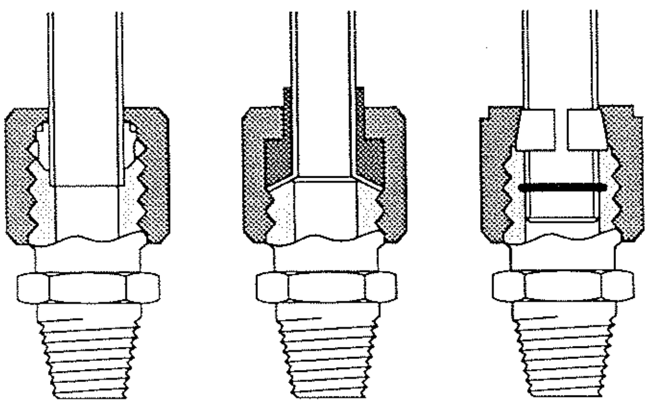
# PROCESS TECHNOLOGY TRAINING PROGRAMME

## Unit 1:

Fluid Mechanics
and the
Flow of Fluids



**Unit 1: Fluid Mechanics and the Flow of Fluids**

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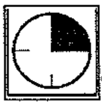
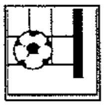
## SECTION 1

# AN INTRODUCTION TO FLUIDS

Time: 1 hour



## LEARNING GOALS

Your learning goals for this Section are:

(1) To know that fluids can be liquids and gases

(2) To know a simple definition of a fluid

(3) To know the fluids used in the plant

(4) To know some of the properties of fluids

(5) To know that the volumes entering and leaving a pipeline are the same

(6) To describe what happens when the velocity of the fluid changes

## STUDY SESSION 1.1

# WHAT IS A FLUID?

## 1 DEFINING A FLUID

Before we answer this question try the following SAQ.

---

**SAQ 1**

See if you can give three examples of fluids below.

(1)

(2)

(3)

Choose your answers from the following list:

| | | |
|---|---|---|
| *air* | *water* | *iron* |
| *plastic* | *earth* | *steam* |

Now check your answers with ours at the end of the unit before continuing.

---

You now know that a fluid can either be a gas or a liquid.

Both gases and liquids will flow into any container and take up the shape of that container. This fact leads to a simple, but perfectly adequate definition of a fluid:

> A fluid is a substance which will flow into and take up the shape of the container holding it.

There is an important difference between gases and liquids. Gases can be easily compressed into smaller volumes; liquids cannot. (Try squeezing two pints into a pint glass!). So liquids are said to be **incompressible** (that is, not able to be compressed). This is an important principle that you will meet again.

The study of moving fluids is called **fluid dynamics**. It is a complicated subject which we will only touch on lightly, but it is of great importance in plant process technology.

Plant processes usually involve transporting of large quantities of fluid along pipelines from one location to another. So plant process engineers are concerned with the movement of fluids. They need to study fluid flow and the changes in pressure, speed of flow and, sometimes, the changes in temperature, which a fluid may experience as it passes through the pipeline.

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✓ **SAQ 2**

What is the most important difference between liquids and gases? (*Tick the correct answer.*)

(1) Liquids are incompressible. ☐

(2) Gases are compressible. ☐

(3) Gases are less dense than liquids. ☐

Check your answers with ours at the end of the unit before continuing.

---

## STUDY SESSION 1.2

# WHAT FLUIDS WILL I COME ACROSS IN THE PLANT?

Many fluids are used in the plant. In the context of this module and fluid mechanics, we are talking about fluids which are transported by pipe for use in the plant process.

---

### ACTIVITY 1

Choose an area of the plant where you work and make 2 lists of the fluids used there; one list should contain gases and one list liquids.

Area of Plant: ______________________________

| Gases | Liquids |
|---|---|
| | |

Ask your trainer to check these lists with you.

---

The different types of fluids being transported by pipe have different characteristics or **properties.**

The properties which are of particular interest are:

- Acidity
- Alkalinity
- Viscosity
- Toxicity
- Melting point

These properties will affect the way we need to treat the fluids.

Try completing the following SAQ.

---

**SAQ 3**

Fill in the gaps in the sentences below with words chosen from the list provided.

(1) Fluids which are very viscous (i.e. have high viscosity such as thick oils) flow ______________

(2) Acidic fluids need ______________ pipes because they are corrosive.

(3) Liquids that freeze easily need to be carried in ______________ pipes which are ______________ .

Choose from:

| | | |
|---|---|---|
| *easily* | *plastic* | *lagged* |
| *metal* | *heated* | *with difficulty* |
| *unlagged* | *unheated* | |

Check your answers with ours at the end of the module before continuing.

---

So you can see that we must consider the basic properties of fluids when deciding on the materials and type of design needed for a pipeline.

## ACTIVITY 2

This Activity falls into 2 parts:

(1) Use the list you compiled in Activity 1 to complete the table below. List the different types of fluid transported in various pipes in the plant, and fill in the columns to show what materials are used, the diameters of the pipes and the design or structure of the pipes used in each case.

(2) Comment on the information you have gathered in the *Comments* column. In this column, you should try to explain the connection between the types of fluid in your table, and pipe material, diameter and design. For example, why are certain fluids transported by plastic pipes?

| Fluid | Pipe Material | Pipe Diameter | Pipe Design | Comment |
|---|---|---|---|---|
| | | | | |

Discuss your table with your trainer.

# STUDY SESSION 1.3

# WHAT GOES IN MUST COME OUT!

Now that you have identified the fluids used in the plant process and established some of their properties, you can take a look at some of the basic principles of fluid mechanics.

Have you ever noticed how the speed of a river changes between wide banks in open country, and a narrow gorge? Similarly, you can use your finger partially to block the gentle flow of water from an open tap to produce a fast flowing jet.

All this happens as a result of flow of fluids. The same principles are used in plant process technology.

A liquid cannot be compressed, that is squeezed into a smaller volume. So when a liquid is flowing through a channel or pipe and it comes to a narrowing or constriction in its flow path, the only way the liquid can get through this constriction, and so prevent any hold up, is to hurry itself along at a faster rate. In the above examples of the river and the finger over the tap the flowing water met with a constriction in its path of flow. The result was that the water flowed at a greater rate.

---

✓ SAQ 4

Water flows faster when the flow area becomes smaller. Do you think this result will be true for all fluids?

YES/NO

Check your answer with ours at the end of the unit before continuing

---

The result of this increase in the rate of flow of liquid when passing through a constriction is that the amount of liquid **leaving** the pipe per second is exactly the same as the amount of liquid **entering** the pipe per second. This is a direct consequence of the fact that a liquid is incompressible (that is, can't be squeezed into a smaller volume). Nor can it be created out of nothing: what comes out must go in, and vice versa.

In other words: THE AMOUNT OF LIQUID ENTERING THE PIPE IN A GIVEN TIME EQUALS THE AMOUNT OF LIQUID LEAVING THE PIPE IN THE SAME TIME.

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## ✓ SAQ 5

Fig.1 shows a liquid being transported along a pipe which is narrower at the outlet than at the inlet.

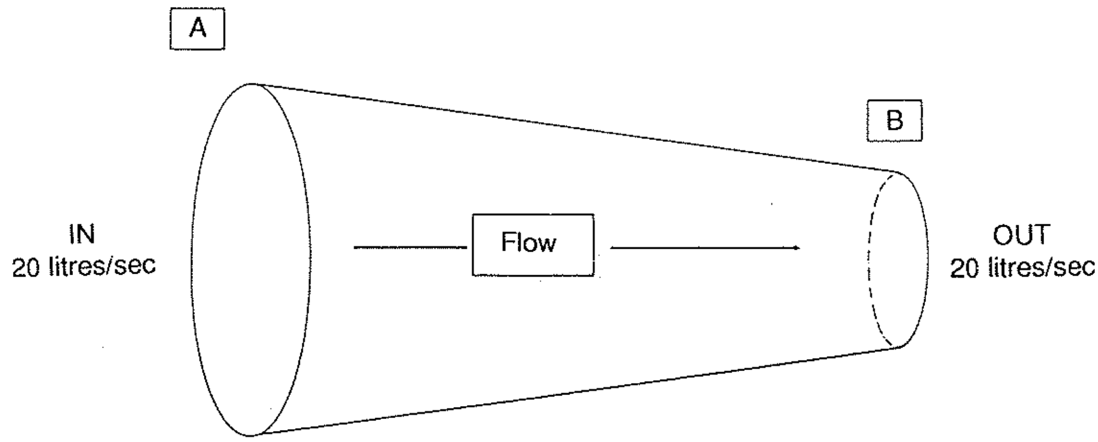



*Fig.1*

Choose T (for 'true') or F ('for false') to describe the following statements.

(1) The volume leaving the pipe is less than the volume entering it. T/F

(2) The liquid is travelling faster at B than at A. T/F

**Hint: Remember that liquids are incompressible.**

Check your answers with ours at the end of the unit before continuing.

---

Note that the **quantity of liquid per second** entering and leaving the pipe is unchanged. Only the speed of flow (measured in metres per second) is changed.

Narrowing the pipe along which a liquid flows causes the liquid to flow faster (increase its rate of flow)

From the point of view of plant process technology and the flow of fluids in pipes, this is a very important result.

Something else also happens when the rate of flow of a liquid increases as it enters a constriction: there is a corresponding fall in the **pressure** of the liquid as it passes through the constriction.

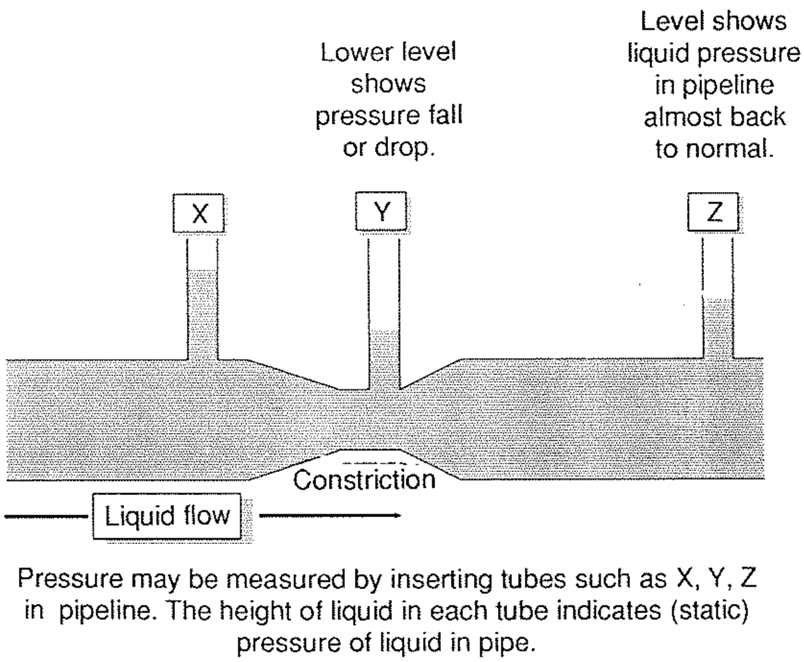



*Fig.2 Liquid Passing Through a Constriction*

The amount of fluid entering and leaving the pipe has to be the same because it is not possible to create more fluid. The amount of energy has to stay the same for the same reason. Now speed, as you know, is a type of energy (kinetic energy). So when the speed increases, pressure, another type of energy has to fall to compensate.

**SAQ 6**

What do you think happens after the fluid has passed the constriction and enters a wider section again? (*Tick the correct answer.*)

(1) It speeds up. ☐

(2) It slows down. ☐

(3) It travels at the same speed. ☐

Check your answer with ours at the end of the unit before continuing.

---

Fig.2 shows the pressure changes when fluid passes a constriction. In the pipe shown:

*Pressure fall or drop* = *Pressure shown by liquid level at X* − *Pressure shown by liquid level at Y*

For a fluid in a pipeline, the increase in velocity of the fluid at a constriction is accompanied by a decrease in pressure. The greater the increase in velocity of flow, the greater the decrease in pressure.

This fact is used when measuring the pressure and the velocity of flow of fluids in plant pipelines.

Now you are ready to have a look in the next study session at the factors which affect control of fluids through pipelines.

## SUMMARY

Now you have finished the work in this Section you should be able to:

(1) State that gases and liquids are fluids

(2) Define a fluid in simple terms

(3) List the fluids used in the margarine plant

(4) List the important properties of fluids

(5) State that the volume leaving a pipeline must be the same as the volume entering a pipeline

(6) State that when the velocity of a fluid increases the pressure decreases and vice versa

## SECTION 2

# FLUID FLOW IN A PIPE

Time: 1 hour

## LEARNING GOALS

Your learning goals for this Section are:

(1) To know what is meant by static pressure

(2) To know that liquid in a tank exerts a pressure due to its height

(3) To know that there is a pressure difference in a pipeline

(4) To know the importance of viscosity and friction

(5) To know that bends and fittings in pipelines affect fluid flow

## STUDY SESSION 2.1

# STATIC PRESSURE OF FLUIDS

Fluids flowing along a pipe are moving and are said to be **dynamic.** However, to understand fluid flow more readily, it is necessary to take a little diversion and consider a fluid which is not moving, that is, a fluid that is **static.**

First of all, we must get some idea of what we mean when we talk about **pressure**. You've already met the idea of pressure in pipes in Section 1. If you studied Unit 0, what follows next will be revision for you.

If you stand on a ping pong ball, you squash it flat. This is because you have applied **pressure**.

This pressure is the result of your **weight** (which is a force) acting over or on the area of the ping pong ball.

So, whenever a force **presses** or acts upon an area, a pressure results.

Engineers can neatly summarise this as follows:

$$\textit{Pressure} = \frac{\textit{Force}}{\textit{Area on which force acts}}$$

In the metric system, pressure is measured in newtons per square metre, written as $N/m^2$ (spoken as newtons per metre squared).

In engineering, the unit $N/m^2$ is often referred to as the pascal (Pa for short). We also use the term bar since this is a more convenient unit for everyday use. There are 10,000 pascals in 1 bar. In addition, 1 bar is approximately the pressure exerted by the atmosphere.

Some idea of pressures encountered in everyday life are given below.

