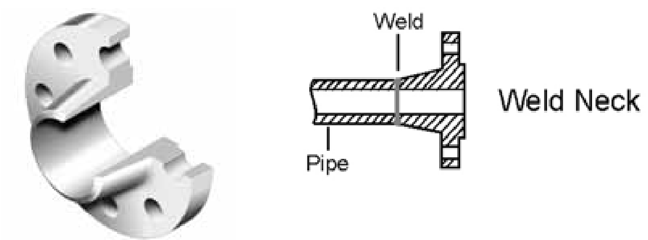
ANSI designations such as ANSI 150, ANSI 300 and so on are often followed by a # (hash symbol). The ANSI number does not directly relate to a pressure rating, but to a class of flange. For example, the hash (#) or 'pound' reference; e.g. 300 pound, can be misleading in that an ANSI 300 flange is actually rated for a test pressure of 740 psi (~5100 kPa), and only within a certain working temperature range (-20 to 100 deg F.)

In most cases these are not interchangeable (e.g. an ANSI flange will not mate against a PN flange). Further many of the flanges in each standard are divided into "pressure classes", allowing flanges to be capable of taking different pressure ratings. Again these are not generally interchangeable (e.g. an ANSI 150 will not mate with an ANSI 300). These "pressure classes" also have differing pressure and temperature ratings for different materials. The flange faces are made to standardized dimensions and are typically "flat face", "raised face", "tongue and groove", or "ring joint" styles, although other obscure styles are possible. Flange designs are available as:

- Weld neck
- Slip-on
- Socket Weld
- Threaded
- Stub-end or Lap flange
- Blind Flange

Weld Neck Flange

Weld neck flanges are used in critical applications. These are circumferentially welded onto the system at their necks which means that the integrity of the butt-welded area can easily be examined by X-ray radiography. The bores of

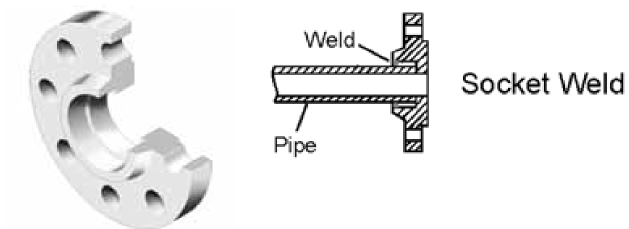


both pipe and flange match thus reducing turbulence and erosion.

Weld Neck Flange

Socket Flange

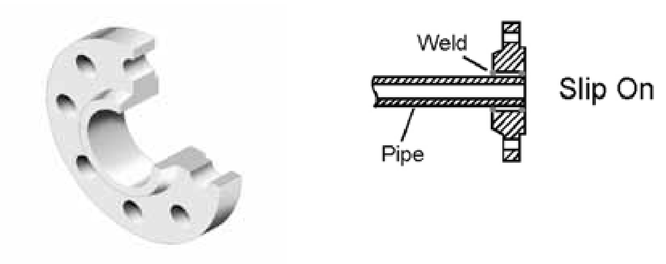
A socket flange is counter-bored to accept the pipe, which is then fillet welded. The bore of both the pipe and the flange are the same to ensure good flows.



Socket Flange Flange

Slip-On Flange

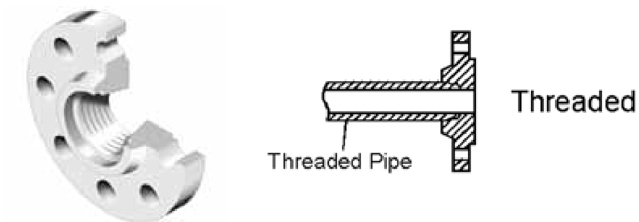
A slip-on flange is slipped over the pipe and then fillet welded. Easy to use in fabricated applications.



Slip-on Flange

Screwed Flange

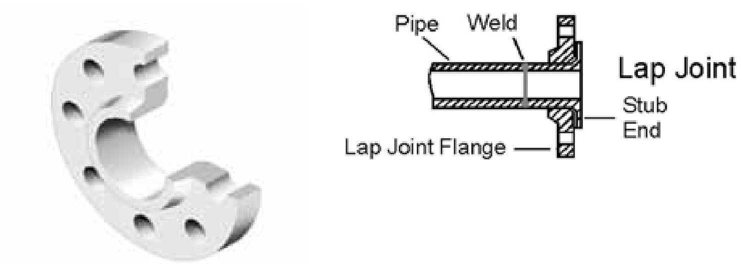
A screwed or threaded flange requires no welding and is used to connect other threaded components in low pressure non-critical applications.



Screwed Flange

Lap Flange

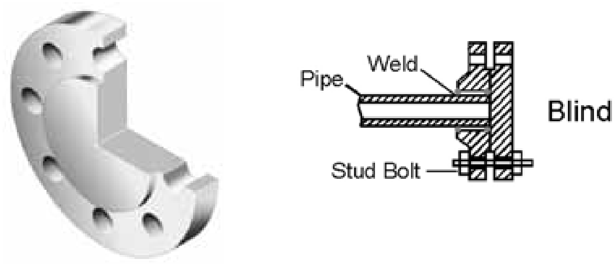
Lap flanges (or backing flanges) are used with a stub end which is butt-welded to the pipe with the lap flange acting as a loose collar behind it. Thus the stub end always provides the sealing face. This type of joint is easily assembled and aligned, and it is favoured in low pressure applications. To reduce costs the 'backing' flanges can be made from a lower grade of material such as stainless steel in Hastelloy systems.



Lap Flange

Blind Flange

A blind flange or sometimes called a blanking flange, this is used for blanking off pipelines, valves and pumps and as an inspection cover.



