Generation-Oahu Division
Operator Trainee Training Program

Section 06
VALVES AND PIPING SYSTEMS

OBJECTIVES:

1. Discuss the basic fundamentals of fluid flow
2. Describe equipment used for power plant piping systems
3. Identify the types and parts of valves commonly used in power plant piping systems.

GENERATION-OAHU DIVISION
OPERATOR TRAINEE TRAINING PROGRAM

Section 06
VALVES AND PIPING SYSTEMS

VALVES AND PIPING

A steam power plant consists of numerous pieces of equipment which are interconnected in such a way that they can perform their function as part of the complete system. Piping, valves, and traps compose the arteries that interconnect these various pieces of equipment. This section will consider the manner in which parts of the fluid systems are interconnected and will discuss the fundamental rules or laws that govern fluid flow and the equipment that makes up the piping systems.

THEORY OF FLUID FLOW

The fundamental laws of fluid flow apply equally well to all fluids, however, these laws are more simple and easy to understand when dealing with incompressible fluids. For this reason the discussion in this section will cover the flow of liquids only. Most liquids are considered to be incompressible.

Consider the condition where water is flowing through a length of pipe. The factors which cause this flow to take place will be discussed later. As long as there are no leaks and no water is added to or removed from the system, the amount of water flowing past any one point is equal to that flowing past any other point. This holds true regardless of any changes in pipe size or shape. A mathematics statement of this fact is known as the Continuity Equation. This is one of the basic laws of fluid flow and it can be demonstrated by the following example. Consider the simple section of a piping system shown in Figure 6.1.

The continuity equation states that the flow at point 1 must be the same as the flow at point 2 and point 3 as long as no water is added or removed. The flow rate at any point in a pipe depends on the area available for flow and the velocity of the flow. The following equation expresses this relationship.

$Q = AV$

Where Q is the flow rate in cubic feet per minute, A is the area of the pipe in square feet and V is the velocity of flow in feet per minute. The basic law states that the flow rate at any point in the system equals the flow rate at any other point. This means that the flow rate Q_1 at point 1 must equal the flow rate Q_2 at point 2. This can be expressed mathematically as:

$$Q_1 = Q_2 -= Q_3$$

or

$$A_1V_1 = A_2V_2=A_3V_3$$

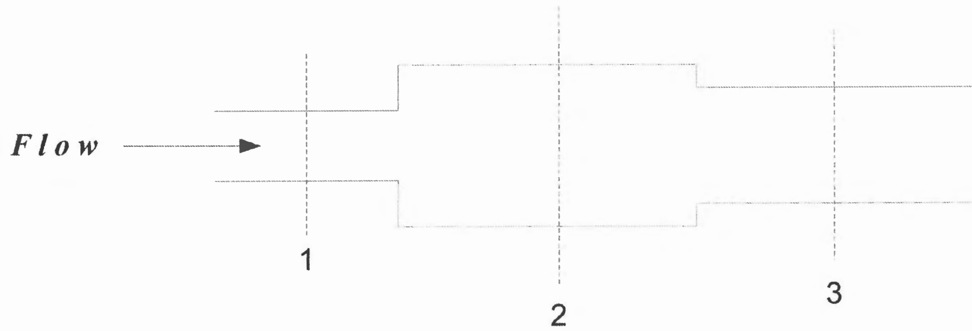


Figure 6.1

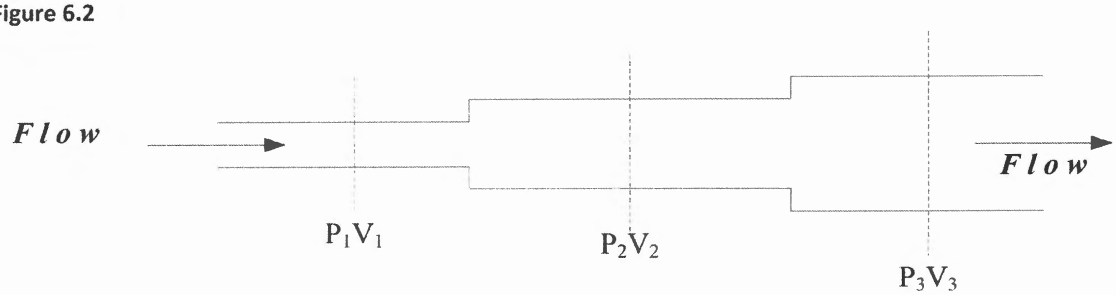
This last equation is of considerable interest. At point 1 there is a certain flow area A_1 and a certain velocity V_1. As the fluid flows toward point 2, flow area increases due to the larger pipe size. Since the product AV must remain constant and since the area (A) has been increased, the velocity (V) must decrease if the continuity equation is to hold true.

This is exactly what happens. The fluid slows down to a lower velocity the when it reaches the larger flow area. In the same manner when the fluid approaches point 3 and the flow area decreases again, the fluid will automatically speed up to compensate for the smaller flow area.

The second important law governing fluid flow is known as the General Energy Equation. This law is based on the principle that energy cannot be created or destroyed but can only be transformed from one form to another. The general energy equation states that the total energy contained in the fluid at one point in the system must be equal to the total energy contained at any other point in the system providing there is no energy added or removed between the two points. To illustrate this law, consider a simple piping system as shown in Figure 6.2. In this system no energy is added to or removed from the fluid. This requires that there is no pump in this part of the system and that there is no heat transfer to or from the system.