A girl of weight 8 stones standing in stiletto heeled shoes with a total area of 2 $cm^2$ (i.e. 2/10 000 $m^2$) exerts a pressure which may be calculated as follows:

Weight of girl = 8 stones = 500 newtons (approx).

Area of heels on which this force (weight) of 500 newtons acts:

$$= \frac{2\ \text{m}^3}{1000}$$
$$= 0.0002\ \text{m}^2$$
$$\text{Pressure} = \frac{\text{Force}}{\text{Area over which force acts}}$$
$$= \frac{500}{0.0002}$$
$$= 2\ 500\ 000\ \text{N/m}^2$$

This is a pressure of about 369 p.s.i. or 25 atmospheres pressure!

A man of 14 stones = 875 newtons (N) standing in a pair of size 10 shoes of approximately 500 $\text{cm}^3$ area will exert a pressure as follows:

$$\text{Area of shoe} = 800/1000\ \text{m}^2 = 0.05\ \text{m}^2$$

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{875\ \text{N}}{0.05\ \text{m}^2}$$

$$= 17500\ \text{N/m}^2$$

This is a pressure of about 0.18 Atmospheres or 2.6 p.s.i.

Obviously from the definition:

$$Pressure = \frac{Force}{Area}$$

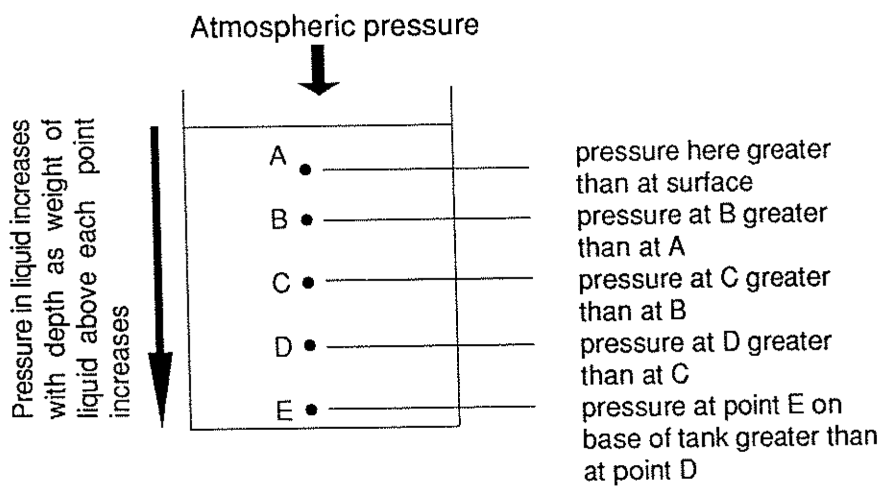
A relatively small force acting over a small area can have a large effect (i.e. produce a large pressure). Thus, as you have seen in the examples above a small woman exerting her weight (force in newtons) on a small area of heel can produce enough pressure to damage a dance floor or even an aircraft!

In engineering, pressure is often more important than the force, and to increase the pressure, we can **decrease** the area over which the force acts. Conversely, we can decrease the pressure by **increasing** the area over which a force acts (as in the example of the 14 stone man).

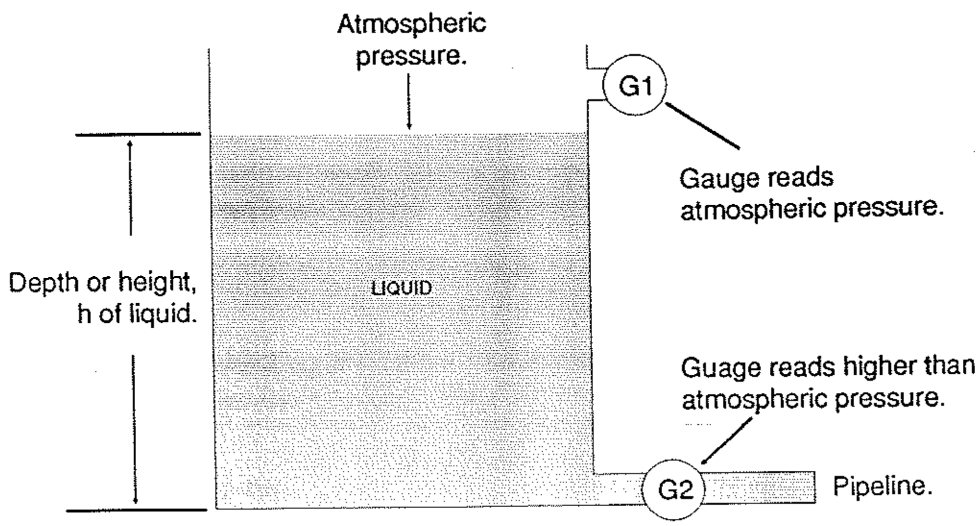
As we go down from the surface deeper and deeper into a liquid, the pressure increases. This is because the deeper we are, the more liquid there is above. This in turn means that a larger weight of liquid is pressing down on us. Since this weight is a force which presses down or acts on the area of our bodies or any object immersed at the depth in the liquid, then by the pressure definition above, the pressure acting on us or the submerged object must increase as the depth from the surface increases.

This situation is summarised in Fig.3(a)

In the plant there are many tanks or containers holding liquids of various kinds. Fig.3(b) is a diagram which could represent any one of these container or tanks.




*(a)*




*(b)*

*Fig.3 How Pressure Gauges Measure*

The pressure gauge G2 in Fig.3(b) will give a **higher** pressure reading than gauge G1.

The upper surface of the liquid is exposed to the air. Now air is made up of tiny particles, each having its own small weight. So the air has a weight which acts downwards on the surface of the liquid.

You already know that weight is a **force** caused by the action of **gravity**. So the air is exerting a force on the area of the surface of the liquid.

You also know that a force applied over an area is a pressure, so the air is exerting a pressure on the liquid. The pressure is what we call **atmospheric pressure** and it is acting on everything, including you!

So the pressure gauge G1 gives the reading of the atmospheric pressure (normally equal to 1.013 bar, 101,300 $N/m^2$ or 14.7 psi).

In Fig.3 the tank or container is shown with a level of liquid at height *h* metres above the lower pressure gauge.

The liquid in the tank, like the air, also has weight. As a result of this weight it exerts a **force downwards** on the **area** of the base of the tank. A force applied over an area gives a pressure. The pressure gauge G2 records this pressure of the liquid in the tank, which is additional to the atmospheric pressure recorded by G1.

---

✓ **SAQ 7**

Can you complete the following formula? (*Tick the correct answer.*)

Pressure reading of G2 - Pressure reading of G1 =

(1) Force due to liquid ☐

(2) Pressure due to liquid ☐

(3) Depth of liquid ☐

Check your answer with ours at the end of the unit before continuing.

---

The pressure exerted by the liquid in the tank is calculated using a very simple formula:

*Pressure exerted by liquid = height/depth of liquid × density of liquid × g*

*g* is a number which always has the same value.

If we use the **metric or SI system of units,** then:

Height (or depth) is measured in metres (m)

Density is measured in kilograms per metre cubed ($kg/m^3$)

*g* is measured in metres per second squared ($m/s^2$)

*g* always has the value 9.81 on the earth's surface. For quick calculations, this can be approximated to 10.

Remember that in the SI or metric system, pressure is normally measured in newtons per square metre ($N/m^2$ for short) or pascals (Pa for short). In the imperial system the unit of pressure is pounds per square inch (psi). You are also familiar with bar for everyday use.

Let's return to the tank in Fig.3.

If the liquid in the tank had a depth of 10.5 m and its density was 850 $kg/m^3$, then the pressure exerted by the liquid could be calculated quite easily as follows:

$$\begin{aligned} \textit{Pressure exerted by liquid} &= \textit{depth} \times \textit{density} \times g \\ &= 10.5 \times 850 \times 9.81 \\ &= 87550 \text{ newtons per square metre } (N/m^2) \end{aligned}$$

The total pressure reading of the lower gauge would be:

*Normal atmospheric pressure + pressure exerted by the liquid*

$$= 101300 + 87550$$
$$= 188850\ N/m^2$$

## ACTIVITY 3

The SI system is not the only system of units used in plant engineering. What other units are in use in your work area? Make a list of them below and then try to find out the conversion factors to convert them to Pascals.

| Unit | Conversion Factor |
| --- | --- |
| | |

Discuss your list with your trainer.

Now try the following SAQ.

✓ **SAQ 8**

The level of oil (i.e. the depth of oil) in a tank is 15 m and the oil has a density of 813 kg/m$^3$.

Remember that:

*Pressure = height of liquid* × *density* × *g*

(1) What would be the pressure reading above atmospheric of a pressure gauge located at the base of the tank?

(Atmospheric pressure = 1.013 bar.)

(2) Oil is allowed to flow out through a feeder pipe until the level reaches 3 metres. What would the pressure gauge now read?

(3) Use the conversion table in Appendix A to change these readings into:

(a) psi

(b) bars.

Check your answer with ours at the end of the unit before continuing.

## STUDY SESSION 2.2

# FACTORS AFFECTING THE FLOW OF FLUID IN A PIPELINE

## 1 PRESSURE ALONG A PIPE

If pressure is applied to a tightly packed pile of marbles or ball bearings, some of the marbles are moved sideways because some marbles are being pressed and forced at a slant against other marbles. In a fluid (which may be a gas or a liquid) which is made up of millions of tiny particles, the same effect occurs when pressure is applied. Water, for example will squirt sideways from a hole in a water tank regardless of the fact that the pressure applied is due to the weight (force) of water acting downwards.

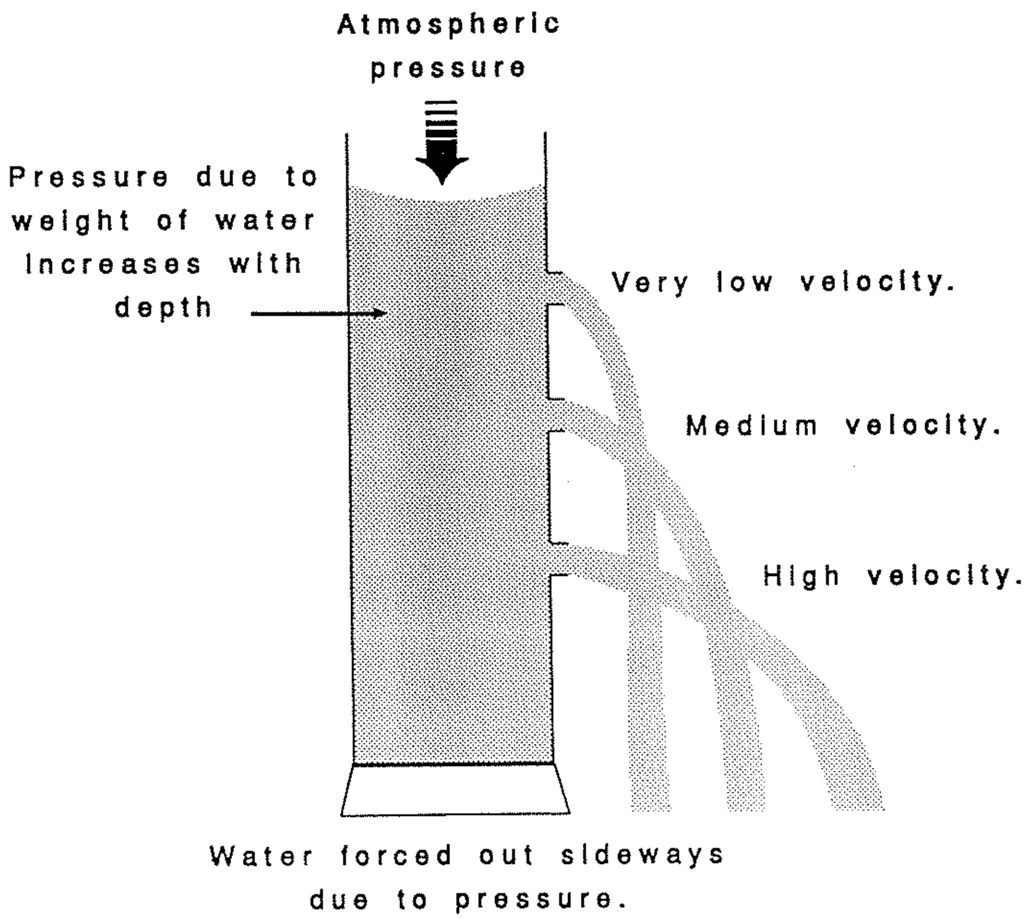



*Fig.4 Effect of Pressure on a Fluid*

Notice that near the base of the tank shown above, where the pressure is greatest (due to there being a greater depth and, therefore, greater weight of water above), the water is forced out at a much higher velocity than at higher levels.

If the fluid is free to move, as with the water escaping through the holes in the above diagram, then you can see that an increase in pressure at one point will make the fluid flow. The direction of fluid flow is from high pressure to low pressure.

Now let's go back to our tank shown in Fig.3.

From what you have just learned, it will now be obvious that the liquid shown in the tank in Fig.3 can be made to flow through a feeder pipe as a direct result of the pressure exerted by the height or depth of liquid in the tank.

If the tank contents are not topped up to keep the liquid depth the same, then as the liquid level falls, so does the pressure exerted by the liquid. This means that the liquid entering the feeder pipeline from the tank will enter at progressively lower pressures. As a result, the rate of flow of liquid in the feeder pipeline progressively decreases. When the tank is empty and the liquid can no longer exert any pressure, the rate of flow of liquid in the pipeline becomes zero.

So the rate of flow in a pipe depends on there being a pressure difference between the ends of the pipe. This is shown in Fig.5.

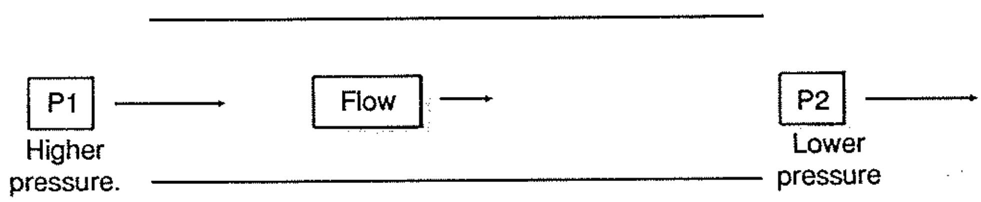



*Fig.5 How Pressure Difference Creates Flow*

✓ **SAQ 9**

Fill in the missing words in the following sentence.