Blind Flange

3.0 Valves for Piping Systems

Key Learning Points

- Identify the need for valves in piping systems
- Identify different types of valves used in piping systems
- Identify applications for the different types of valves

3.1 Valves for Piping Systems

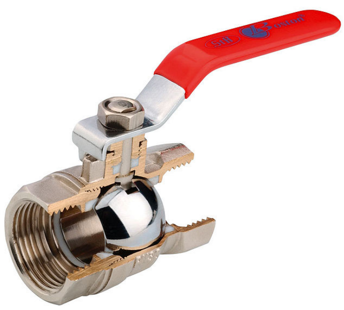
Fluids and gassed do not just flow freely through piping systems. They must be regulated and at certain points stopped. There are a number of different types of valves used in piping systems, the most common types of stop valves being :

- Ball valve
- Butterfly valve
- Globe valve
- Check valves
- Diaphragm valve
- Process control valves
- Safety Relief valves

Valves may be operated manually, either by a hand wheel, or a lever or operated automatically by a pneumatic actuator or electrical drive motor. Complex control systems will use feedback from an instrument to control these types of valves to regulate pressure, temperature or flowrate depending on the control parameters required.

3.2 Ball Valve

A ball valve is a valve with a spherical centre which controls the flow through it. The sphere has a hole, or port, through the middle so that when the port is in line with both ends of the valve, flow will occur. When the valve is closed, the hole is perpendicular to the ends of the valve, and flow is blocked. The handle or lever is also inline with the port through the sphere which allows the operator to know whether the valve is opened or closed.



Manual Ball valve

Ball valves do not offer the fine control that may be necessary in throttling applications; however they are durable and usually work to achieve perfect shutoff even after years of disuse and are suitable for high pressures and temperatures.

3.3 Butterfly Valve

The butterfly valve like the ball valve are are part of the family of quarter turn valves, i.e. they only require a quarter turn to achieve their fully open position. The butterfly valve can be used for isolating or regulating flow. The closing mechanism takes the form of a disc whose position is again indicated by the position of the opening lever. Butterfly valves are generally favored because they are lower in cost to other valve designs as well as being lighter in weight, meaning less support is required. The disc is positioned in the center of the pipe, but unlike a ball valve, the disc is always present within the flow, therefore a pressure drop is always induced in the flow, regardless of valve position.

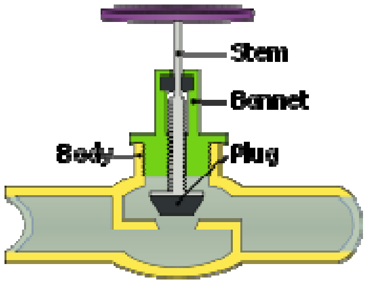
Actuated Butterfly valve with visual indicator

3.4 Globe Valve

A globe valve is a type of valve used for regulating flow in a pipeline, consisting of a movable disk-type element (the plug) and a stationary ring seat in a generally spherical body. (See section through a globe valve below. While they can be used as a shut-off valve they are not generally selected for this function alone as the baffle inside the valve restricts flow even when the valve is fully open.

In a globe valve, the plug is connected to a stem which is operated by screw action in manual valves. Typically, automated valves use sliding stems. Automated globe valves have a smooth stem rather than threaded and are opened and closed by an actuator assembly. When a globe valve is manually operated, the stem is turned by a hand wheel which requires 3 to 4 complete revolutions to open or close the valve.

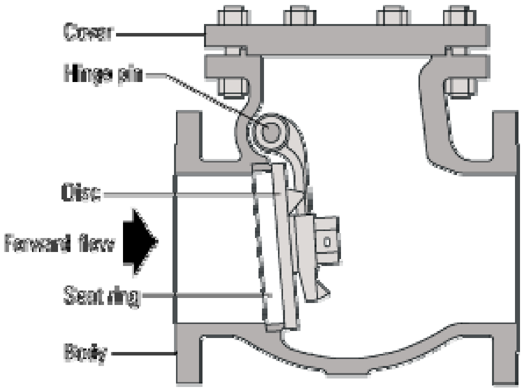
Globe valve



Section through a globe valve

3.5 Check Valve

A check valve, non-return valve or one-way valve is a mechanical valve, which normally allows fluid (liquid or gas) to flow through it in only one direction. An important concept in check valves is the cracking pressure (or opening pressure) which is the minimum upstream pressure at which the valve will operate. Typically the check valve is designed for and can therefore be specified for a specific cracking pressure.



Full bodied swing check valve

Check valves are often used before and after pumps to ensure that they do not run dry once they have been primed or to prevent a system from draining if a pump was to fail. Diaphragm pumps use a ball check valve as part of the internal workings of the pump to ensure flow goes only in one direction. Check valves are also often used when multiple gases are mixed into one gas stream. A check valve is installed on each of the individual gas streams to prevent mixing of the gases in the original source. For example, if a fuel and an oxidizer are to be mixed, then check valves will normally be used on both the fuel and oxidizer sources to ensure that the original gas cylinders remain pure and therefore non-flammable.