At point 1 the fluid contains three types of energy: Potential energy due to its elevation, kinetic energy due to its velocity and flow energy due to its pressure. The sum of these three quantities at point 1 must be equal to the

Figure 6.2



sum at point :2 and at point 3. This can be stated mathematically as:

$$PE_1+KE_1+FE_1 = PE_2+KE_2+FE_2 = PE_3+KE_3+FE_3$$

In the example in Figure 2 the pipe is horizontal and there is no change in elevation so the potential energy is the same at all three points. This term can therefore be canceled out and eliminated. Kinetic energy is proportional to the velocity squared (V^2) and flow energy is proportional to pressure (P). Using this information the general energy equation can be rewritten for the example in Figure 2 as follows:

$$V_1^2 + P_1 = V_2^2 + P_2 = V_3^2 + P_3$$

As the fluid flows from point 1 to point 2 the flow area increases, and from the continuity equation the velocity at point 2 must be leas than the velocity at point 1 due to the increase in area. Since the velocity at point 2 is lower than at point 1 it follows that the kinetic energy at point 2 is less than the kinetic energy at point 1. Since the sum of kinetic energy and flow energy at point 1 must equal the sum of these two energies at point 2 and since the kinetic energy at point 2 is less than at point 1, it follows that the flow energy and therefore the pressure at point 2 must be greater than the pressure at point 1. *What this really means is that when the flow area increased, the velocity decreased according to the continuity equation, and the decrease in velocity resulted in an increase in pressure according to the general energy equation.* In the act of slowing down the fluid converted some of its velocity energy into pressure energy. If the flow area were to decrease the opposite would take place. That is, some of the fluid's pressure energy would be converted to velocity energy. This principle is utilized in many flow meters where the flow area is deliberately restricted to cause a velocity change and thereby a pressure change. This pressure change is measured and related to flow rate.

The discussion so far has covered the ideal situation only. Actually the total energies at two points in a system are never exactly the same. There are always some losses associated with fluid flow that were not taken into account. The walls of a pipe exert a friction force on the fluid that tends to slow it down. In order to have flow continue it is necessary to overcome this friction. The amount of friction produced will depend on many factors, some of which are listed below:

- Increasing the velocity increases friction.
- Increasing the flow area decreases friction.
- Increasing the length of piping increases friction.
- Increasing the roughness of the inside of the pipe increases friction.

All of these factors must be considered when designing a piping system. It is possible to state one more general rule of fluid flow. Fluid always flows from an area of high total energy to an area of lower total energy. In many applications this can be reduced to saying that fluid flows from a high pressure area to a low pressure area. This simplification is only true when the pressure is high and the velocity is low. The correct relationship is one of total energy and not just pressure.

PIPE MATERIAL

The fluids used in power plants and their properties such as pressure, temperature and chemical composition vary widely. For this reason there is no single materia1 that is best for all uses. A great number of different materials are used in an attempt to get the best material for the lowest cost. In many instances it is better to replace a section of pipe occasionally rather than use some highly expensive material. A short list of some of the more common materials and their typical uses is given below.

Material	Typical Uses
Alloy Steel	High pressure, high temperature service.
Carbon Steel	High pressure, moderate temperature service.
Stainless Steel	Extreme high pressure and temperature or maximum corrosion and erosion resistant service.
Copper	Low pressure, low temperature where cleanliness is essential.
Brass	Low pressure, low temperature where corrosion resistance is important.
Plastic:	Low pressure and temperature where corrosion resistance is important. Plastic is replacing brass in many applications.

Pipe size is usually specified according to the inside diameter of the pipe. The wall thickness is usually specified in terms of a special numbering system known as the pipe schedule. Regular pipe is schedule 40 while pipe with a thicker wall will have a higher schedule number such as 80.

JOINING SECTIONS OF PIPE

There are three common methods of joining or connecting pipe and pipe fittings. These are screwed connections, flanged connections and welded connections.

Screwed connections are usua1ly limited to pipe 3 inches or smaller while flanged connections cover the larger sizes. Both the above methods are normally used on low to medium pressure systems. Welded connections are used on all size pipes and particularly for high pressure service. Some of the more common pipe fittings used for connecting pipe sections are shown in Figure 6.3. When sections of large, heavy walled pipe are joined by welding, the high localized temperature sets up areas of stress concentration. To eliminate this undesirable condition, the section of pipe is usually stress relieved by slowly heating