The first essential of efficient ____________ ____________ in pipes is the maintenance of an adequate _________________ difference between the sections of the pipe.

Choose from: *pressure* *velocity* *fluid flow* *diameter* *viscosity*

Check your answer with ours at the end of the unit before continuing.

# 2 VISCOSITY AND ITS IMPORTANCE

ALL fluids are made up of tiny particles called **molecules** which can move about in the bulk of the fluid. In gases, the movement of the molecules is quite free. In liquids this molecular movement is limited to the molecules 'sliding' over and around each other.

When a fluid flows in a pipe, the pressure difference we mentioned causes the molecules of the fluid to move in the direction of the lower pressure. With gases, the movement again is relatively free and fairly fast. However, in liquids flowing in pipes, the molecules move in such a way that layers of molecules 'slide' along relative to one another. The layers of molecules of liquid in contact with the walls of the pipe are practically stationary, while those layers of molecules in the centre of the pipe are moving more rapidly. If a liquid is viscous, that is, it has a **high viscosity**, the 'sliding' motion of the layers or molecules is made much more difficult. More energy has to be used to make the molecules move. This energy is taken from the liquid itself and from the pressure difference existing in the pipe (remember that pressure is a form of energy).

---

✓ **SAQ 10**

The energy to overcome viscosity comes from (1) the liquid and (2) the pressure difference in the pipe.

What changes would result if a high viscosity fluid is transported in the pipe? (*Tick the correct answer.*)

(1) The liquid would flow more quickly. ☐

(2) The liquid would flow more slowly. ☐

(3) The liquid would flow at the same speed. ☐

Check your answers with ours at the end of the unit before continuing.

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The pressure loss in the pipeline is called the **pressure drop**. Fig.6 shows the effects of viscosity.

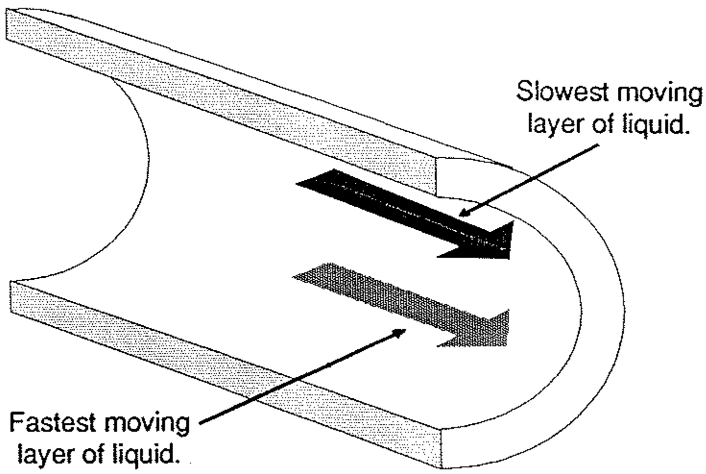


*Fig.6 (a) Effect of Viscosity on a Liquid in a Pipe*

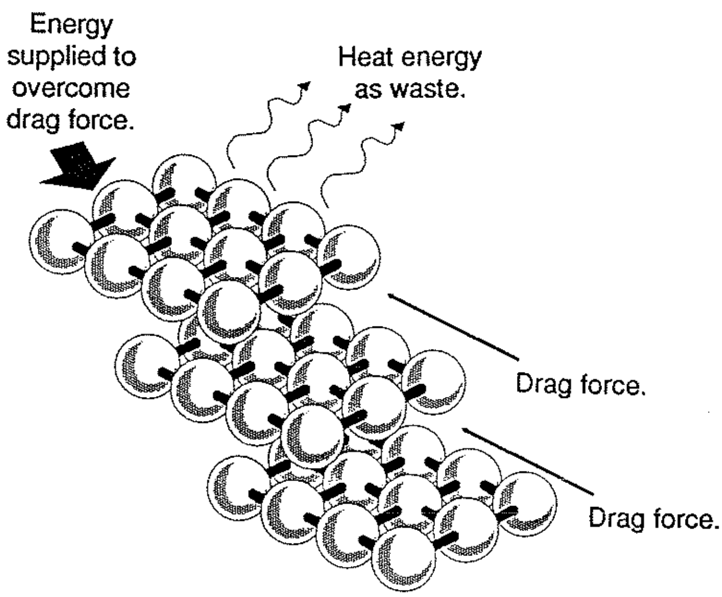


*Fig.6 (b) Effects of Viscosity in Liquids*

The net effect is that the rate of flow of liquids of high **viscosity** is considerably reduced and a lot of energy is wasted in the process of shifting very viscous liquids by pipe.

The effect of high viscosity on the flow of fluids can be compared with the drag or slowing effect of frictional forces on objects such as moving cars, planes and boats. The effects of high viscosity can be thought of as the effects of 'internal friction' in a fluid.

# 3 EFFECT OF PIPE DIMENSIONS ON RATE OF FLOW OF A FLUID.

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**ACTIVITY 4**

For this Activity, you need to look again at the various pipelines which you observed in Activities 1 and 2. Bearing in mind what you have just learned about the viscosity of fluids, we would like you to carry out the following activities, using the blank pages at the end of this workbook.

(1) Make a note of the diameters of the pipes used to transport the various fluids. (You could devise a table for this similar to the ones you used in Activities 1 and 2.) Remember that fluids include gases, so you will also need to note down the diameters of the air and steam lines.

(2) Compile a short report (about ½ page) on your findings to include:

(a) Any connection you have found between the diameter of the pipes and the viscosity of the fluids they transport.

(b) Any examples where you have discovered that pipelines are exceptionally wide or particularly narrow, along with any ideas you may have about the significance of this.

Discuss your findings with your trainer.

---

## 3.1 Diameter of Pipe

The diameter of pipe through which a fluid flows affects the rate of flow of fluid within that pipe. How does this occur?

No surface is absolutely smooth. Sliding contact between any two surfaces will result in **friction**, producing heat which is lost to the surroundings. The same is true for fluid in a pipe. There is contact between the surface of the inner wall of the pipe and the surface of the moving fluid. Depending on the roughness of the pipe surface, the frictional force varies. It is greater for rough, uneven surfaces than it is for smooth surfaces.

In a large diameter pipe, the fluid flows more easily. There is a **reduction** in the frictional 'rubbing' effects of the fluid with the pipe wall.

If the frictional effect is less, then not much extra energy has to be used to ease the flow of fluid through the pipe. This means that less kinetic energy is lost by the fluid itself and there is less pressure drop along the pipe. So the rate of flow is fairly steadily maintained.

In narrower pipes, the fluid encounters more friction as it flows along the pipe. Because the energy losses due to friction are greater, the rate of flow decreases.

---

**SAQ 11**

Complete the following sentences, putting one word in each of the spaces.

(1) 'The rate of flow ____________ in narrow pipes due to ____________ friction.'

(2) 'In a large diameter pipe ________ energy is lost and the rate of flow is ____________ maintained.'

Choose from: *increases* *more* *less* *more easily* *greater* *decreases*

Check your answer with ours at the end of the unit before continuing.

---

## 3.2 Length of Pipe

The longer the pipe, the greater the area of inner pipe surface that is exposed to the flowing fluid, so the greater the friction losses. This means that pressure drops are greater along longer lengths of the same pipe.

Fig.7 shows how this can affect rate of flow.

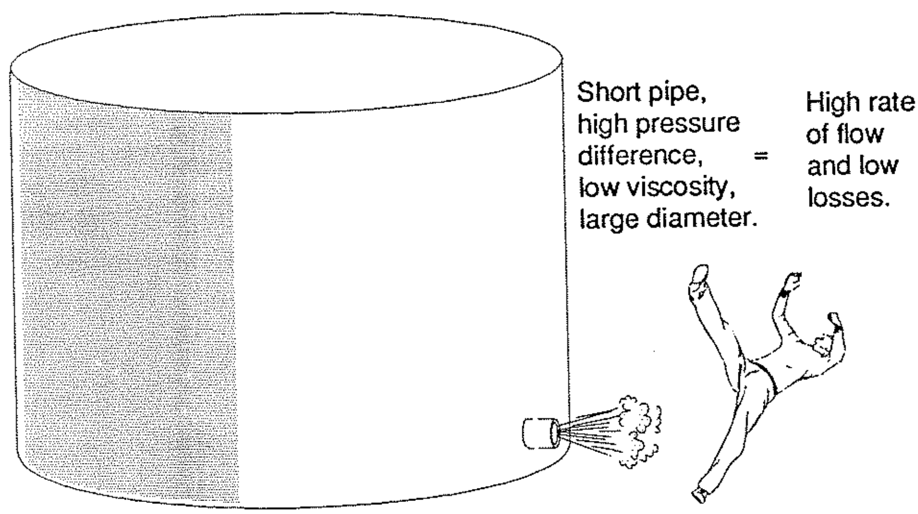


*Fig.7 (a) How Pipe Dimensions Affect Fluid Flow (1)*

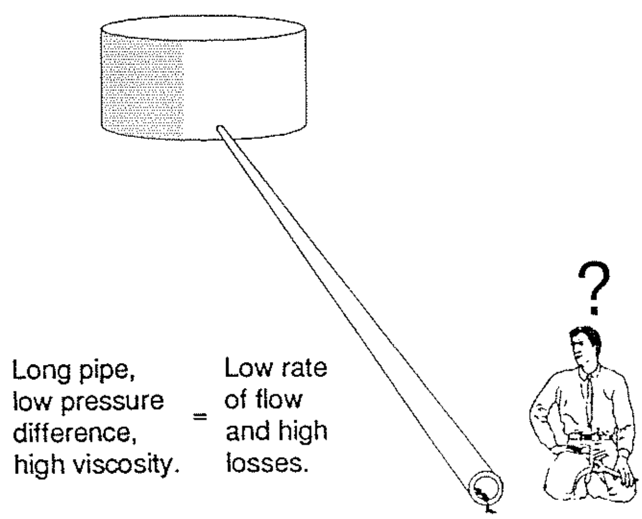


*Fig.7 (b) How Pipe Dimensions Affect Fluid Flow (2)*

In plant engineering, rates of flow may be expressed in terms of **mass rate of flow** or **volume rate of flow**.

For **mass rate of flow** the units are:

kilogram/sec (kg/sec) in the metric system
pound/sec (lb/s) in the imperial system

For **volume rate of flow**, the units are:

cubic metres/sec or metres/sec ($m^3/s$)

cubic feet/sec ($ft^3/s$) }
UK gallons/sec gal/s } in the imperial system

Sometimes when you are reading technical material or plans it may become necessary to convert from one system of units to another. We have included some conversion tables in Appendix A at the back of this unit.

## STUDY SESSION 2.3

# WHERE TO FIND THE GREATEST PRESSURE DROPS IN A PIPELINE

You already know that pressure drop in a pipeline is caused by energy losses occuring as the fluid flows along it. Pressure drop can also vary when the fluid flow in a pipeline is **altered** or **distorted,** for example, when eddies and turbulence are created in the fluid. Examples of turbulence are found when fluid flows round bends in the pipeline or through pipeline fittings of differing cross sectional areas, such as valves, sudden changes in pipe section, sharp inlets or exits from tanks, etc.

The turbulence causes more energy to be lost as heat. The result again, as with friction, is a pressure drop and a decrease in the rate of flow of the fluid. The greatest pressure drop occurs where the turbulence occurs, e.g. around bends and fittings, valves, etc.

These losses in the pipeline fittings can be calculated, but it is often better to use tables of results based on practical observations.

---

### ACTIVITY 5

For this Activity, you will need to observe pipelines in the refinery. You will also need to draw up a table for recording your findings for (1), so read the whole of this Activity and design the table before carrying out the activities.

(1) Look at the various fittings in the plant, and at any pressure or flow gauges associated with them. Make a note of the readings on these gauges both **upstream** and **downstream** of the fittings. You should record any significant changes in pressure across the fittings and note whether there is any evidence of reduced flow rate of fluid velocity. Enter all your findings in your table. Use the blank pages at the end of the workbook to do this.

(2) Explain briefly why pressure drop in a pipe will result in a decreased rate of flow of fluid in the pipe.

Discuss your answers with your trainer.

## STUDY SESSION 2.4

# EQUIVALENT LENGTHS OF PIPE

Sometimes it is more convenient to talk about pressure drops across fittings in terms of **equivalent lengths** of straight piping. This assumes that the fitting is replaced by a fictitious length of straight pipe which produces the same pressure drop (due to friction) as the fitting. So the various fittings are regarded as equivalent lengths of straight pipe and the total friction losses can be calculated from the **total** pipe length, made up of the **actual** and **equivalent** lengths of pipe.

---

### SAQ 12

Complete the following sentence putting one word in the spaces provided.

'When fluid flow in a pipeline is disturbed by ______________ and fittings, more energy is ________________ through friction, causing pressure to ________________.'

Choose your answers from the following list:

| | | |
|---|---|---|
| *pipes* | *valves* | *instruments* |
| *lost* | *gained* | *fall* |
| *stay the same* | *rise* | |

Check your answer with ours at the end of the unit before continuing.

---

Typical equivalent lengths of some fittings are shown below:

**Table 1: Equivalent Lengths of Fittings in Metres**

| Pipe Diameter | Globe Valve | Gate Valve | Elbow | Side Tee |
|---|---|---|---|---|
| 2 inches | 23 | 0.4 | 1.0 | 2.1 |
| 3 inches | 34 | 0.6 | 1.5 | 3.1 |
| 4 inches | 45 | 0.9 | 2.0 | 4.0 |
| 6 inches | 67 | 1.3 | 3.0 | 6.1 |
| 8 inches | 88 | 1.7 | 4.0 | 7.9 |
| 12 inches | 134 | 2.5 | 6.0 | 12.2 |

## SUMMARY

Now you have finished the work in this Section you should be able to:

(1) State what is meant by static pressure

(2) State the relationship between the height of a liquid and the pressure it produces

(3) Say that flow in a pipe is due to the pressure difference along it

(4) Describe the effects of viscosity and friction and how to reduce them

(5) Describe what happens at bends and fittings

## SECTION 3

# CORRECT FLOW OF FLUID IN A PIPE

Time: 1 hour

Your learning goals for this Section are:

(1) To know how to measure pressure

(2) To know the instruments used to measure pressure

(3) To know how to measure rate of flow

(4) To know the instruments used to measure rate of flow

(5) To know that valves control pressure and fluid flow in pipelines

(6) To know the different types of valves

## STUDY SESSION 3.1

# MEASUREMENT OF PRESSURE

Before you start this Section try to answer the following SAQ.