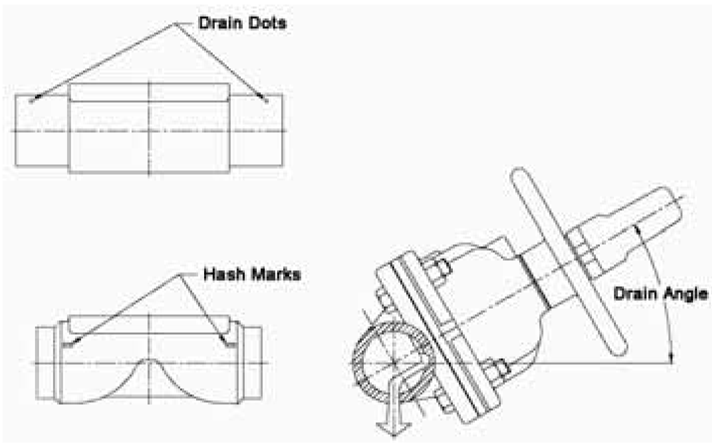
3.5 Diaphragm Valve

Diaphragm valves (or membrane valves) consists of a valve body with two or more ports, a diaphragm, and a "saddle" or seat upon which the diaphragm closes the valve. Because the diaphragm valve has no seal cavities for contaminants or microbes to lodge and it can withstand sanitizing and sterilizing methods this type of valve is used extensively in biotechnology and pharmaceutical industries.

There are two main categories of diaphragm valves: one type seals over a "weir" (saddle) and the other (sometimes called a "straight-way" valve) seals over a seat. The main difference is that a saddle-type valve has its two ports in line with each other on the opposite sides of the valve, whereas the seat-type has the in/out ports located at a 90 degree angle from one another. The saddle type is the most common in process applications and the seat-type is more commonly used as a tank bottom valve but exists also as a process valve. While diaphragm valves usually come in two-port or three-port forms, they can also come with much more. Diaphragm valve manufacturers are now offering be-spoke valve manifolds to perform clean in place and sterilize in place functions while minimizing the dead space in the valve body.

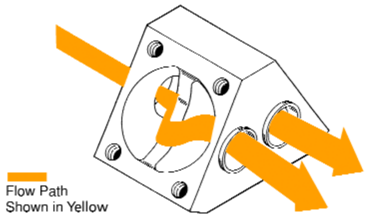
Stainless steel Diaphragm valves

When diaphragm valves are installed on the horizontal it is important to rotate them at an angle to ensure they are free draining around the weir. There is usually a mark on the body of the valve which indicates the correct angle of rotation.



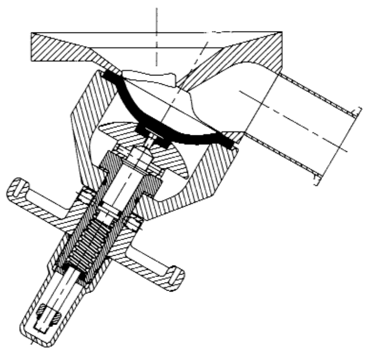
Diaphragm valve offset to free drain around weir

In addition to the well known, two way shut off diaphragm valve, other orientations of diaphragm valves include: two way divert valve, zero deadleg valve, sterile access port, block and bleed and tank bottom outlet valves just to name a few.



Two way divert diaphragm valve

Tank bottom outlet diaphragm valve



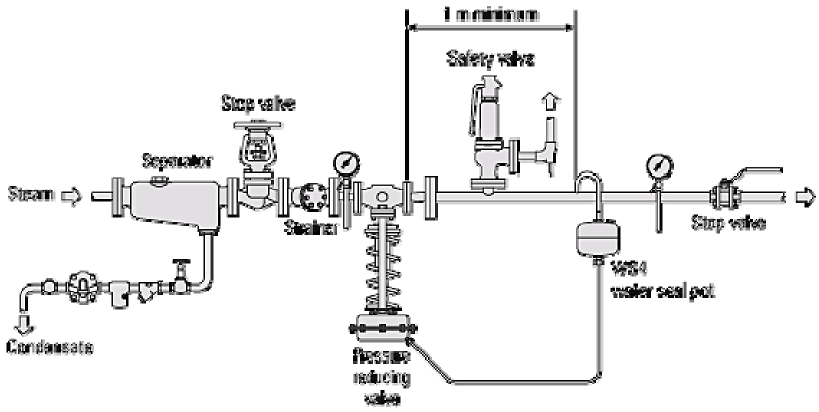
3.6 Process Control Valves

Process plants consist of many control loops all networked together to produce a product to be offered for sale. Each of these control loops is designed to keep some important process variable such as pressure, flow, level, temperature, etc. within a required operating range to ensure the quality of the end product.

A control loop consist of 3 main elements, an instrument or sensor to measure the process variable, a controller to process this information and to direct the control valve to respond and the control valve which manipulates the process fluid to regulate the process variable as close as possible to the desired set point. It is not accurate to say that the control valve is the most important part of the loop. It is useful to think of a control loop as an instrumentation chain. Like any other chain, the whole chain is only as good as its weakest link. It is important to ensure that the control valve is not the weakest link.

Globe control valve with pneumatic actuator and smart positioner

There are numerous types of control valves some of which are self regulating, like a pressure regulator on a gas bottle while others rely on feedback from instruments for their control. Control valves are normally installed as part of a set of valves including local isolation valves so that the control valve can be removed for maintenance and service at regular intervals. See illustration below which identifies the main components of a steam pressure reducing station which includes the necessary isolation valves, instruments, safety valves and steam traps which are required to provide effective steam pressure reduction.