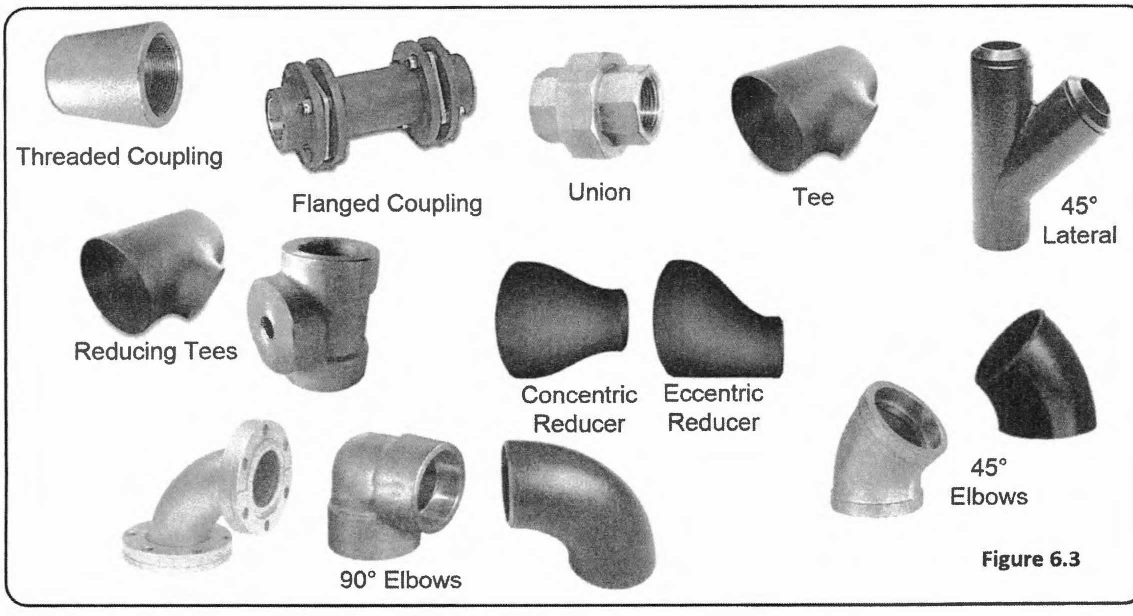


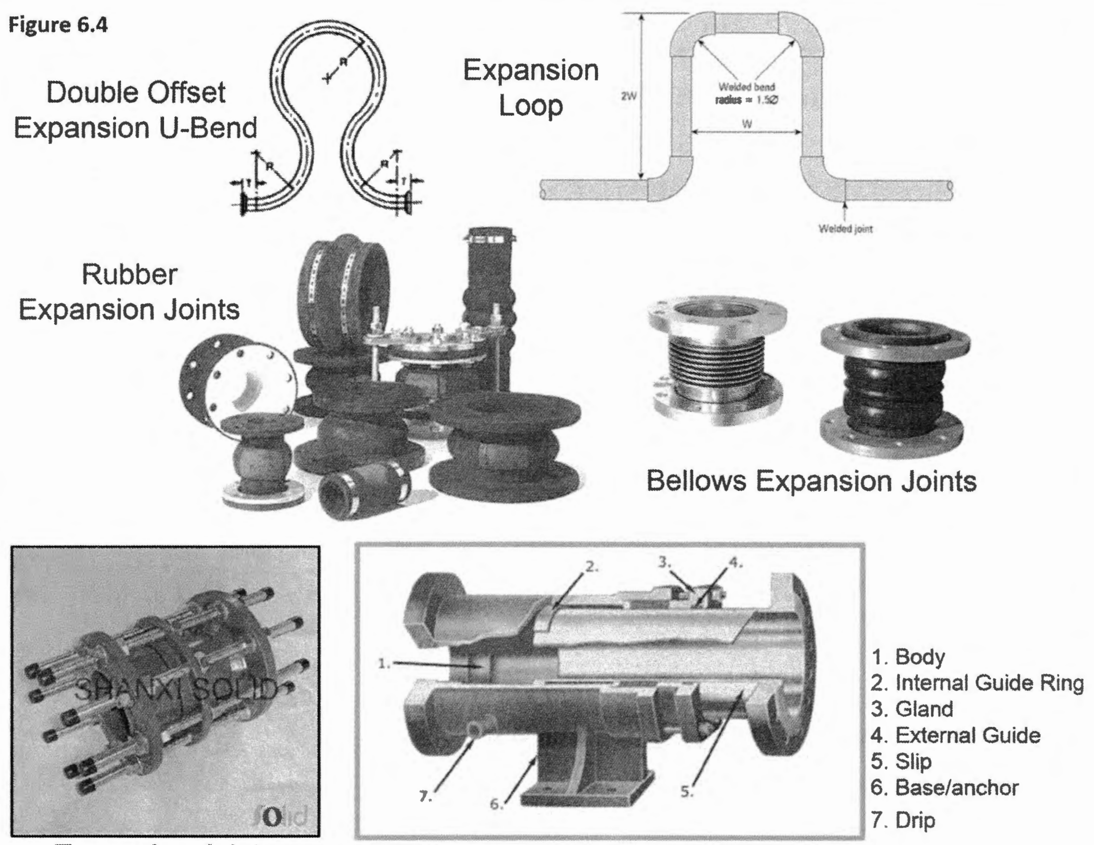
Figure 6.3

and then cooling. This procedure allows the internal stress set up by welding to be dissipated. The quality of welded joints in high pressure pipes is frequently checked by taking x-ray pictures of the weld.

PIPE EXPANSION

Many piping systems are subjected to considerable variations in pressure and temperature during routine operation of the plant. Temperature changes of 1000°F and pressure changes of 4000 psi may be experienced. The temperature changes cause expansion and contraction of the metal piping system while pressure and flow changes can exert other mechanical forces on the pipe system. Expansion joints or bends are placed in lines to compensate for the forces set up by temperature changes. A 1000°F rise in a 100 foot section of pipe will cause it to expand almost 9 inches in length. If provision is not made for this expansion, it can result in broken lines or damaged equipment. Two of the most common methods of providing for expansion and contraction are expansion joints and bends or loops. Examples of each of these are shown in Figure 6.4. The forces exerted by pressure and flow are usually overcome by the proper use of pipe hangers and supports. These are designed

Figure 6.4



Expansion Joint – Slip Type

Expansion Joint – Slip Type Packed Gland to allow the pipe to move in a specific direction to relieve the forces while restraining the pipe from moving in other directions. Hangers are frequently spring loaded while supports usually provide for sliding motion.

VALVES

Valves can be designed to provide one or more of three (3) basic functions:

1. on-off
2. control of flow rates, and
3. prevention of flow reversal.

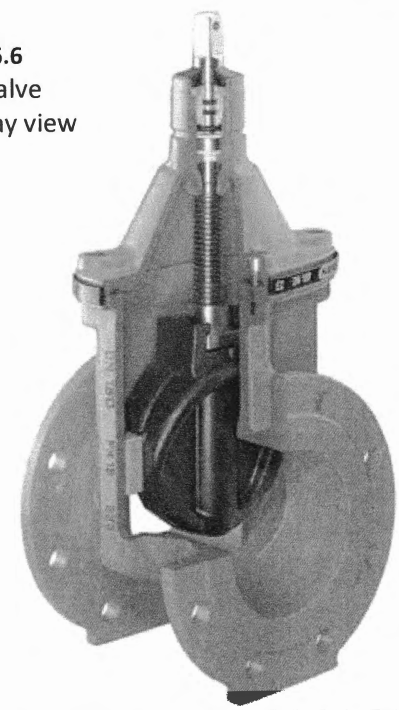
They may be classified according to their function (stop valve, throttle valve, control valve, etc.) or according to their construction. For discussion purposes it is better to classify them according to construction. The types of valves commonly used in power plants are the gate valve, globe valve, plug valve or cock, the check valve, the butterfly valve, and the diaphragm operated control valve. Figure 6.5 shows some of these types of valves.