---

✓ **SAQ 13**

What do you think you should measure to decide whether fluid is flowing correctly? (*Tick the correct answer.*)

(1) Pressure. ☐

(2) Temperature ☐

(3) Velocity ☐

Check your answer with ours at the end of the unit before continuing.

---

You should monitor **variables** such as pressure, velocity, etc. This makes sure that you know how the pipeline is operating at any given time and you are able to take any steps necessary to control and maintain correct fluid flow.

Before you move on, let's recap on what you know about measuring pressure.

✓ **SAQ 14**

See if you can remember the two metric units used for measuring pressure.

(1)

(2)

Check your answers with ours at the end of the unit.

---

Newtons per square metre are too small for most applications so we use multiples. For example:

$1000\ N/m^2 = 1 \times 10^3\ N/m^2$ (sometimes called a kilopascal or kPa)

$1{,}000{,}000\ N/m^2 = 1 \times 10^6\ N/m^2$ (sometimes called a megapascal, MPa)

**Note:** $100{,}000\ N/m^2 = 1 \times 10^5\ N/m^2 = 1$ bar (14.5 psi)

In Unit 0, you learned that there are two kinds of pressure measurement:

(1) **Gauge pressure** — This is the pressure measured by a gauge and is the pressure over and above atmosphere pressure

(2) **Absolute pressure** — This is the value of pressure above absolute zero (nil) pressure.

The pressure measurements used in engineering are mostly gauge pressures.

## STUDY SESSION 3.2

# INSTRUMENTS USED TO MEASURE AND CHECK FOR CORRECT FLOW

## 1 PRESSURE MEASURING INSTRUMENTS

As you have seen, correct flow depends upon having a suitable pressure difference along the pipe. This pressure difference can be measured by using suitable instruments. Fig.8 shows a piezometer tube, which is the simplest measuring device. The pressures are different in this example because there is a large distance between the tubes.

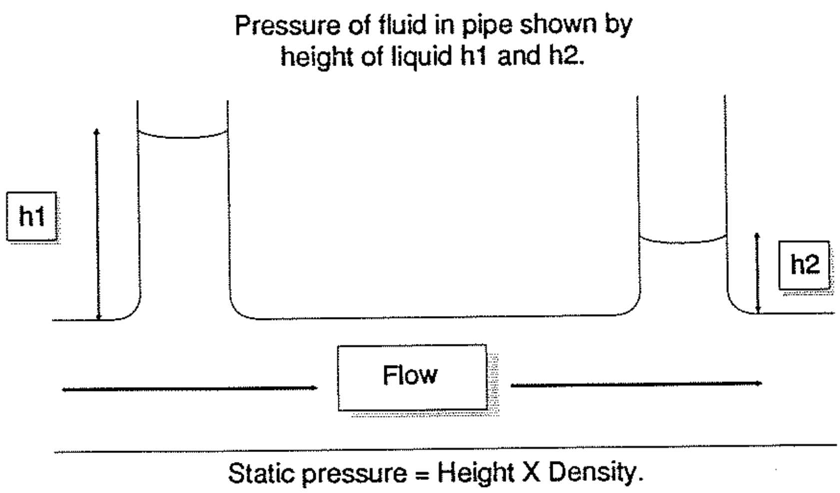


*Fig.8 Piezometer Tube*

*Pressure difference = Weight of measuring fluid being supported by pressure*

The weight of measuring fluid being supported by $P_1$ - $P_2$ is equal to ($h_1$ - $h_2$), the difference in levels of the liquid in the U-tube. ($P$ = pressure.)

So:

*Pressure difference* $P_1 - P_2 = (h_1 - h_2)$

This difference in levels may be stated in metres, centimetres or inches.

Alternatively if you want the pressure difference in N/m$^2$ (Pa) you can say:

$$P_1 - P_2 = (h_1 - h_2) \times \textit{density of measuring liquid} \times g.$$

(Remember that the pressure of a column of liquid = height of liquid × density × $g$)

There are also a number of other pressure measuring instruments.

## 1.1 The Simple U-tube Manometer

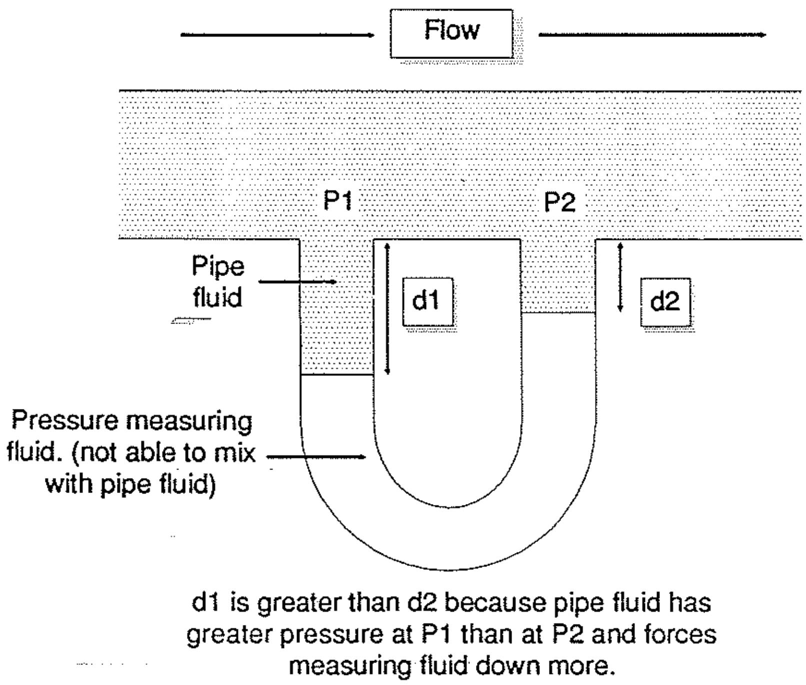


*Fig.9 The U-Tube Manometer*

$$\textit{Pressure difference} = \textit{Difference in depths } (d_1 - d_2) \times \textit{density of liquids} \times g.$$

## 1.2 Bourdon Tube

This gauge is used extensively in industry for measurement of pressures from $1 \times 10^5$ $N/m^2$ to $5 \times 10^5$ $N/m^2$ (100 kPa to 500 kPa, or in imperial units, 14.5 to 72.5 psi).

The Bourdon coiled tube tends to straighten itself when put under internal pressure. The degree of straightening is directly proportional to the difference between the pressure inside the tube and the outside pressure. The straightening of the tube operates a lever through a gear-link mechanism.

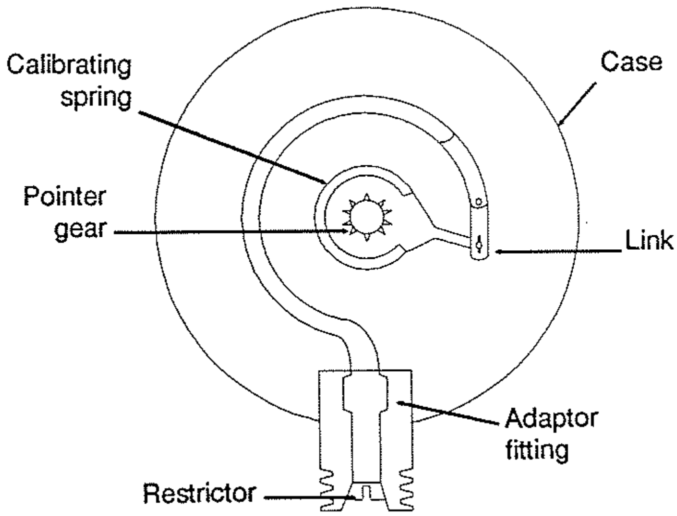


*Fig.10 The Bourdon Tube*

## 1.3 Diaphragm and Bellows Gauges

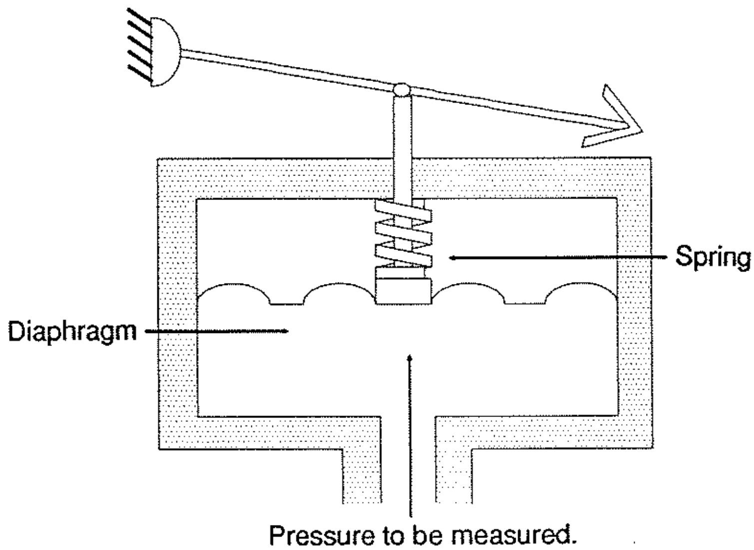


*Fig.11 Diaphragm Gauge*

The pressure to be measured acts on the diaphragm pushing it upwards against the stiffness of a spring. The pointer is thus made to move over a scale.

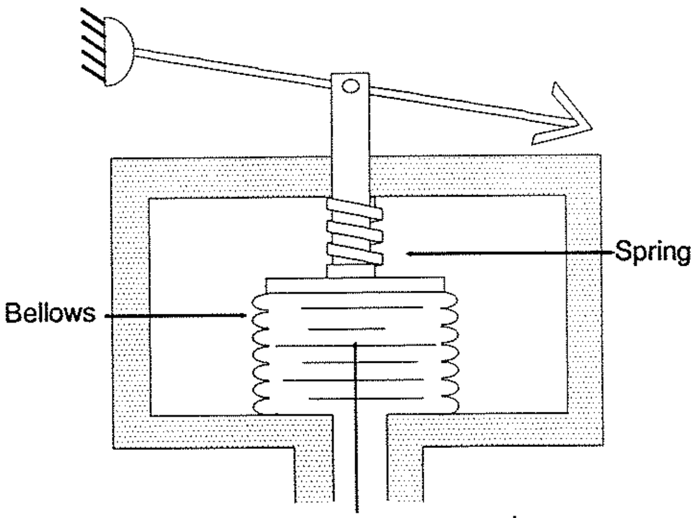


*Fig.12 Bellows Gauge*

The pressure to be measured causes the bellows to expand against the stiffness of the spring.

These gauges are used to measure pressures below $1 \times 10^5$ N/m$^2$ (100 kPa or 14.5 psi) where the Bourdon tube gauge is not accurate enough.

---

**SAQ 15**

All the ways of measuring pressure depend on one simple principle. What is it? (*Tick the correct answer.*)

(1) Force on an area. ☐

(2) Velocity. ☐

(3) Velocity through an area. ☐

Check your answer with ours at the end of the unit before continuing.

**SAQ 16**

(1) A U-tube manometer is connected across the bend of a pipe as shown in Fig.13.

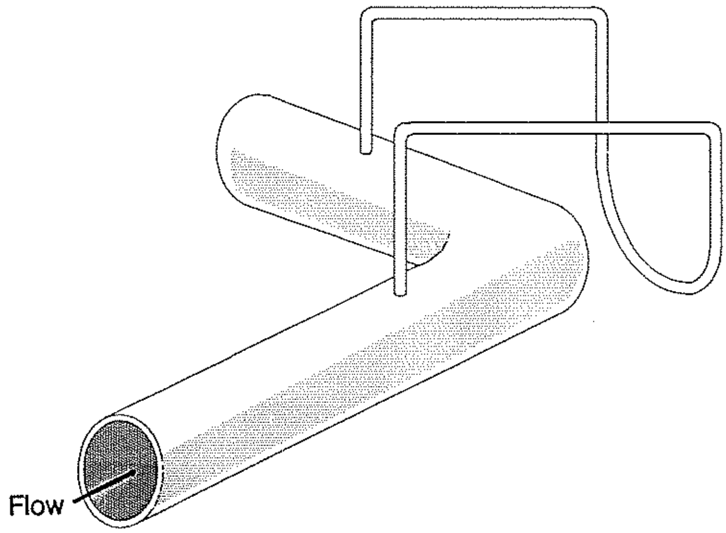


*Fig.13*

Mark in the levels of the liquid in the U-tube on the diagram.

(2) The same manometer is now connected across 2 points in a straight section of pipe. Sketch the arrangement and show the possible levels of the liquid in the U-tube. How would these levels differ from the arrangement shown in Fig.13?

Check your answer with ours at the end of the unit before continuing.

# 2 MEASUREMENT OF FLOW

Pressure differences can also be used to work out the rate of fluid flow.

## 2.1 Venturi and orifice flowmeters

At the beginning of this module you discovered that if the flow of fluid is constricted, i.e. the fluid is allowed to flow from a wider section of pipe to a narrower section, then the velocity of the fluid increases, but there is an accompanying decrease of pressure. This is basis of the Venturi and orifice flowmeters.

Venturi and orifice flowmeters are differential pressure flowmeters (i.e. they use difference of pressure as a measurement).

Look at Figs. 14 and 15.