Typical steam pressure reducing station

3.7 Safety Relief Valve

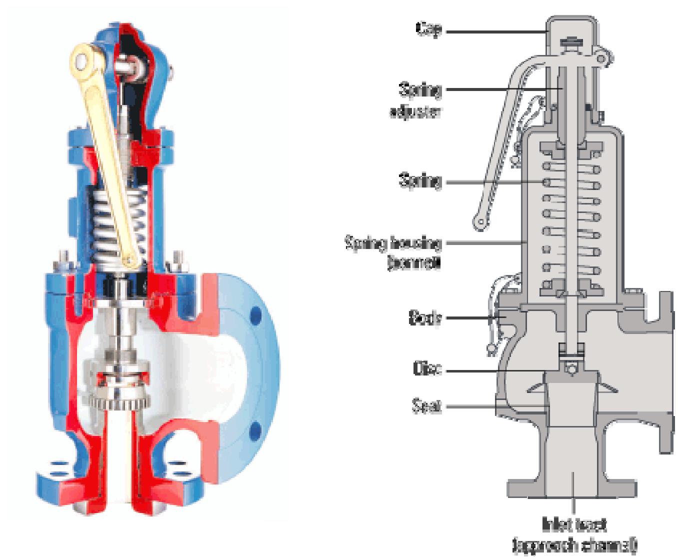
A safety valve is a valve mechanism for the automatic release of a substance from a system when the pressure or temperature exceeds preset limits. It is a type of valve which is part of a larger family of valves known as pressure safety valves (PSV) or pressure relief valves (PRV).

The ASME / ANSI PTC25.3 standards applicable to the USA define the following generic terms:

- **Pressure relief valve -** A spring-loaded pressure relief valve which is designed to open to relieve excess pressure and to reclose and prevent the further flow of fluid after normal conditions have been restored. It is characterised by a rapid-opening 'pop' action or by opening in a manner generally proportional to the increase in pressure over the opening pressure. It may be used for either compressible or incompressible fluids, depending on design, adjustment, or application. This is a general term, which includes safety valves, relief valves and safety relief valves.
- **Safety valve -** A pressure relief valve actuated by inlet static pressure and characterised by rapid opening or pop action. Safety valves are primarily used with compressible gases and in particular for steam and air services. However, they can also be used for process type applications where they may be needed to protect the plant or to prevent spoilage of the product being processed.
- **Relief valve -** A pressure relief device actuated by inlet static pressure having a gradual lift generally proportional to the increase in pressure over opening pressure. Relief valves are commonly used in liquid systems, especially for lower capacities and thermal expansion duty. They can also be used on pumped systems as pressure overspill devices.
- **Safety relief valve -** A pressure relief valve characterised by rapid opening or pop action, or by opening in proportion to the increase in pressure over the opening pressure, depending on the application, and which may be used either for liquid or compressible fluid. In general, the safety relief valve will perform as a safety valve when used in a compressible gas system, but it will open in proportion to the overpressure when used in liquid systems, as would a relief valve.

The European standards (BS 6759 and DIN 3320) provide the following definition:

Safety valve **-** A valve which automatically, without the assistance of any energy other than that of the fluid concerned, discharges a certified amount of the fluid so as to prevent a predetermined safe pressure being exceeded, and which is designed to re-close and prevent the further flow of fluid after normal pressure conditions of service have been restored.



Typical Safety valve

Relief valves for liquid applications are generally characterized by the relatively small size of the valve necessary to provide protection from excess pressure caused by thermal expansion. In this case a small valve is adequate because most liquids are nearly incompressible, and so a relatively small amount of fluid discharged through the relief valve will produce a substantial reduction in pressure. Relief valves for gas applications have larger connections sizes due to a gas being compressible under pressure which will expand rapidly in volume when the pressure is lowered, i.e. when a relief valve lifts.

4.0 Handling and Installing Valves

Key Learning Points

- Identify the common requirements for valve nameplates
- Identify the correct procedure for storing and handling valves.

4.1 Valve Nameplates

As there are many different types of valves and different standards that are applicable for each type of valve it is not possible to give a definitive list of the exact information required to be marked on a valve. For example a safety valve requires very specific information which must be carried on the valve. Marking is mandatory on both the shell, usually cast or stamped, and the name-plate, which must be securely attached to the valve. A general summary of the information required is listed below:

On the Shell

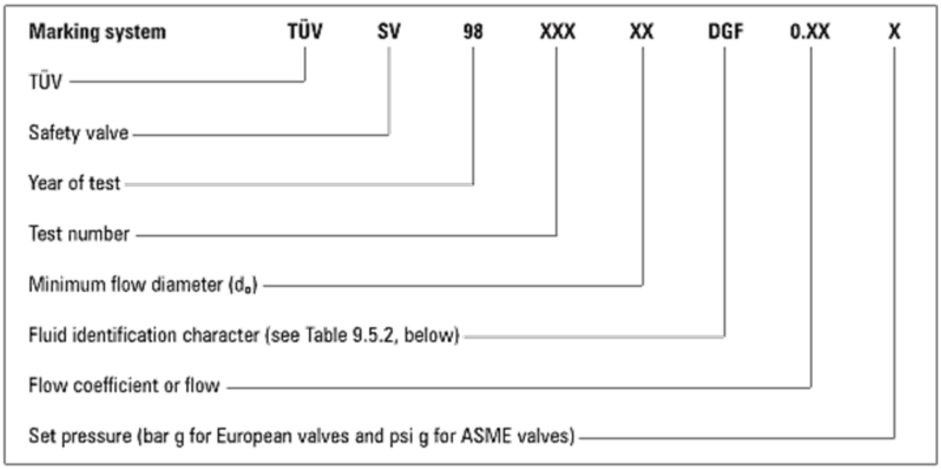
- Size designation.
- Material designation of the shell.
- Manufacturer's name or trademark.
- Direction of flow arrow.

On the Identification Plate

- Set pressure (in bar g for European valves and psi g for ASME valves).
- Number of the relevant standard (or relevant ASME stamp).
- Manufacturer's model type reference.
- Derated coefficient of discharge or certified capacity.
- Flow area.
- Lift and overpressure.
- Date of manufacture or Serial reference number.