The **gate valve** (Figure 6.6) consists of a body containing two inclined seats mounted in a plane nearly perpendicular to the line of flow and a wedge which has the same angle as exists between the two seats. The wedge is moved up and down by the stem to which it is attached. Gate valves offer very little opposition to flow when they are wide open. The wear on the seats and wedge of a gate valve is uneven when the valve is not fully open. For this reason they should not be used to throttle the flow. Gate valves are used as stop or shutoff valves where they can be either full open or closed.

The **globe valve** consists of a body containing a seat ring usually placed in a horizontal position parallel to the line of flow and a valve disc which is made to bear

Figure 6.5

Figure 6.6
Gate Valve
Cutaway view



against the seat ring. The disc is raised and lowered by the hand wheel and stem. The globe valve, because of its construction offers a considerable restriction to flow even when it is wide open. Globe valves are designed so that they can be used for controlling flow by throttling.

Check valves are automatic operating valves which allow flow in one direction only. Most check valves consist of a body containing a seat and a hinged disc balanced in such a way that the disc swings open allowing flow in one direction and swings closed preventing flow in the opposite direction. Check valves are normally installed where several pumps discharge into a common line or header. This prevents flow in the reverse direction through an idle pump. Scale, rust or other foreign material may collect above the disc preventing it from opening or under the seat preventing it from closing. The cover must be removed and the obstruction cleared whenever this occurs.

The **plug or cock valve** consists of a body in which a cylinder or plug is fitted with close tolerances. The cylinder has a slot which permits flow through the valve when it is in one position and stops or prevents flow when the cylinder is rotated 90°. The plug valve is cheaper to make and when fully open withstands the action of abrasive liquids better than globe or gate valves.

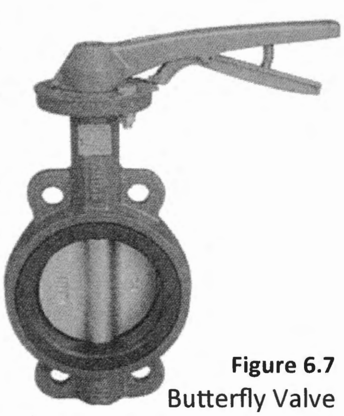
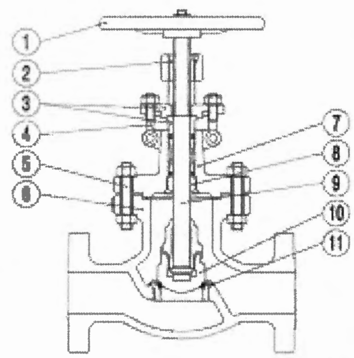


Figure 6.7
Butterfly Valve

The **butterfly valve** shown in Figure 6.7 is finding more use in the plants. This type of valve has several advantages; it is light weight, small, provides tight shutoff, can be used for throttling, and is inexpensive. The



IT.	DESCRIPTION
1	HANDWHEEL
2	YOKE SLEEVE
3	GLAND FLANGE
4	GLAND EYE BOLT
5	BONNET BOLT
6	BODY
7	BONNET
8	BACK SEAT
9	STEM
10	DISC
11	SEAT RING

Figure 6.8—Globe Valve

valve consists of a body, a soft resilient seat of rubber or neoprene and a handle with a notched positioning plate. The valve is operated from full closed to full open by rotating the handle 90° or 1/4 of a turn.

Butterfly valves are relatively easy to maintain, the soft seat is held in place mechanically and can be easily replaced. This means that the valve seat does not require lapping, grinding or machine work.

Some of the parts of a globe or gate valve are the handwheel, stem, packing, gland, body seat, bonnet, stem, and disc seat. Figure 6.8 shows the parts of a typical globe valve. These valves require occasional packing or adjustment of the gland to prevent leakage around the stem.

If the threads on the stem are exposed, they should occasionally be cleaned and lubricated to prevent wear and keep the