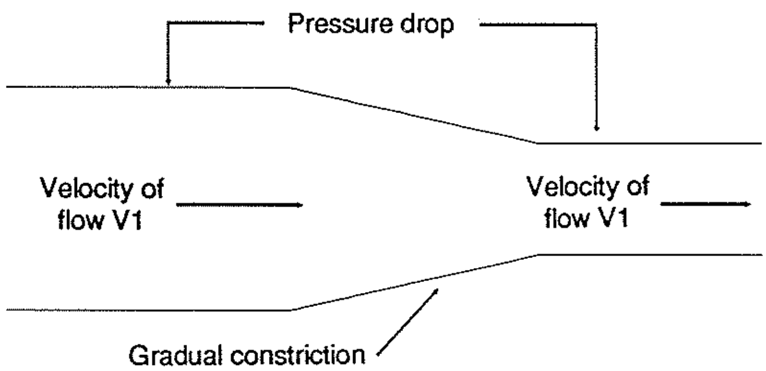


*Fig.14 How Venturi and Orifice Flowmeters Work*

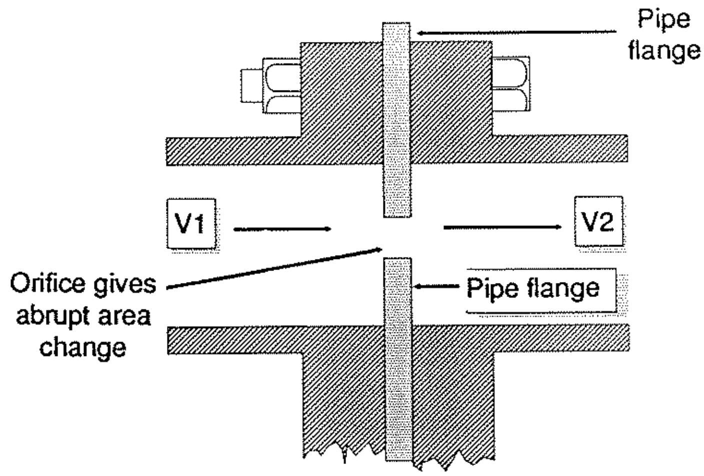


*Fig.15 Orifice Plate Meter*

If the fluid is a liquid, then there is a decrease of pressure across the narrow orifice. This difference in pressure can be measured and used to calculate the velocity of flow.

In general, rate of flow (in $m^3/s$ or $ft^3/s$) is related to the difference in pressure which exists across a section of pipeline through which the liquid is flowing, in such a way that the bigger the pressure difference, the faster is the flow of liquid in the pipe.

Pressure readings (tappings) should be taken at the points shown in Fig.16.

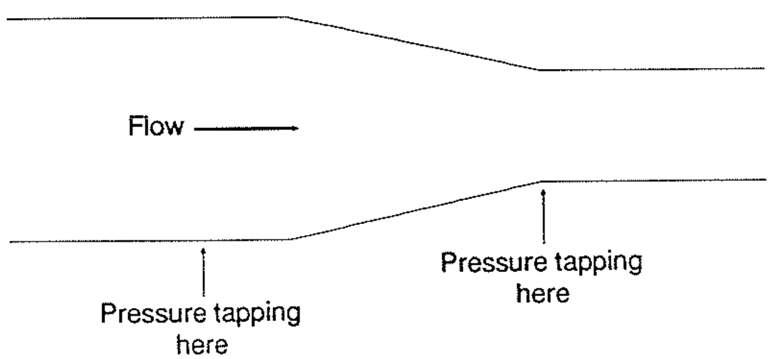


*Fig. 16(a) Taking Pressure Readings (1)*

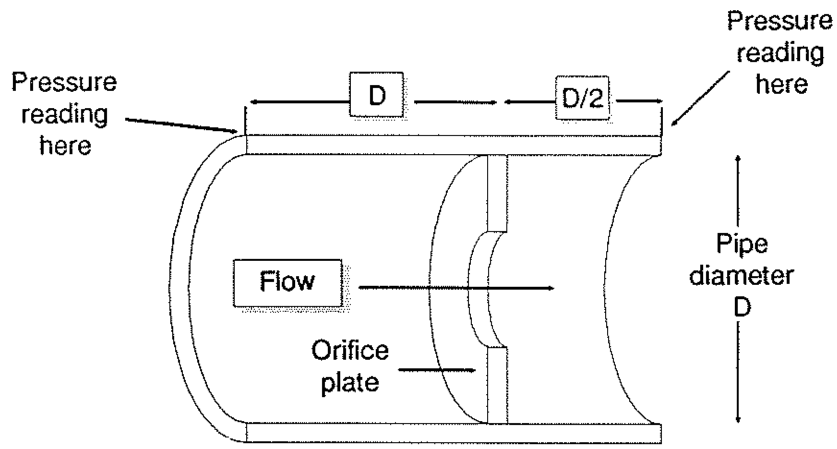


*Fig.16(b) Taking Pressure Readings (2)*

Orifice plate meters are extremely cheap and could be made relatively easily and quickly in a workshop.

Venturi meters are more expensive, have much larger dimensions and present problems when fitting into an existing pipeline. In contrast, orifice plate meters can often be installed in existing pipelines by springing the pipe flanges apart to allow for insertion of the plate.

There are other types of flowmeter.

## 2.2 Turbine flowmeter

The turbine wheel is turned by the moving liquid. A magnetic pickup gives an electrical impulse each time the wheel turns. These electrical pulses are connected to an electronic circuit with a timing device and meter. The meter can be calibrated in $m^3/s$, $ft^3/s$, etc. See Fig.17.

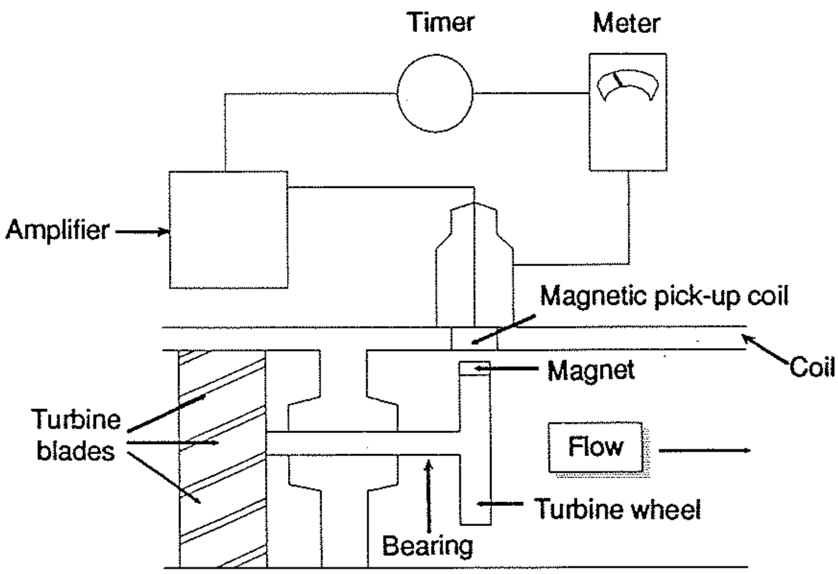


*Fig.17 Turbine Flowmeter*

## 2.3 Electromagnetic flowmeter

The action of this flowmeter depends on the fact that when a liquid which conducts electricity passes across the magnetic field of a magnet, a voltage is produced. The size of this voltage depends on the speed of flow of the liquid: the faster the flow the larger the voltage; and the slower the flow the smaller the voltage. By measuring this voltage we can measure the velocity (or the quantity) of liquid flowing in one second.

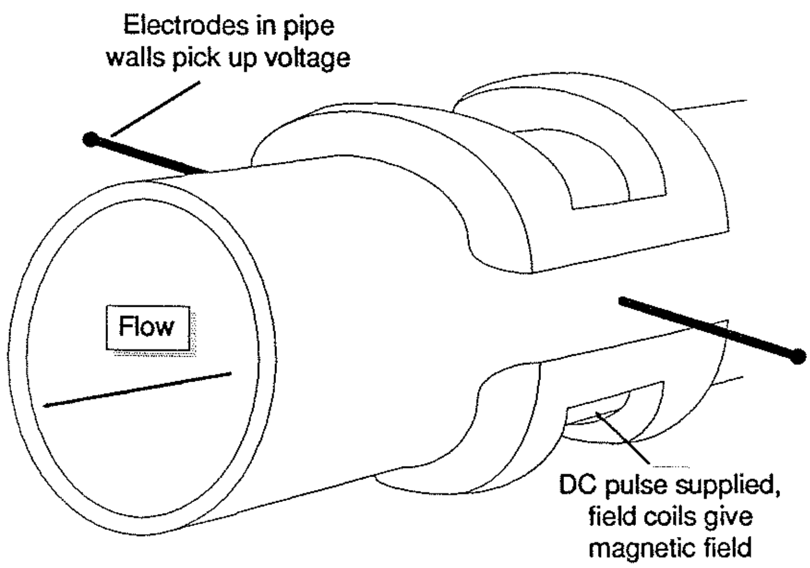


*Fig.18 Electromagnetic Flowmeter*

The electromagnetic flowmeter can only be used to measure the flow of fluids which are conductors of electricity. Therefore this type of meter is of no use when dealing with oils and fats. It can, however, be used to measure the flow of brine, acids and other conducting liquids.

## SAQ 17

Fig.19 is a diagram of a cross-section through a Venturi meter.

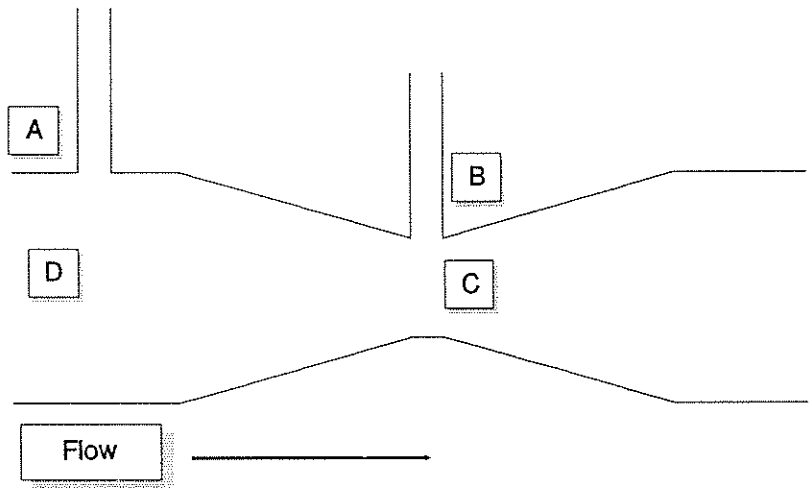


*Fig.19 Cross-section Through Venturi Meter*

(1) What are the levels of fluid you would expect to see in the piezometer tubes in the diagram? Mark your answers on Fig.19.

(2) At which point, D or C, is the fluid in the pipe moving faster?

(3) If the same Venturi meter were fitted with a U-tube manometer as shown in Fig.20, what would the levels of liquid in the U-tube look like? Mark your answers on Fig.20.

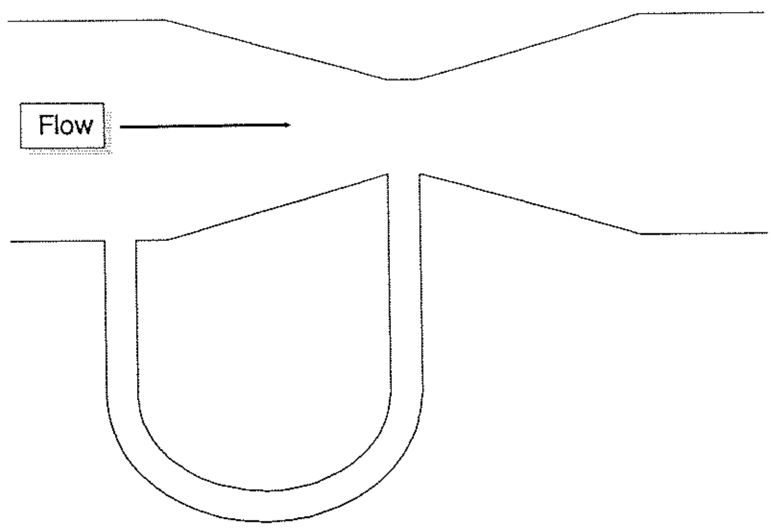


*Fig.20 U-tube Fitted to Venturi Meter*

Check your answers with ours at the end of the unit before continuing.

# 3 MEASURING GAS FLOW

Fig.21 shows how a pitot-static tube measures gas flow.

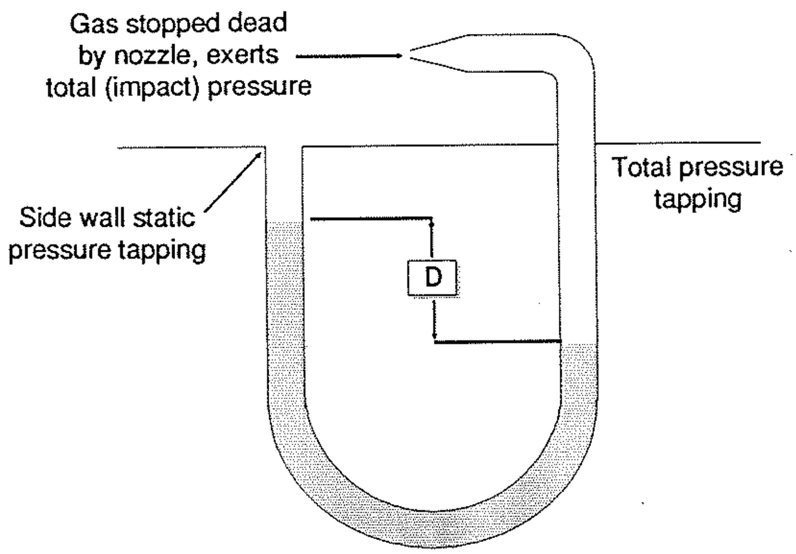


*Fig.21 Pitot-static Tube*

Other flowmeters used for measuring the flow of gases depend on the cooling effect of the gas flowing over a hot wire (this is the **hot wire anemometer**) and the rotation of small propellers when placed in a gas stream (**rotating anemometers**).

## ACTIVITY 6

For this Activity, you will need to go out into the plant to observe the flowmeters in operation. Again, the simplest way of recording what you find is to draw up a table, so read through what you are required to record in (1), (2) and (3) below before you begin. Use the blank pages at the end of this workbook to draw up the table.

(1) Make a note of which flowmeters in the plant are of the differential pressure type.