Other Information that May Be on Different Types of Valves

- Surface finish if applicable
- Heat Number
- PED and ATEX classification



Details the valve marking system required by TÜV

4.2 Storage and Handling of Valves

Proper storage and protection should be considered early in the selection process, before the valve is shipped. Typically, manufacturers have packaging standards that are dependent upon the destination and intended length of storage before installation. Because most valves arrive on site some time before installation, many problems can be averted by making sure the details of the installation schedule are known and discussed with the manufacturer at the time of valve selection. In addition, special precautions should be taken upon receipt of the valve at the final destination. For example, the valve must be stored in a clean, dry place away from any traffic or other activity that could damage the valve.

4.3 Installation Instructions for Valves

Valves form a critical part of any piping system and because they are integral to the system construction they need to be installed in parallel with the piping installation. This differs from other critical equipment such as instruments and large piping components which can be installed close to the end where they are not exposed to risk of damage from construction activities. As there are many different types of valves it is not possible to give a definitive list of installation instructions for every valve. The following list is meant only as a guideline, please consult the specific valve manual and your supervisor for specific instructions:

- ***Intended use:*** Refer to the Installation and Maintenance Instructions, name-plate and Technical Information Sheet, to ensure that the product is suitable for the intended use/application. Inspect the valve before use and ensure that it is in safe working order and that there was no damage during shipping.
- ***Access:*** Ensure safe access and if necessary a safe working platform (suitably guarded) before attempting to work on any valve. Arrange suitable lifting gear if required.

- ***Hazardous liquids or gases in the pipeline:*** Consider what is in the pipeline or what may have been in the pipeline at some previous time. Consider: flammable materials, substances hazardous to health, extremes of temperature.
- ***Hazardous environment around the product:*** Consider: explosion risk areas, lack of oxygen (e.g. tanks, pits), dangerous gases, extremes of temperature, hot surfaces, fire hazard (e.g. during welding), excessive noise, moving machinery.
- ***Be Sure the Pipeline Is Clean:*** Foreign material in the pipeline could damage the seating surface of the valve or even obstruct the movement of the valve plug, ball, or disk so that the valve does not shut off properly. To help reduce the possibility of a dangerous situation from occurring, clean all pipelines before installing. Make sure pipe scale, metal chips, welding slag, and other foreign materials are removed. In addition, inspect pipe flanges to ensure a smooth gasket surface.
- ***The system:*** Consider the effect on the complete system of the work proposed. Will any proposed action (e.g. closing isolation valves, electrical isolation) put any other part of the system or any personnel at risk? Dangers might include isolation of vents or protective devices or the rendering ineffective of controls or alarms. Ensure isolation valves are turned on and off in a gradual way to avoid system shocks.
- ***Pressure systems:*** Ensure that any pressure is isolated and safely vented to atmospheric pressure. Consider double isolation (double block and bleed) and the locking or labeling of closed valves. Do not assume that the system has depressurised even when the pressure gauge indicates zero.
- ***Temperature:*** Allow time for temperature to normalise after isolation to avoid danger of burns.
- ***Tools and consumables:*** Before starting work ensure that you have suitable tools and/or consumables available. Use only genuine replacement spare parts for seal replacements.
- ***Permits to work:*** All work must be carried out or be supervised by a suitably competent person. Installation and operating personnel should be trained in the correct use of the product according to the Installation and Maintenance Instructions. Where a formal 'permit to work' system is in force it must be complied with. Where there is no such system, it is recommended that a responsible person should know what work is going on and, where necessary, arrange to have an assistant whose primary responsibility is safety. Post warning notices' if necessary.
- ***Handling:*** Manual handling of large and/or heavy valves may present a risk of injury. Lifting, pushing, pulling, carrying or supporting a load by bodily force can cause injury particularly to the back. You are advised to assess the risks taking into account the task, the individual, the load and the working environment and use the appropriate handling method depending on the circumstances of the work being done.

- ***Residual hazards:*** In normal use the external surface of the product may be very hot. If used at the maximum permitted operating conditions the surface temperature of some products may reach temperatures of 232°C (450°F). Many products are not self-draining. Take due care when dismantling or removing the product from an installation (refer to 'Maintenance instructions').
- ***Freezing:*** Provision must be made to protect products which are not self-draining against frost damage in environments where they may be exposed to temperatures below freezing point.

4.4 Maintenance of Valves

Please note, always follow the valve manufacturer's recommended maintenance instructions. Optimization of a valve service life depends on an effective maintenance philosophy and program. Three of the most basic approaches to maintenance are:

- **Reactive** – Action is taken after an event has occurred. Wait for something to happen to a valve and then repair or replace it.
- **Preventive** – Action is taken on a timetable based on history; that is, try to prevent something bad from happening.
- **Predictive** – Action is taken based on field input using state-of-the-art, non-intrusive diagnostic test and evaluation devices or using smart instrumentation.

Although both reactive and preventive programs work, they do not optimize valve potential as reactive maintenance can be very disruptive to an operating plant and preventative maintenance can result in valves being serviced before they require it. The most effective approach is predictive maintenance which consists of four distinct modes:

- **Fault Detection** A majority of valve maintenance effort is spent in monitoring valves while in service to detect the occurrence of a fault. When a fault is identified, the maintenance process transitions to fault discrimination.
- **Fault Discrimination** During this mode, valve assets are evaluated to determine the cause of the fault and to establish a course of corrective action.
- **Process Recovery** Corrective action is taken to fix the source of the defect.
- **Validation** In this final mode, valve assets are evaluated relative to either as-new condition or the last established baseline condition. Once validated, the maintenance process returns to fault detection status.