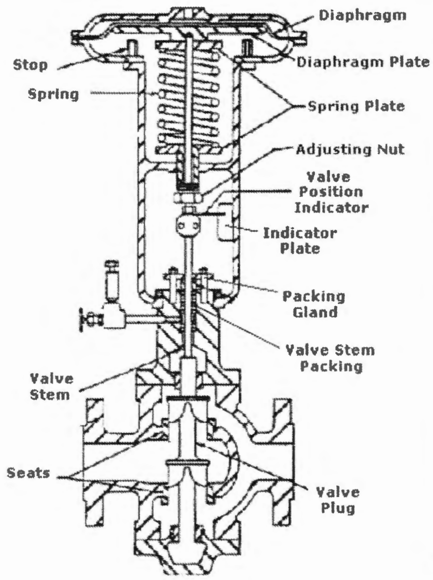


Figure 6.9a—Diaphragm Operated Double Seated Control Valve

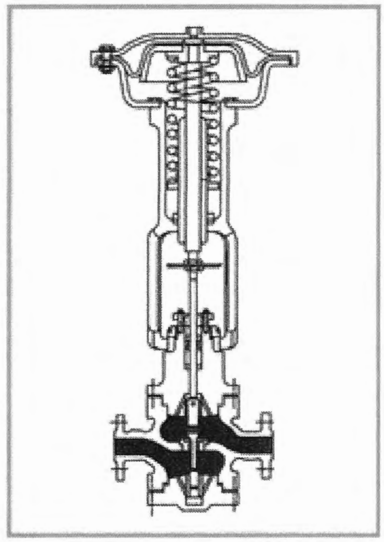


Figure 6.9b—Diaphragm Operated Single Seated Control Valve

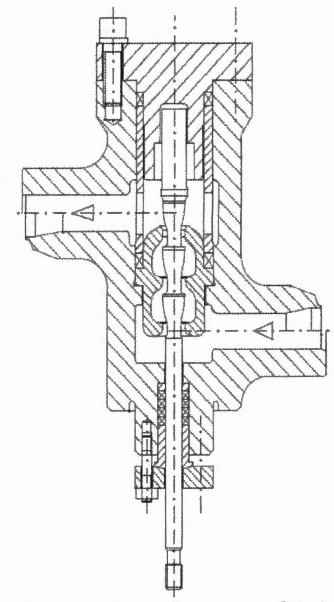


Figure 6.11—diagram of Sulzer control valve

stem operating freely. Forcing the gate or disc or a valve closed when scale or foreign material is lodged under the seat may damage the seat permanently or spring other parts beyond repair.

Diaphragm operated control valves are used for automatically controlling the flow in a piping system. There are two general types of this kind of valve which are the single seated valve and the double seated valve. The single seated valve is primarily used where tight shutoff is required. The double seated valve is used where tight shutoff is not required. See Figure 6.9a & 6.9b. In the spring diaphragm operated control valve, air is admitted to the top of the diaphragm forcing the valve stem downward. This may either open or close the valve depending on the seat

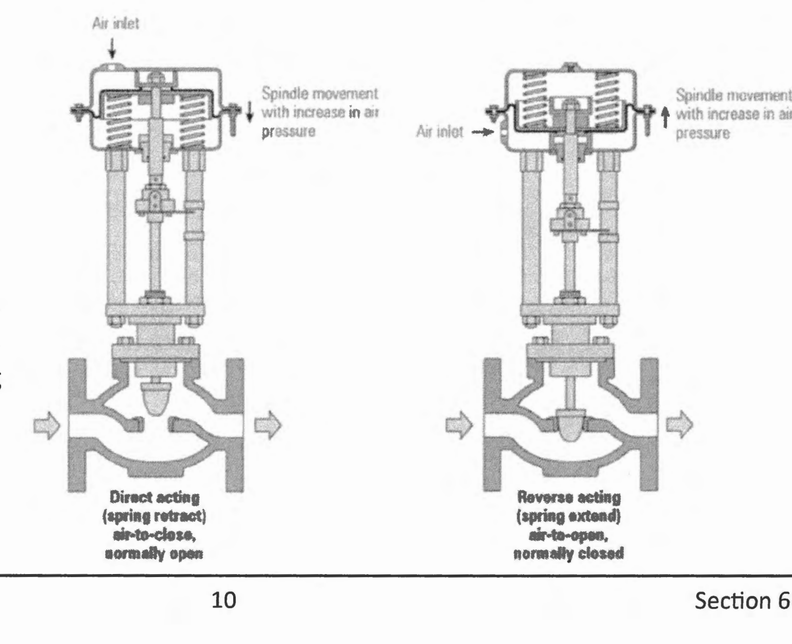


Figure 6.10
Diagram illustrates different effects of air on diaphragm operated control valve. Note position indicator on direct acting and reverse acting valves.

arrangement (Figure 6.10). As the air pressure on the upper side of the diaphragm is released, the spring raises the valve stem.

The valves have three sections; valve body, actuator, and motor or motors.

Figure 6.11 shows one of the many Sulzer valves now in use. These valves differ very little from other high pressure, high temperature valves. Each valve is equipped with a manual hand wheel which is snapped in with a mechanical lock to allow the valve to be operated remote manual and automatically. These valves are used to control pressure, flow etc. as any other high pressure, high temperature valve would be used.

VALVE OPERATION

Valves are provided with hand wheels or other devices of sufficient diameter to give the necessary leverage to close them properly. If a valve is always closed properly and used properly it should operate indefinitely without leakage. If a valve leaks when closed it may be caused by sca1e or other foreign material which has been caught between the disc and the seat. Opening the valve slightly and closing it a few times will usually remove the foreign material. This operation allows the fluid to wash the material off the seating surface. This procedure should always be tried before using any additional force on the hand wheel. More force will only result in driving the scale into the seating surface thus creating a permanent leak.

If a valve is allowed to leak through when closed, the valve seats will eventually be eroded or cut by the fluid. When this occurs it becomes impossible to prevent further leakage no matter how much force is applied.

In some cases where positive shutoff is required, two valves are provided in series. This application is usually provided on blowdown or drain lines from a pressure vessel or line. When opening these valves the first or upstream valve (Closest to the vessel or line) should be opened wide. The second or downstream valve should be opened part way and used to throttle or control the flow. In this way all the wear takes place on the second valve. When it requires repair or replacement, this can be done with the equipment in service because the first valve is still in good condition.

Large gate valves with pressure on one side can be very difficult to open. The pressure acting on the area of the gate forces it tightly against the seat. For example, an 8 inch valve with 600 psig on one side will have a force of approximately 30,000 pounds pushing it against the seat. This creates a lot of friction where the gate slides along the seat when opening the valve. To improve this condition small pressure equalizing lines are installed around gate valves in lines 8 inches and larger with pressures of 600 psig and over. The equalizing line and valve are usually 3/4 inch. This small valve can be easily opened and allows a slow buildup of pressure downstream of the large valve. When the pressure on each side of the large valve is equal, it can be opened easily. When installed, equalizing valves should always be opened prior to opening the main valve and should be closed after the main valve is open.