(2) Make a note of any other types of flowmeter in operation (i.e. those which are not of the differential pressure type.) You will need to identify which types are in use, and where they are used.)

(3) Make a note of the type of reading given by the flowmeters, and of where and how the reading is recorded.

Discuss your answers with your trainer.

## STUDY SESSION 3.3

# USE OF VALVES TO CONTROL FLOW

A valve is a device for controlling the rate of flow of fluid in a pipe.

There is one valve that everyone uses! This is the common water tap (Fig.22). A tap controls the flow of water in the water main by exposing '**no entry**' to water, '**partial entry**' to water or '**full entry**' to water. These positions are controlled by the person turning the tap.

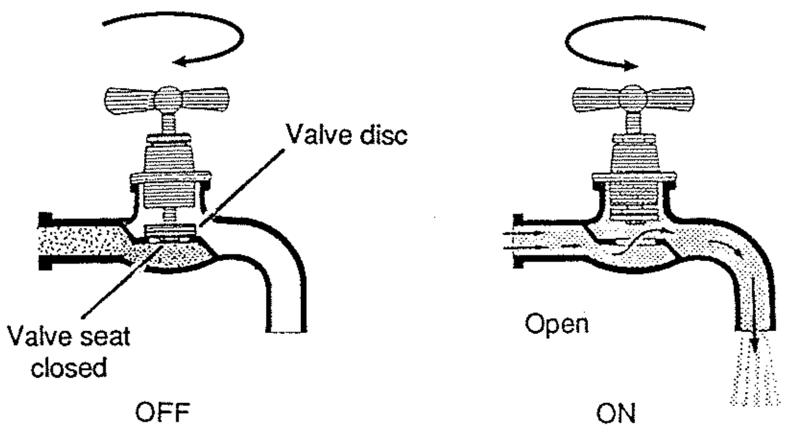


*Fig.22 Water Tap as a Valve*

Another simple type of valve is the plug cock (Fig.23) seen on beer and water barrels.

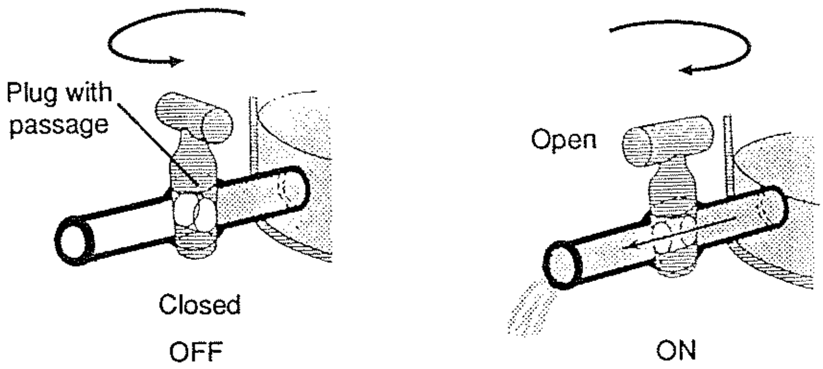


*Fig.23 Plug Cock*

Valves met with in industrial plants can control the flow of fluid very accurately but the basic idea is essentially similar to that of the tap and plug cock.

The valves used in pipelines may be of different types, but the basic structure of all of these types can be generalized as shown in Fig.24.

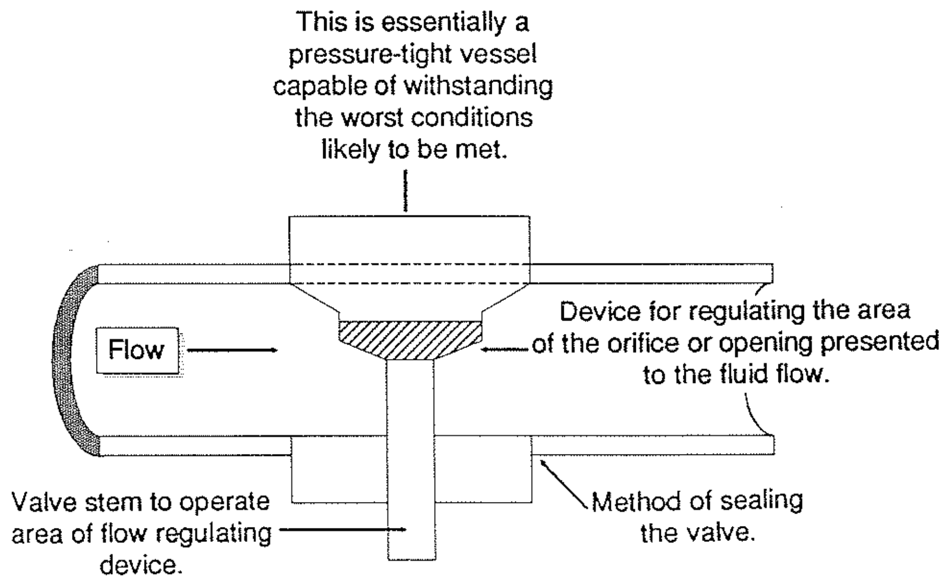


*Fig.24 Basic Structure of Valves*

## ✓ SAQ 18

Can you think of 6 different types of valves?

| | |
|---|---|
| (1) | (4) |
| (2) | (5) |
| (3) | (6) |

Check your answers with ours at the end of the unit before continuing.

Some of the valves commonly used in pipelines are described in the next Study Session.

# STUDY SESSION 3.4

# WHAT TYPE OF VALVE?

## 1 GATE VALVE

These valves operate by closing a flat usually wedge shaped disc which moves up and down at the turn of a screw thread. Gate valves are usually only used in the 'fully open' or 'fully closed' positions. See Fig.25.

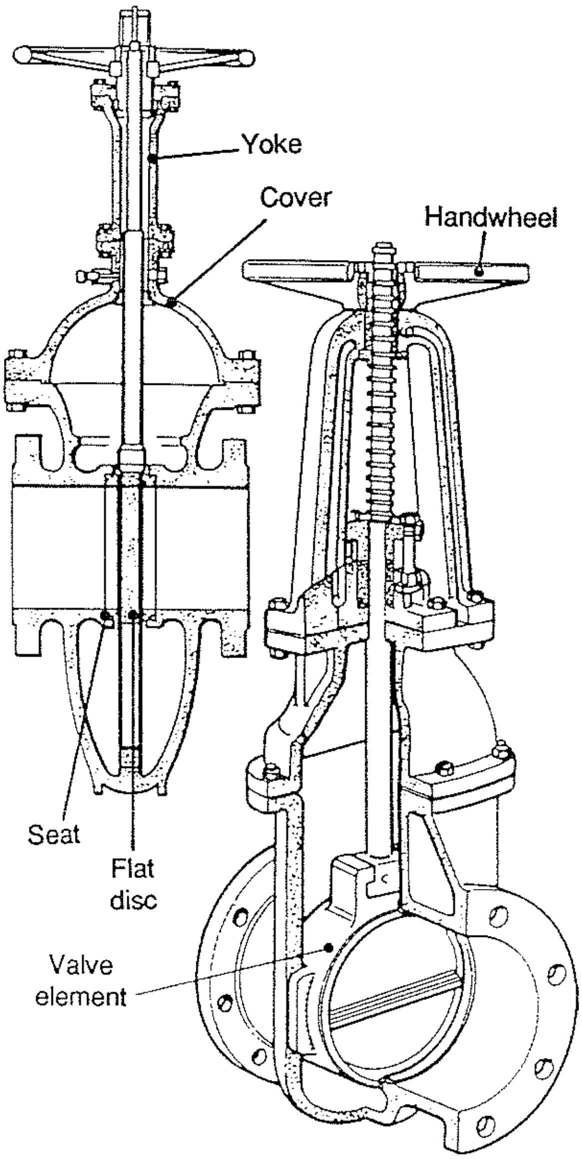


*Fig.25 Gate Valve*

# 2 PLUG VALVES

These depend for their action on turning a tapered or cylindrical plug which has a through port for the fluid to flow. The 'fully closed' to 'fully open' positions are achieved by turning the plug through 90°, giving a shearing action which helps to remove foreign matter from the **seat** (where the plug sits).

Plug valves can be used for '**throttling**' (that is, cutting down the fluid flow) and also to turn the flow of fluid on and off in the 'fully open' and 'fully closed' positions. Plug valves may be lubricated or non-lubricated (see Fig.26).

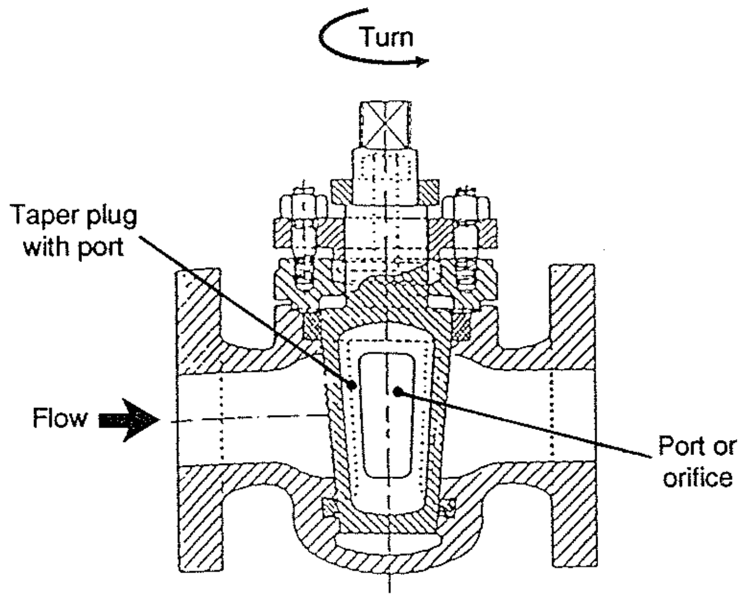


*Fig.26 (a) Plug Valve In 'Off' Position*

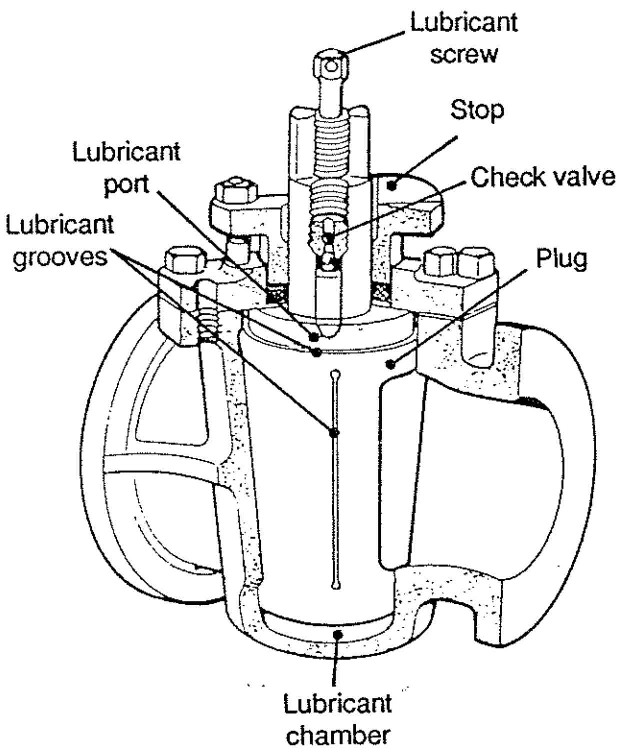


*Fig.26 (b) Lubricated Plug Valve*

# 3 BALL VALVES

Here the valve is fitted with a ball through which runs a hole for fluid flow. You turn this ball to produce 'fully closed', 'throttling' and 'fully open' positions.

These valves are non-sticking and give tight closure. The seat of the valve (which is where the ball sits) can be made from nylon and other polymers. Graphite seats are used when dealing with high temperature fluids. Ball valves are quick acting, needing only a quarter turn from 'fully open' to 'fully closed' (see Fig.27).

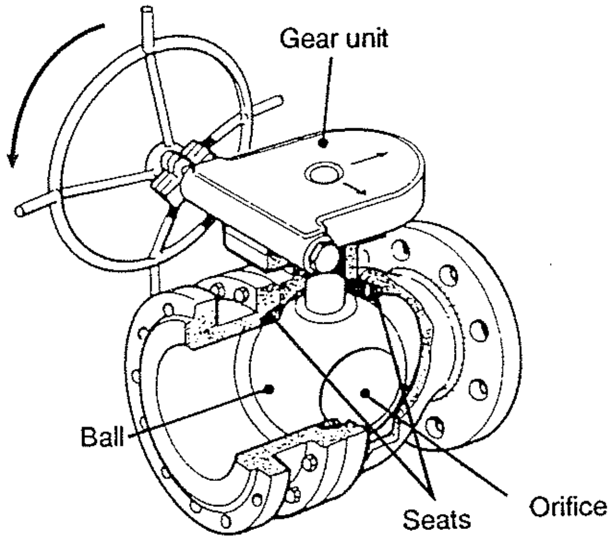


*Fig.27 Ball Valve In 'Off' Position*

# 4 GLOBE VALVES

The commonest example of a globe valve is the domestic water tap. The fluid flows through a **horizontal** port or channel in the valve. This port can be closed by a circular disc or plug which moves vertically **up** or **down** onto a **seat** for shut off (Fig.28).

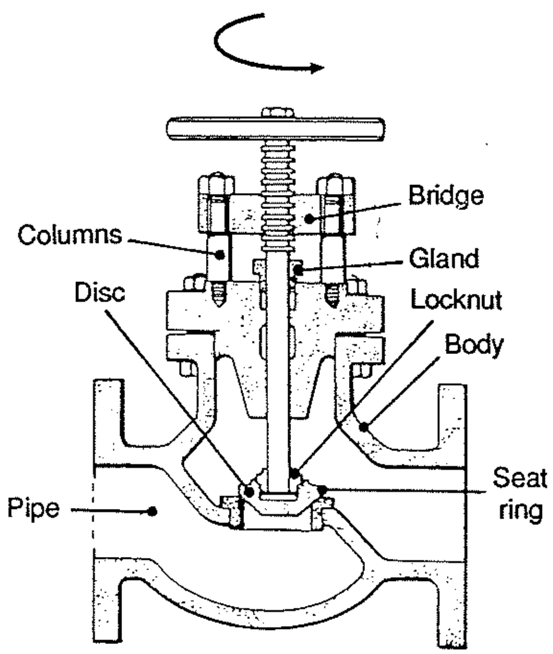


*Fig.28 Industrial Globe Valve in 'Off' Position*

Globe valves seal off tightly and are good for controlling flow, but the pressure drop across the valve is high.