5.0 Pumps for Piping Systems

Key Learning Points

- Identify the need for pumps in piping systems
- Identify different types of pumps used in piping systems
- Identify applications for the different types of pumps

5.1 Pumps for Piping Systems

A pump is a device used to move fluids, such as liquids or gases. A pump displaces a volume by physical or mechanical action. Pumps alone do not create pressure; they only displace fluid, causing a flow. Adding resistance to the flow causes pressure in a system. There are numerous different types of pumps and often there is a clue in their name that describes the method the pump employs for moving the fluid. We will deal the following 3 popular types of pumps:

- Centrifugal Pump
- Rotary lobe pump
- Air operated diaphragm pump

Every pump has a different set of characteristics which should be considered when selection a pump for a particular application. The table below compares some of the common characteristics for the 3 different types of pump. Please note that the values given are for base line comparisons only and are not meant to be a definitive list of maximum flow rates and pressures achievable.

Pump Type	Typical Flow Range (L/Hr)	Max Pressure (Bar)	Self Priming	Pulsless flow	Fluid viscosity	Particulate matter	Run Dry	Advantages
Centrifugal pump	400,000	10	Poor	Excellent	Light	No	No	Fluid transfer at high flow rates and low pressures
Rotary lobe pump	200,000	15	Fair	Very good	Heavy	No	No	High-pressure capabilities low shear
Air operated Diaphragm pump	100,000	8	Excellent	Fair	Medium	Yes	Yes	Use for highly viscous or particulate-laden fluids and where electric is not available

5.2 Useful Terminology when Dealing with Liquid Pumps

- ***Cavitation***—Process in which small bubbles are formed and implode violently; occurs when $NPSH_a < NPSH_r$.
- ***Dead Head***—The ability of a pump to continue running without damage when discharge is closed off. Only recommended for centrifugal pumps.
- ***Density (specific weight of a fluid)***—Weight per unit volume, often expressed as grams per cubic centimeter.
- ***Flooded Suction***—Liquid flows to pump inlet from an elevated source by means of gravity. Recommended for centrifugal pump installations.
- ***Flow***—A measure of the liquid volume capacity of a pump. Usually given in liters per hour (L/hr).
- ***Fluids***—Include liquids, gases, and mixtures of liquids, solids, and gases.
- ***Head***—A measure of pressure, expressed in meters of head for centrifugal pumps. Indicates the height of a column of water being moved by the pump (without friction losses).
- ***Pressure***—The force exerted on the walls of a tank, pipe, etc., by a liquid. Normally measured in Barg.
- ***Prime***—Charge of liquid required to begin pumping action when liquid source is lower than pump. Held in pump by a foot valve on the intake line or by a valve or chamber within the pump.
- ***Seals***—Devices mounted in the pump housing and/or on the pump shaft that prevent leakage of liquid from the pump.
- ***Self-Priming***—Pumps that can draw liquid up from below pump inlet (suction lift), as opposed to pumps requiring flooded suction.
- ***Specific Gravity***—The ratio of the weight of a given volume of liquid to pure water. Pumping heavy liquids (specific gravity greater than 1.0) will require bigger motors.
- ***Static Discharge Head***—Maximum vertical distance (in meters) from pump to point of discharge with no flow.
- ***Strainer***—A device installed in the inlet of a pump to prevent foreign particles from damaging the internal parts.
- ***Sump***—A well or pit in which liquids collect below floor level; sometimes refers to an oil or water reservoir.
- ***Total Head***—Sum of discharge head, suction lift, and friction loss.

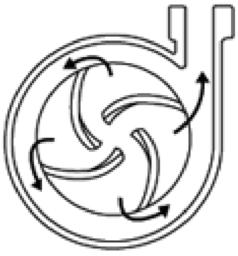
Valves

- ***Bypass Valve*—** Internal to many pump heads that allow fluid to be re-circulated if a given pressure limit is exceeded.
- ***Check Valve*—** Allows liquid to flow in one direction only. Generally used in discharge line to prevent reverse flow.
- ***Foot Valve*—** A type of check valve with a built-in strainer. Used at point of liquid intake to retain liquid in system, preventing loss of prime when liquid source is lower than pump.
- ***Relief Valve*—** Used at the discharge of a positive displacement pump. An adjustable, spring-loaded valve opens when a preset pressure is reached. Used to prevent excessive pressure buildup that could damage the pump or motor.
- ***Viscosity*—** The "thickness" of a liquid or its ability to flow. Most liquids decrease in viscosity and flow more easily as they get warmer.

5.3 Centrifugal Pump

Centrifugal pumps are the most common type of pump used to move liquids through a piping system. The energy changes occur into two main parts of the pump, the impeller and the volute. The impeller is the rotating part that converts driver energy into the kinetic energy. The volute is the stationary part that converts the kinetic energy into pressure. Liquid enters the pump suction and then the eye of the impeller. When the impeller rotates, it spins the liquid sitting in the cavities between the vanes outward and imparts centrifugal acceleration. As the liquid leaves the eye of the impeller a low pressure area is created at the eye allowing more liquid to enter the pump inlet.

Centrifugal pumps are typically used for large volume, low pressure applications and should be installed with flooded suction as they are not capable of self priming.

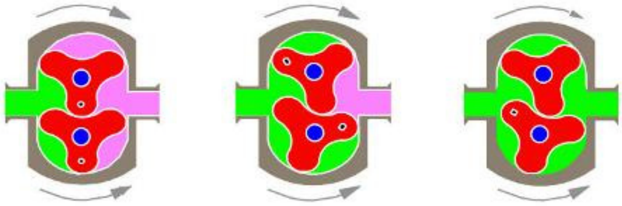


Impeller and volute

Centrifugal pump

5.4 Rotary Lobe Pump

A rotary lobe pump (positive displacement pump) has two rotors spinning in opposite directions within the pump head. Fluid is carried through the pump in the cavities formed between the dwell of the rotor and the interior of the rotor case. The illustration (below) shows the displacement of fluid from pump inlet to outlet.