STEAMTRAPS

All steam lines should be adequately drained of condensate. Even superheated steam lines need drains since condensate forms during the warming up operation. The automatic removal or condensate from steam lines is accomplished by steam traps. The name comes from the fact that the unit traps steam preventing it from flowing while allowing the condensate to flow. Two of the most common types of traps used in power plants are the impulse trap shown in Figure 6.12 and the bucket trap shown in Figure 6.13a & 6.13b.

In the impulse trap shown in Figure 6.12 is a constant flow trap and allows a continuous flow of steam into the high-pressure drain line as long as its cutout valves are open. The valve disc is a piston type disc with a flange at its top and a "control orifice" drilled through it. The piston valve works up and down within a cylinder which is machined with a reverse taper and which is, at its smallest point the same size as the flange on the valve disc. The position of this cylinder is factory-adjusted so that, with the valve closed, a specific clearance between the flange and cylinder walls is maintained. The area of the control orifice is slightly greater than that of the space between the cylinder and flange. Due to the larger area of the control orifice, condensate flowing from the steam line when warming up will

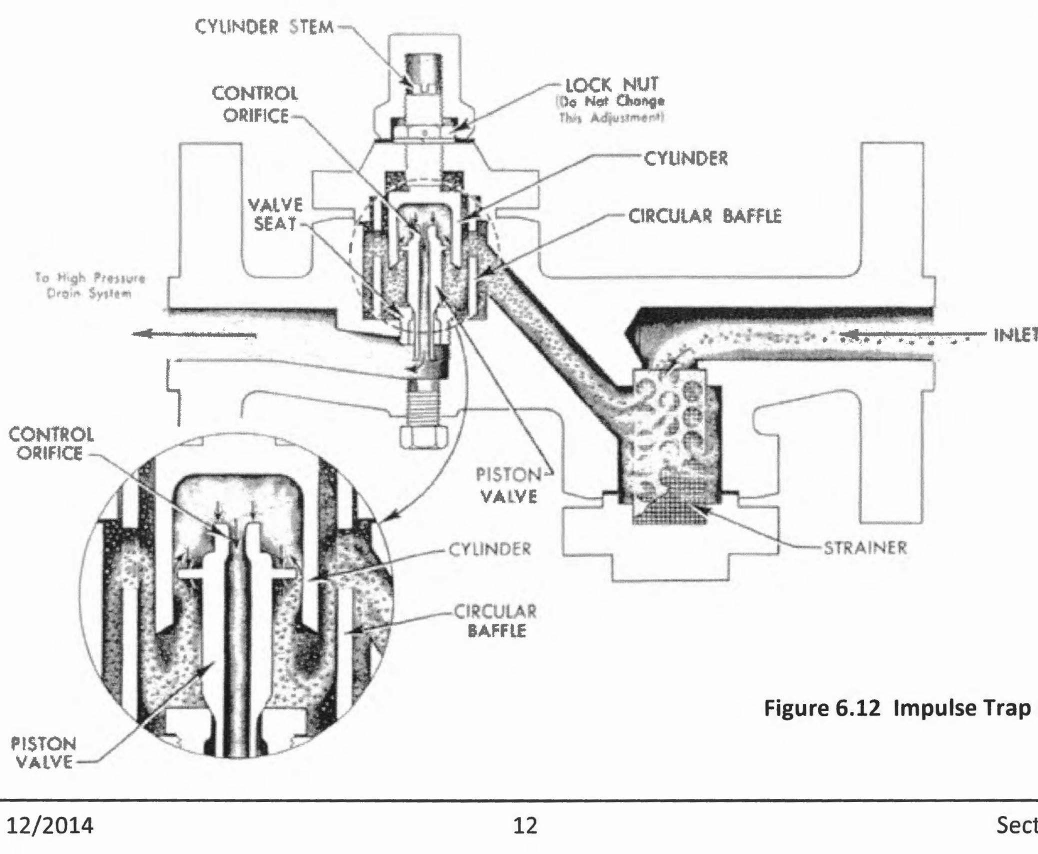


Figure 6.12 Impulse Trap

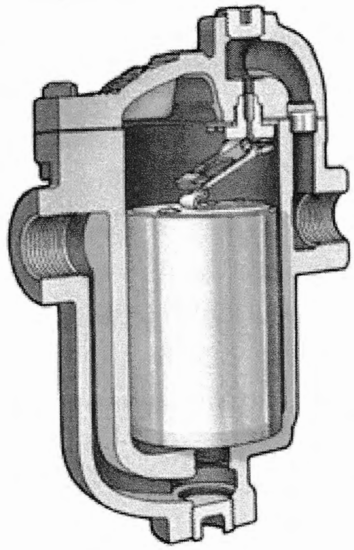
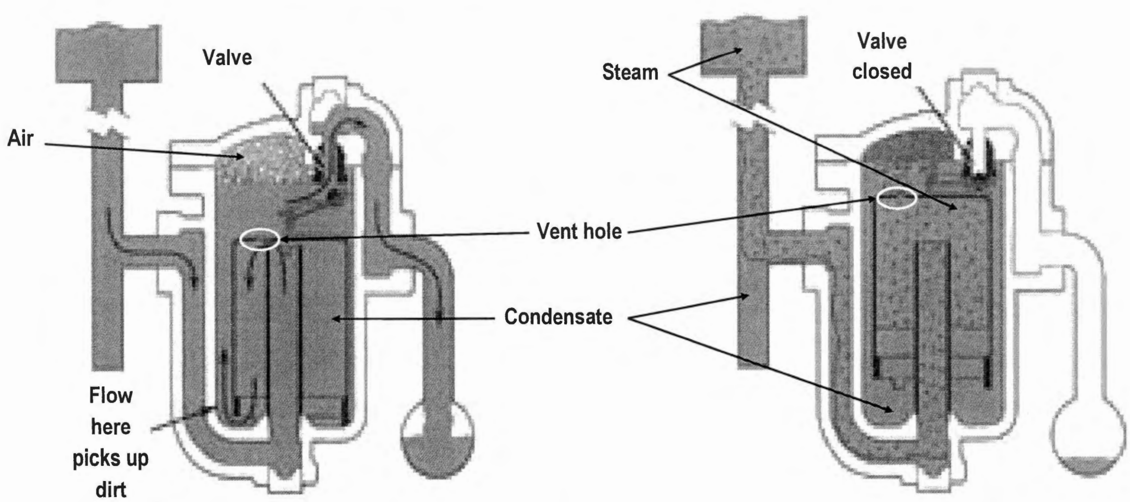