# 5 BUTTERFLY VALVES

These operate through discs arranged to swing or turn on a vertical or horizontal axis, so controlling fluid flow through the pipe in any position (Fig.29).

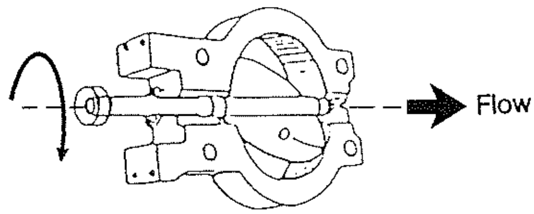


*Fig.29 Butterfly Valve*

Butterfly valves are good as on, off and throttling devices. They are cheap, have low pressure drop across them and are ideally suited for low pressure systems and large capacity, low temperature duties. Their design prevents the build-up of sediment in the valve so they can be used for flows of gas, liquid or slurry which carry large amounts of suspended matter.

# 6 DIAPHRAGM VALVES

These are used for the same sort of situations as the butterfly valve. A flexible diaphragm is used to control the flow of fluid. In diaphragm valves there is no need for stem sealing since the diaphragm itself isolates the valve mechanism from the fluid. Depending on the material used to construct the diaphragm, these valves can be used to control flow of viscous fluids and corrosive fluids. (See Fig.30.)

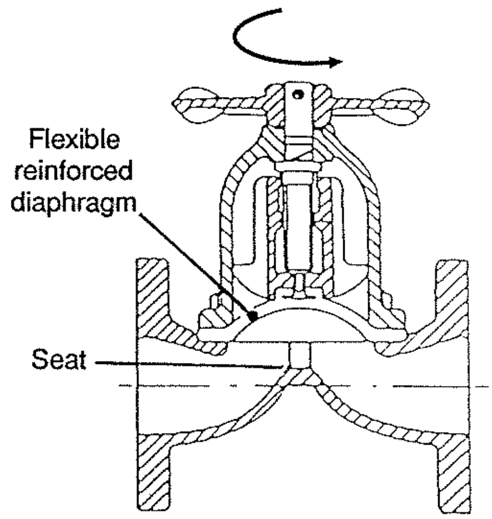


*Fig.30 Diaphragm Valve*

# 7 NEEDLE VALVES

The plug controlling the area of flow of fluid is a sharp pointed shape, giving the valve its name. Needle valves are usually used in association with instruments in line. Very good and accurate throttling is obtained by using needle valves and they are therefore used a great deal in high pressure and high temperature pipelines. (See Fig.31.)

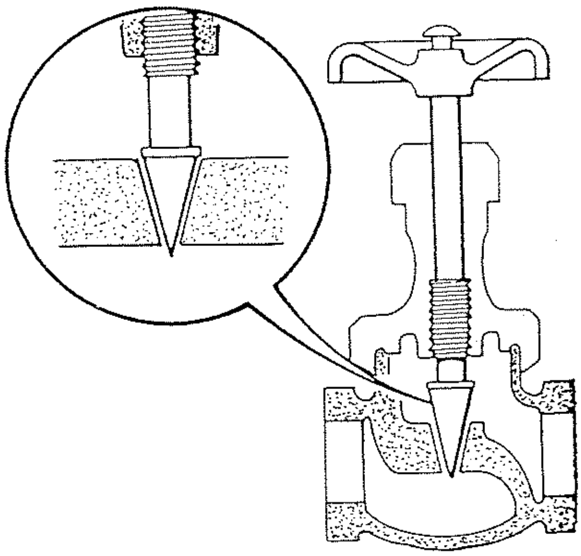

*Fig.31 Needle Valve*

# 8 CHECK VALVES

Another name for check valves is **non-return** valves. They are used to prevent backflow in pipelines. Two types of check valves are shown in Fig.32.

In the piston check valve, flow in the correct direction raises the piston, and reverse flow causes lowering of the piston.

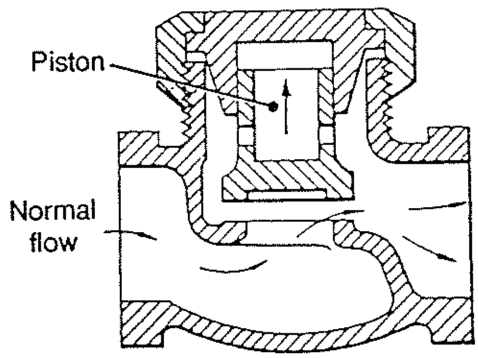


*Fig.32 (a) Piston Check Valve*

In the flap type check valve, correct flow raises the flap while reverse flow returns the valve to the seat.

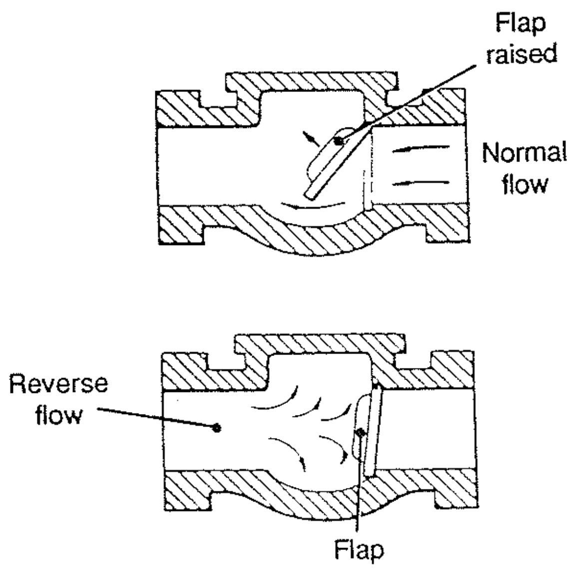


*Fig.32 (b) Flap Type Check Valve*

# 9 RELIEF VALVES

These are **safety devices** which prevent the build-up of excess pressure in pipelines and process vessels. In relief valves, the valve is held closed by a retaining device, such as a spring, until a preset pressure is reached. When this pressure is reached, it acts on the spring, compressing it and causing the plug to lift off the seat. The valve opens and the fluid can escape and reduce the pressure in the pipeline. The escaped fluid is vented to a flare through a relief pipe system. When the pressure has dropped sufficiently, the spring acts to seat the plug again and so closes the valve (Fig.33).

The right hand diagram in Fig.33 shows an enlarged section of the valve in an open position.

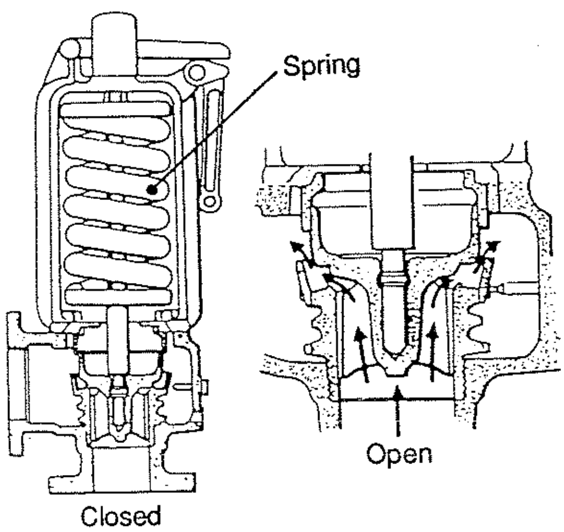


*Fig.33 Relief Valve*

# 10 CONTROL VALVES

Not all valves are operated by hand. In modern plants, many of the valves are operated through the use of power such as electricity, compressed air and hydraulic pressure. In this way, continuous control of fluid flow can be achieved. Pressures, rates of flow and temperatures of fluid in a pipeline can be monitored continuously. Any deviation results in a signal to the process system that all is not well, which activates the appropriate valves to maintain control. We will look at this again in the next study session.

Valves which 'control' the fluid flow in pipelines in this way are called, quite sensibly, **control** valves.

A typical control valve is shown in Fig.34.

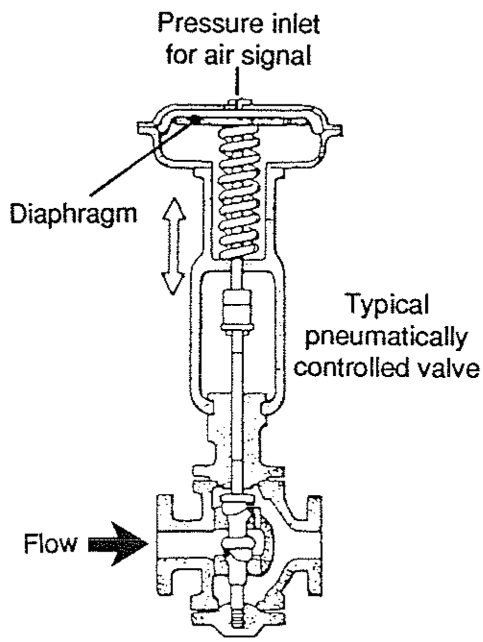


*Fig.34 Pneumatic Control Valve*

Increased pressure (air) signal causes the diaphragm in Fig.34 to push the valve plug into closed position.

## STUDY SESSION 3.5

# USE OF VALVES TO CONTROL PRESSURE OF FLUID IN PIPELINE

Plant process control is concerned with maintaining **variables** such as fluid flow at a desired, pre-set level or measurement. Control valves play an important part in this.

A simple control circuit, using control valves, is shown in the simple diagram in Fig.35. Remember that this is a very simple picture of what happens in the control process but it serves to show the basic ideas.

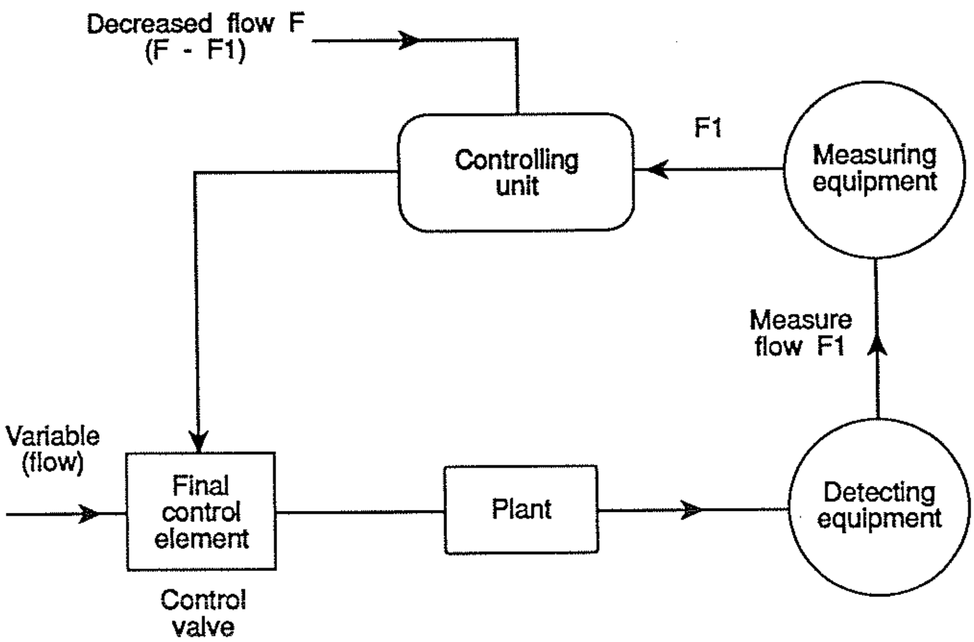


*Fig.35 A Simple Control Circuit*

Let's look at what happens.

The flowmeter detects a certain measurement of the **variable** (which is flow in this case), such as pressure difference, volume or velocity of flow.

This information is received and evaluated by the measuring equipment. It then goes to a **controlling unit** which compares the **actual** measurement received from the measuring equipment with the **desired** measurement needed to operate the plant efficiently (i.e. correct volume flow, correct pressure difference, etc.)

Any difference between the actual measured value of the variable and the desired value of the variable produces a signal from the controlling unit which is sent to the final control element (in this case, a control valve).

On receiving the signal from the controlling unit, the final control element responds by adjusting the process. In this case, the valve simply opens or closes more to increase or decrease the flow of fluid.

Flow is just one variable. Other control circuits exist in the plant to control variables such as temperature, liquid level, pressure and other physical quantities.

The above example, where valve and flowmeter are final control element and detecting element respectively, shows how flow can be controlled by measuring and maintaining pressure (using a differential pressure flowmeter) and also how valves can function, in such cases, as pressure control devices.

Control valves can act as final control elements in other control circuits to maintain variables such as temperature, pressure, liquid level, density and other physical quantities.

## STUDY SESSION 3.6

# THE TYPES OF VALVE PRESENT IN THE PLANT AND WHAT THEY DO

---

### ACTIVITY 7

You will need to go out into the plant to inspect FOUR sections of pipeline for this Activity.

(1) Make a sketch of the pipelines you have examined, using the blank pages at the end of the workbook.

(2) Label the valves on each, indicating which type it is and how it is operated (i.e. manually or otherwise.)

(3) Label clearly the valves which must be closed off for emergency and/or before starting maintenance work on the pipeline.

(4) Taking one particular pipeline, explain how pressure can be controlled.

Discuss your answers with your trainer.

---

## SUMMARY

Now you have finished the work in this Section you should be able to:

(1) Measure pressure in a pipeline

(2) Name instruments used to measure pressure

(3) Measure rate of flow in a pipeline

(4) Name instruments used to measure rate of flow

(5) Describe how valves control pressure and fluid flow

(6) List the different types of valves

## SECTION 4

# ACHIEVING A GOOD PIPELINE SYSTEM

Time: 1 hour

Your learning goals for this Section are:

(1) To know how to choose the correct pipe materials

(2) To know how to lay and join pipes

(3) To know the importance of adequate support

(4) To know the main factors affecting pipeline design

## STUDY SESSION 4.1

# CHOOSING PIPE MATERIALS

## 1 PROPERTIES OF PIPING MATERIALS

The first consideration is the correct choice of pipe materials. It is no use building a strong pipeline if the fluid to be transported eats through the pipe. The choice of pipe material also depends on the pressure at which the fluid is to be forced through the pipe. So strength of material for the pipe has to be considered. Pipelines can be fairly long, involving long sections of pipe which have to be safely supported. Pipe material of heavy weight will create problems when this aspect of pipeline construction is taken into account. So, another factor to be considered is the **weight** of piping material in relation to its strength.