Fluid being displaced (pumped) by rotating lobes

Positive displacement pumps, unlike centrifugal pumps, will produce the same flow at a given speed (RPM) no matter the discharge pressure. A Positive Displacement Pump must not be operated against a closed valve on the discharge side of the pump because it has no shut-off head like Centrifugal Pumps. A Positive Displacement Pump operating against a closed discharge valve, will continue to produce flow until the pressure in the discharge line are increased until the line bursts or the pump is severely damaged - or both. A relief or safety valve on the discharge side of the Positive Displacement Pump is therefore absolutely necessary. The relief valve can be internal or external. The pump manufacturer normally has the option to supply internal relief or safety valves. The internal valve should in general only be used as a safety precaution, an external relief valve installed in the discharge line with a return line back to the suction line or supply tank is recommended.

Positive pump with external safety relief valve

Rotary lobe pumps are more gentle on the liquid being pumped and can handle higher viscosity liquids and for these reasons this types of pumps are suitable for pumping creams and ointments

5.5 Air Operated Diaphragm Pump

Air operated diaphragm pumps uses compressed air pulsations to move two flexible diaphragms which are connected by a rod to displace liquid while check valves control the direction of the fluid flow through the pump. This type of pump can self prime and can suck liquid from up to 3m below it and pump up to 80 meters of head height (if 8 bar compressed air is available).

Air operated diaphragm pump

Air operated diaphragm pumps are used for viscous or particulate-laden fluids and because they are powered by compressed air they can operate where electric power is not readily available.

6.0 Instruments for Piping Systems

Key Learning Points

- Identify the need for instruments in piping systems
- Identify different types of instruments used in piping systems
- Identify applications for the different types of instruments

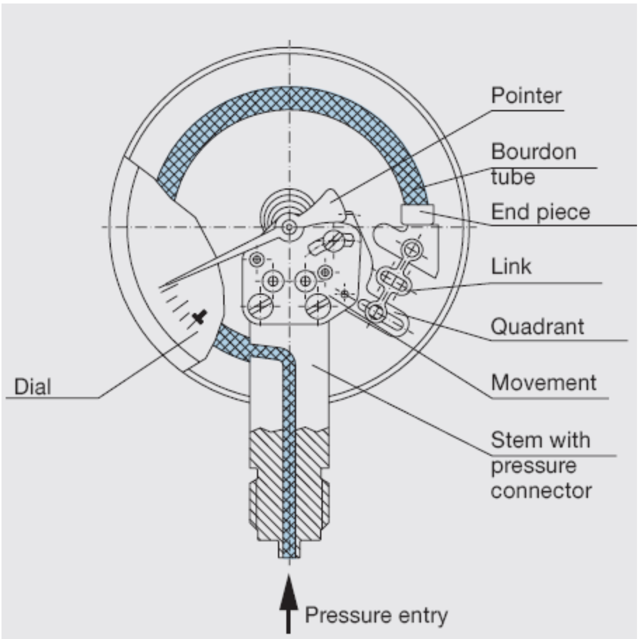
6.1 Instruments for Piping Systems

There is a vast range of instrumentation available for piping systems depending on the parameters being monitored and measured.

- Pressure Gauge
- Temperature Gauge
- Flow meter

6.2 Pressure Measurement

Most pressure gauges in piping systems are based on the Bourdon gauge which was patented in France in 1849 by Eugene Bourdon. The bourdon tube, which is a hollow metallic tube sealed at one end, flexes when pressure is applied. It flexes because it naturally wants to straighten out, but cannot because it is linked to a geared movement. As it tries to flex, this linear movement is changed to a rotational one by means of small gears, this in-turn cause the pointer to indicate the measured pressure. Gauges like this are designed for clean, non-clogging liquids and gases.



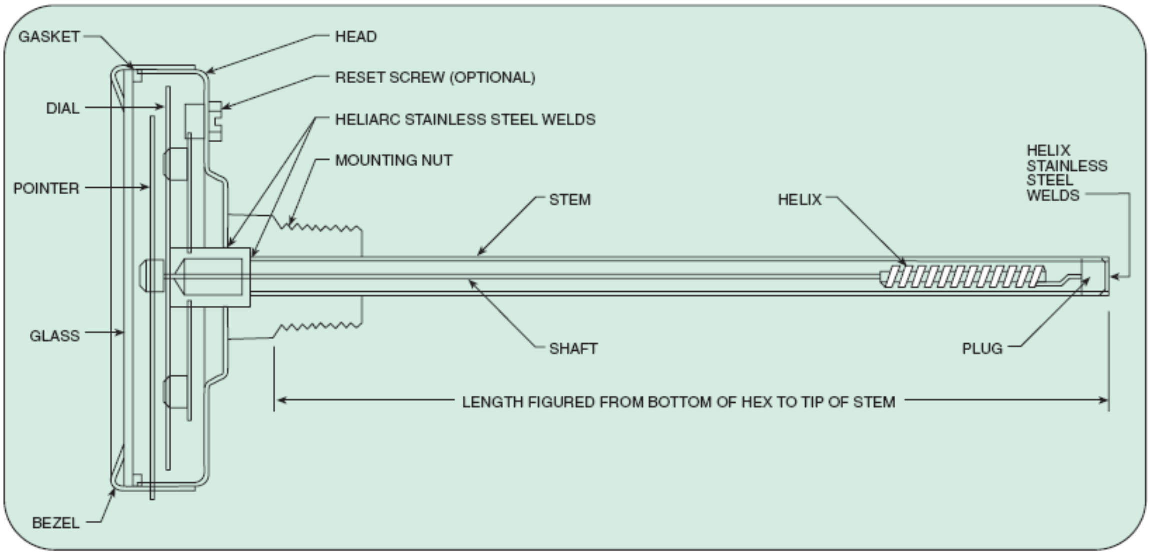
Bourdon Pressure gauge

When selecting a pressure gauge for a piping system the following criteria should be considered:

- Pressure range
- Accuracy
- Dial size
- Visual and or electronic output
- Materials of construction
- Connection type and size
- Connection location

6.3 Temperature Measurement

Most temperature gauges used for piping systems are based on the bimetal design. The bimetal is made from two metal strips, permanently joined together, each metal having a different thermal expansion coefficient. This causes the strip to deflect in proportion to the temperature variation. The actual bimetal system consists of a bimetal strip that is either a helically or spirally wound, depending on the size of the sensor and the temperature range to be measured. Any temperature variation causes the bimetal to rotate an attached spindle. This rotation is indicated by a pointer on a dial scale. Bimetal thermometers are available for temperature ranges from -70 °C up to +600 °C.



Bimetallic temperature probe

When selecting a temperature gauge for a piping system the following criteria should be considered:

- Temperature range
- Accuracy
- Dial size
- Visual and or electronic output
- Materials of construction

- Connection type and size
- Connection location

6.4 Flow Measurement

Perhaps the simplest way to measure volumetric flow is to measure how long it takes to fill a known volume container. A simple example is using a bucket of known volume, filled by a hose. The stopwatch is started when the flow starts, and stopped when the bucket overflows. The volume divided by the time gives the flow. The bucket-and-stopwatch method is an off-line method, meaning that the measurement cannot be taken without interrupting the normal flow.

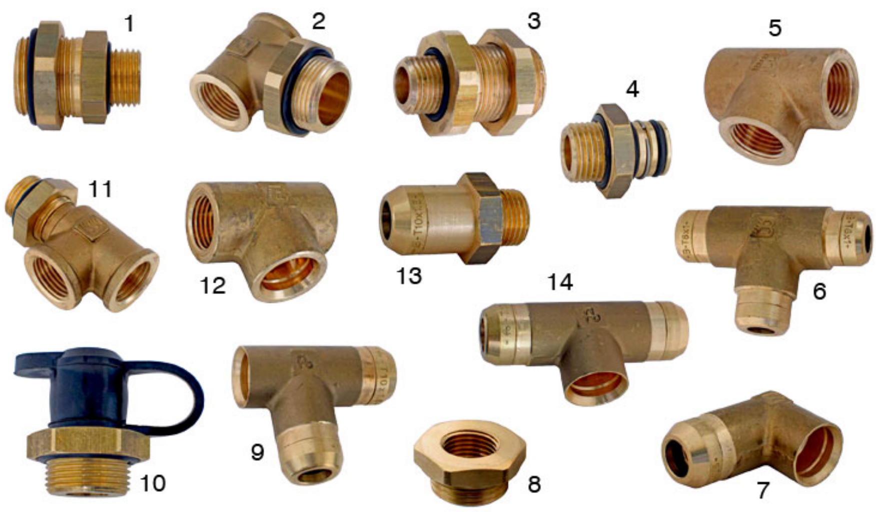
The variable area (VA) meter, also commonly called a rotameter, consists of a tapered tube, typically made of glass, with a float inside that is pushed up by fluid flow and pulled down by gravity. As flow rate increases, greater viscous and pressure forces on the float cause it to rise until it becomes stationary at a location in the tube that is wide enough for the forces to balance. Floats are made in many different shapes, with spheres and spherical ellipses being the most common. Some are designed to spin visibly in the fluid stream to aid the user in determining whether the float is stuck or not. Rotameters are available for a wide range of liquids but are most commonly used with water or air. They can be made to reliably measure flow down to 1% accuracy.

Rotameter for manual flow measurement

There are many other types of flow meters such as orifice based flow meters, turbine flow meters or electronic flow meters which operate on ultrasonic or mass flow measurement however there are too many to be covered in this document.

Exercises

1. Identify 6 of the 14 fittings shown in the illustration below:



2. Give one reason why a lap flange and stub end would be used instead of a weld neck flange?
3. Give one reason why a weld neck flange would be used instead of a lap flange and stub end?
4. Give another name for a check valve and explain what it is used for?
5. Give one reason why an air operated diaphragm pump would be used instead of a centrifugal pump?
6. Name 3 criteria to be considered when selecting a pressure or temperature gauge?

Additional Resources

- Nayyar, P.E., Mohinder L. (2000). "A1". in Mohinder L. Nayyar, P.E.. Piping Handbook (7th ed.). New York: McGraw-Hill. ISBN 0-07-047106-1.
- David L. Goetsch (2000). ***Technical Drawing*** (5th ed.). Thompson Delmar Learning ISBN: 1-4018-5760-4
- International standard ISO 7-1: Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation. International Organization for Standardization, Geneva.
- BS EN 10226: Pipe threads where pressure tight joints are made on the threads. (The European version of ISO 7.)
- Part 1: Taper external threads and parallel internal threads — Dimensions, tolerances and designation.
- Part 2: Taper external threads and taper internal threads — Dimensions, tolerances and designation.
- BS 21: Pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions). British Standards Institution, 1985. (Superseded by BS EN 10226:2004).
- International standard ISO 228-1: Pipe threads where pressure-tight joints are not made on the threads — Part 1: Dimensions, tolerances and designation.
- BS 2779: Specification for pipe threads for tubes and fittings where pressure-tight joints are not made on the threads (metric dimensions), 1986.
- BS EN 10226-1:2004
- ASME B31.9 ***Building Services Piping;*** 937 – Leak Testing, 1996 Edition
- Elements of Plumbing by Samuel Edward Dibble, 2010

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