Figure 6.13a
Inverted Bucket Trap

flow through it faster than it will flow past the flange. This will cause a reduction pressure within the cylinder. When this pressure is reduced to 86 percent of the inlet pressure or less, the force on top of the valve disc is less than the force below the flange and the valve will be forced open, allowing a full flow of condensate through the valve. As the line warms up the temperature of the condensate flowing through the trap increases and as it approaches the temperature of saturated steam, the condensate flowing through the control orifice will start to flash into steam (due to the large drop in pressure through the orifice). This steam having much greater volume than the same quantity of condensate will cause the control orifice to become "choked" up and thereby reduce the flow of condensate. This will cause the pressure within the cylinder to be built up until it is greater than the inlet pressure and the trap will be closed due to the greater area of the top of the disc. With the trap closed, hot condensate or steam will continually flow through the control orifice, discharging into the high-pressure drain line. Should a shot of cool condensate enter the trap at any time, the same action will occur to drain off the condensate, with the valve closing when the condensate temperature is approximately 30 degrees F. less than the steam temperature. The stein seen attached to the cylinder can be used to raise the cylinder, catching the flange at the base of the taper and manually lifting the valve disc for the purpose of blowing through it to clean off the seat. The lock nut shown is pinned in place. It has been adjusted at the factory to provide the proper clearance between the cylinder and valve flange. The baffle shown shrouding the cylinder and

Figure 13b
Schematic of Inverted Bucket Steam Trap



valve disc is placed there to prevent direct impingement of the steam on the cylinder or disc and in addition, provide a guard against possible jet action on the flange.

The inverted bucket trap shown in Figure 6.13a & 6.13b operates as follows. When the trap is full of water, the bucket rests on the bottom of the reservoir with its open end over the trap inlet. At this time the trap discharge valve is open. Water is expelled from the trap due to steam pressure acting on the water. As the water is discharged, steam will displace the water in the bucket, causing it to rise and close the trap discharge valve. The closed end of the bucket has a vent hole for air and steam to escape. The escape of steam and air allows more water to rise into the bucket. As the water rises the bucket loses buoyancy and sinks, thereby opening the discharge va1ve again. The water is never completely discharged, thereby maintaining a seal which prevents steam from blowing through.

Traps should be checked to make sure they are operating correctly by feeling the trap body and discharge line. If the trap is warm, it indicates proper operation. Excessive temperature indicates that the trap is allowing steam to blow through and be wasted. A cold trap usually indicates that no drainage is taking place.

BYPASS AND DRAIN LINES

Bypass lines are secondary pipelines through which flow is routed while a section of the main line is out of service.

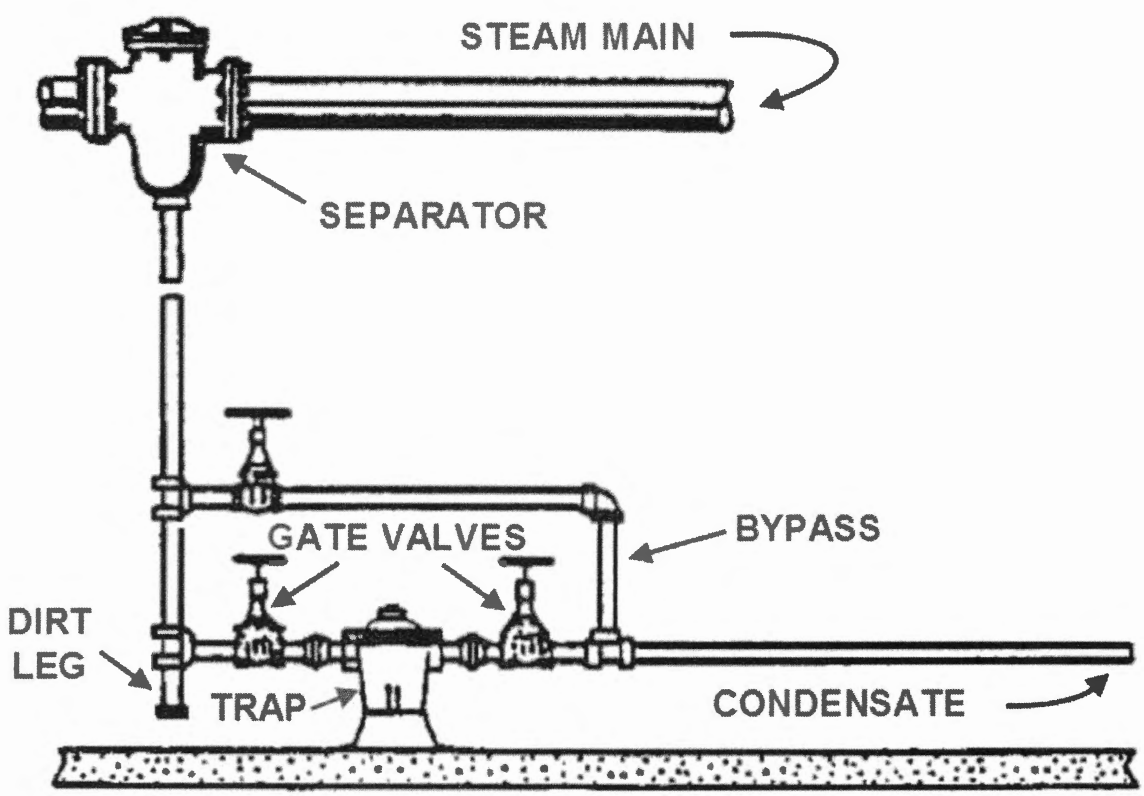


Figure 6.14: Steam Trap—Typical Installation

When lines carry steam, they are provided with drains to remove condensate formed when warming the line or while in service. Drains are also used to drain or depressurize a collection of piping when it must be taken out of service for repair.

The valve bypass and drain line, shown in Figure 6.14, serves two purposes. The drain line from the separator can be used to remove condensate from the steam or to drain the steam line when the steam flow is cut off. When the two valves next to the trap are opened and the valve in the bypass line closed, the trap automatically drains condensate from the steam line. By closing either one of the valves next to the trap, the trap is cut out of service. The valve on the bypass line can then be regulated to permit drainage around the trap.

Opening a valve suddenly where the pressures are not equal increases the likelihood of **water hammer**. A cold line should always be warmed up slowly. Adequate drainage of the line should be maintained at all times while pressures and temperatures are equalized to avoid damage due to rapid expansion and water hammer. The drain valve should be opened enough to provide drainage of condensate, yet not waste excessive amounts of steam. Water or condensate in a steam line will cause water hammer in the pipelines and, if it is permitted to progress, it can seriously damage steam driven equipment. Funnels in drain lines permit the operator to observe drainage and eliminate any possibility of back-pressure from the drain to the bypass line which might prevent drainage from taking place.

WATER HAMMER

There is one danger often present when working with high-pressure lines which all operators should know about. This danger is commonly known as water hammer. Water hammer can reach destructive proportions under certain circumstances.

Water hammer is the force or shock of confined water when its flow is suddenly arrested. Under certain conditions, a series of shock waves may be set up. These shock waves may increase or decrease in intensity, depending on conditions.

One example of water hammer which most people have probably experienced is the sudden rap sometimes heard when closing a water faucet. This hammer is not serious because the flow or force of the water suddenly interrupted by closing the faucet is small. A water line ten inches in diameter and at a given head would exert a shock or hammer, if suddenly closed, over 400 times greater than the hammer in a half-inch waterline. The larger the diameter of the line, the higher the head and the greater the velocity of flow, the greater the danger of water hammer. There is usually more danger of water hammer in vertical waterlines than in horizontal waterlines. Sudden operation of check valves sometimes causes water hammer in waterlines.

WATER HAMMER IN STEAM LINES

There is always danger of water hammer in warming up a cold steam line. Condensate which forms in the cold line may be driven up and down the line by steam with a force sufficient to wreck the line or tear it from its hangers. Hammer is more apt to happen in long horizontal steam lines or steam lines with a slight upgrade. Steam should always be admitted to cold lines slowly and the condensate drained from the line as fast as it forms.

A water hammer similar to the hammer in a steam line results when opening a valve which admits hot water into a cold line. An example of this situation would be the opening of a valve on a boiler feedwater header to fill a cold empty section of a waterline. Some of the high temperature water under high pressure will flash into steam as it passes the valve, setting up conditions identical to those in the steam line just discussed.

A good general rule to prevent serious consequences due to water hammer is to always open or close valves, which regulate the flow of any fluid, slowly. This makes it easier to close the valve if a hammer develops and in any case minimizes its effect. Where bypass valves are provided around large valves, use the bypass to equalize pressures and temperatures before opening the large valve. Keeping vents or drains open while cutting in a line, helps to prevent water hammer.

Notes:

Section 06

VALVES AND PIPING SYSTEMS

Study Questions

1. Most liquids are considered
   a) Compressible
   b) Incompressible
2. When the flow area decreases, the velocity of the fluid increases. True / False
3. A decrease in fluid velocity results in a n increase in pressure to maintain the same flow rate. True / False
4. The walls in a pipe exert friction force on fluid that tends to slow it down. The amount of friction depends on many factors. List three (3) of these factors.
   a)
   b)
   c)
5. Fluid always flows from an area of low total energy to an area of higher total energy. True / False
6. List four (4) of the more common materials used for manufacturing piping.
   a)
   b)
   c)
   d)
7. Pipe size is usually specified according to the ________________ of the pipe.
   a) thickness
   b) length
   c) Inside diameter
   d) Manufacturer's specifications
8. The three common methods of joining or connecting pipe and pipe fittings are:
   a) ______________________ connections
   b) ______________________ connections
   c) ______________________ connections

9. What are two of the most common methods of providing for pipe expansion and contraction?

    a)

    b)

10. What are three (3) basic functions provided by valves?

    a)

    b)

    c)

11. Gate valves are used as ____________________ valves.

    a) throttle

    b) control

    c) stop

12. Globe valves are used as ____________________ valves

    a) throttle

    b) control

    c) stop

13. One of the specific features of a check valve is that it _________________________.

    a) offers considerable restriction to flow even when it is wide open.

    b) allows flow in on e direction only.

    c) withstands the action of abrasive liquids better than the globe valve.

14. There are two general types of the diaphragm operated control valves, the single seated valve and the double seated valve. True / False

15. If a valve leaks when closed, one should open it slightly and close it a few times. True / False

16. Describe, briefly , what happen to a closed valve if it is allowed to leak through continuously.

17. When two valves are provided in series, the second or downstream valve should be opened wide, and the first or upstream valve (closest to the vessel or line) should be opened part way and used to throttle or control the flow. True / False

18. What is the purpose of a bypass line?

19. A general rule to prevent consequences due to water hammer is to always open or close fluid regulating valves slowly. True / False

20. List two other ways to avoid or prevent water hammer in steam lines.