In plant processes concerned with the production of foodstuffs, great emphasis must be placed on maintaining the pipe surfaces in absolutely clean condition. This means choosing a pipe material which will not corrode easily and which can be cleaned without too much intensive, abrasive scouring. Also the pipe material must not present any possible toxic (poisonous) hazards, either before or during cleaning. The actual materials from which pipes are made are many and various. The principal ones are:

- Stainless steel
- Carbon and low alloy steel
- Wrought and cast iron
- Aluminium
- Copper
- Brass
- Plastics

**(1) Stainless Steel**

Generally speaking, stainless steel piping is the most satisfactory for pipelines. It is strong, relatively light, fairly resistant to corrosion by most of the fluids met with in plant and easy to clean. But it cannot be used in transporting highly acidic fluids.

**(2) Aluminium**

Aluminium is light, but surprisingly strong and can be cleaned easily. It is not recommended for hot water, steam, acid or alkali transport. In each of these cases, the pipe will corrode.

**(3) Cast iron**

Cast iron is strong but very brittle and fractures easily.

**(4) Copper and Brass**

Copper and brass are suitable for carrying gases, but they are both expensive and may present toxic hazards when liquids are being transported.

**(5) Plastic**

Plastic pipes are suitable for transport of fluids at low pressures, but high pressures may cause problems at pipe joints. Plastic pipes tend to discolour internally with the passage of certain fluids. They can be used for fluids which corrode metal, such as acids.

✓ **SAQ 19**

Complete the following table, putting ticks where a material has the properties shown.

| | Light | Corrosive-resistant | Strong | Easily cleaned |
|---|---|---|---|---|
| Stainless steel | | | | |
| Aluminium | | | | |
| Cast iron | | | | |
| Copper/brass | | | | |
| Plastic | | | | |

Check your answer with ours at the end of the unit.

# 2 OTHER FACTORS

The properties of the material aren't the only factors to be taken into account when choosing piping materials.

Higher pressures in fluid flow mean thicker pipe walls for withstanding these high pressures. This means increased weight and increased cost of pipes. Larger diameter piping also means thicker pipe walls. Both high pressure and large diameter make for faster rate of flow, but this has its drawbacks.

Both the British Standards Institute and the American Standards Association specify suitable pipe diameters and thicknesses for steel pipes and for tubes to be used in pressure situations. The American specification is more explicit and direct and gives pipe numbers (schedule numbers) relating pipe diameters to suitable pipe wall thickness for stated design pressure.

Both quality and cost have to be taken into account when considering piping.

Pipes may be obtained in sections in which the material is welded or seamless.

Generally speaking, steam piping should be made of an alloy of steel which can be used above 900°C. Compressed air piping and high velocity gas piping is made of wrought iron of steam quality.

British Standards BS4825 contains more information about stainless steel pipes and fittings for the food industry.

---

**ACTIVITY 8**

For this Activity, we would like you to imagine that you are asked to give technical advice on:

(1) Suitable materials for use in piping oil, hydrogen and steam.

(2) Pipe size for the various pressures that will be used.

Write about half a page of notes which you could use for a briefing. Use the blank pages at the end of this workbook.

Discuss your answer with your trainer.

---

## STUDY SESSION 4.2

# SITING AND SUPPORTING PIPES

## 1 SITING PIPES

Plant layout and architecture will greatly influence the final siting and layout of pipeline. However, the pipeline should be sited so that it is easily accessible for maintenance at all points. The siting and layout should allow immediate emergency shut down.

Siting should be such that long sections of straight pipe are used wherever possible.

---

✓ **SAQ 20**

Can you suggest why it is desirable to have long sections of straight pipe in a pipeline?

Choose your answer from:

(a) To minimize pressure loss? ☐

(b) To avoid blockages? ☐

(c) For easier construction? ☐

Check your answers with ours at the end of the unit.

---

# 2 SUPPORTING PIPES

Piping should be anchored to support its weight, and to prevent excessive movement. Wrongly designed or inadequate anchors or supports cause more pipeline trouble than any other single item and the damage is not only confined to the pipework, but may also spread to the connected plant.

Pipes are normally supported by support brackets, which tend to restrain the pipe completely, or by slings from a spring loaded pivot joint. This arrangement gives the pipe adequate controlled vertical support, yet at the same time, allows some degree of freedom of movement.

Roller supports can give support to a pipe and allow a certain degree of movement along its axis.

If a pipe is correctly anchored, movements in the pipe will be directed onto structures which can cope with them.

# STUDY SESSION 4.3

# LAYING AND JOINING PIPES

Wherever possible pipes should be laid horizontally. This avoids excess pressure gradients caused by **static pressure** as the pipe climbs. In this way, excess power use is avoided when forcing the fluid along the pipe.

In compressed air lines, it is permissible to lay the pipes so that they climb through a specified gradient. This is to allow drainage of moisture which condenses from the air in the pipeline.

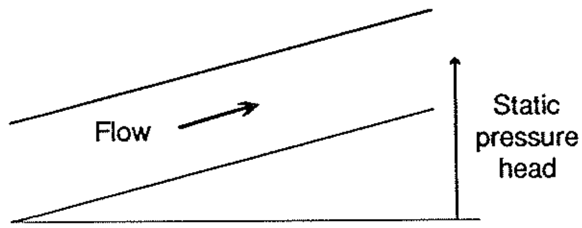


*Fig.36 (a) Effect of Gradients on Fluid Flow*

Laying a pipe as shown in Fig.36 (b) increases fluid pressure by the static pressure head shown. More energy (and power) is needed to make the fluid flow.

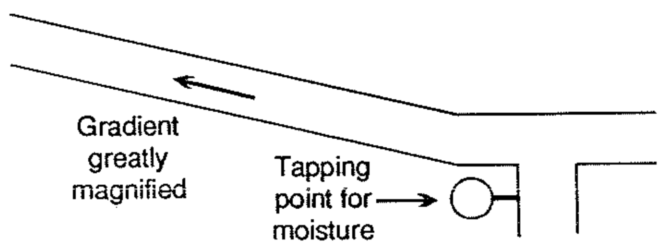


*Fig.36 (b) Gradient in Air Lines*

In air lines a specified gradient is allowed so that condensed moisture can be drained off.

In laying the pipes, allowance must be made for the pipes to expand and contract as a result of changes in temperature, both in the fluid being carried and in the surrounding temperature. If you don't allow for this then the pipework will be subjected to unwanted strains and stresses when contraction or expansion occurs.

Some of the common methods used to compensate for expansion or contraction are:

(1) Clever use of **pipe layout**, making use of the natural elasticity of the pipe material and fittings. This method is only practicable for long pipe runs with adequate space.

(2) **Corrugated expansion loops** in the pipe. Use of these causes increased turbulent flow and higher friction loss (Fig.37).

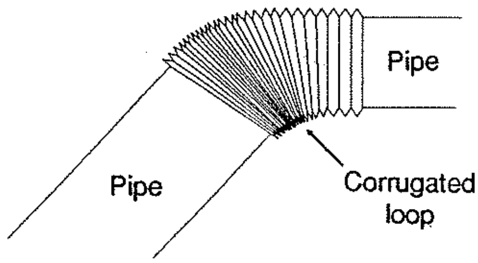


*Fig.37 Corrugated Expansion Loops*

(3) **Flexible metal tube joints**

(4). **Slip type gland packed joints**. These require absolutely perfect alignment to avoid unnecessary wear and failure.

(5) **Bellows type joints**. These may be:

(a) Rubber (suitable for vacuum and low pressure).

(b) Disc type, made from welded metal rings.

(c) Corrugated tube bellows.

Good leak-proof joints are a must in pipelines. Various methods of joining pipes are used. Choice of method depends on:

(1) Pipe material

(2) Pressure in the pipe

(3) Pipe diameter

Pipe joints or couplings may be:

**(1) Screwed connections**

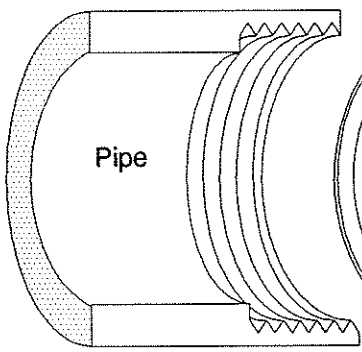


*Fig.38 (a) Straight Thread*

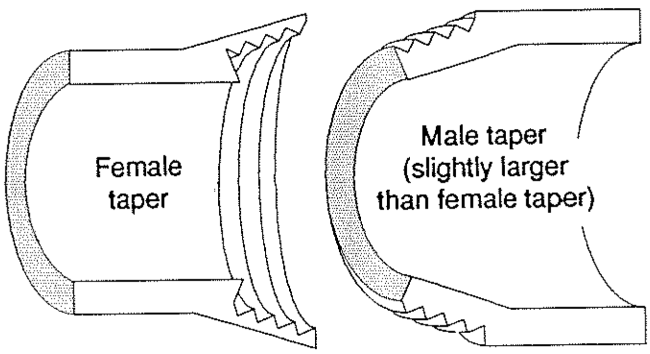


*Fig.38 (b) Taper Thread*

These are suitable for low pressure systems on thick walled metal tubes.

**(2) Brazed or soldered connections**

Not generally encountered and suitable only for low pressure pipes

(3) **Welded connections**

Used often in high pressure, high temperature steam piping. Butt welding techniques are most often used

(4) **Flanged couplings or connections**

These are widely used. The flange may be screwed or welded to the prepared pipe ends or may be manufactured as an integral part of the pipe length.

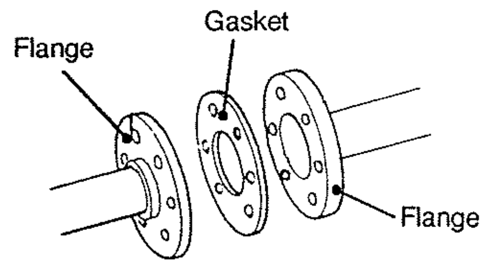


*Fig.39 Flange Coupling*

The flanges or flange joints of the pipe sections are brought together and the jointing is completed by bolting the flanges through bolt holes and through the gasket.

To ensure a leak-proof joint, a gasket sealing compound must be used to seal.

O-rings are an alternative to gaskets, but are only used for very high pressure lines.

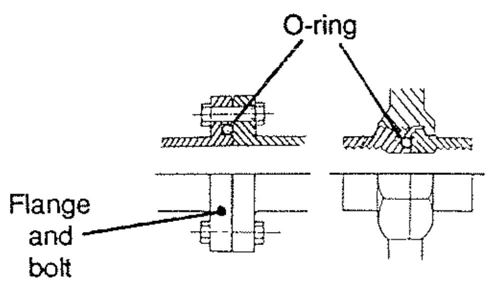


*Fig.40 (a) On clamping, the O-ring provides a pressure seal.*

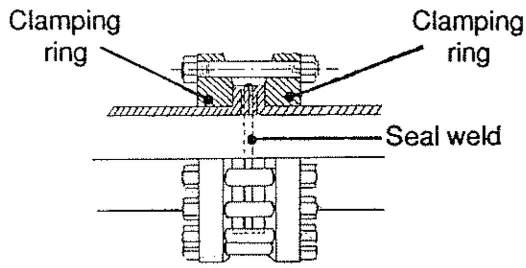


*Fig.40 (b) Seal weld with compression ring (the joint can be broken and remade).*

Under excessive pressures, flanges can spring apart, so it is important that the correct flange is used.

British Standards BS1560 specifies pressure ratings for cast and forged steel flanges for use for oil, water, steam and gas and chemical services. Various classes are given numbers which represent their pressure ratings. Pipe diameter sizes are included for most of the classes.

Similarly, the American Standards Association give pressure classes for steel flanges. Such aids as these allow you to obtain a **flange rating** or pressure class for a given pipeline with a specified maximum pressure and temperature of fluid.

## (5) Compression Fittings

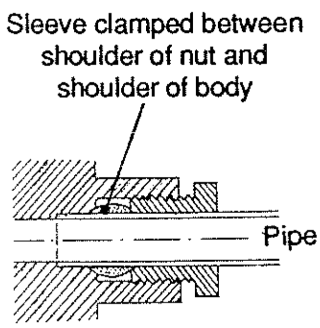


*Fig.41 Compression Fitting*

Tightening of nut causes the sleeve to grip more tightly and make an effective seal.

**SAQ 21**

(1) Make a list of all the types of joint available for pipes, without looking back in the workbook.

(2) Next to each, note whether it would be suitable for:

(a) High pressure gas flow.

(b) Low pressure oil flow.

(c) High temperature, high pressure steam.

(d) Low pressure hydrogen flow.

Check your answers with ours at the end of the unit.

## STUDY SESSION 4.4

# FACTORS AFFECTING PIPELINE DESIGN

Pipelines are designed to transport fluids efficiently and economically from one place to another. As such they must be leak-proof and must be able to withstand whatever pressure has to be applied to force the fluid through the pipeline. The pipes must also be made of a substance which will not corrode or suffer any other physical damage from the substance they are transporting.

It is important to cut down energy losses in pipelines as much as possible since these losses result in loss of pressure along the pipeline (pressure drop) with a resulting slowing of rate of flow of the liquid in the pipeline. Since these energy losses, caused by friction, occur at bends, constrictions and pipeline fittings, then the number of such bends, constrictions and pipeline fittings must be reduced as far as possible.

Industry aims at balancing the **fixed charges** for a pipeline (i.e. the cost of materials and fitting) and the **operating costs** of the pipeline (which will be concerned with the power used in operating the line).

From the point of view of fixed costs a small diameter pipeline will be cheaper, but due to energy losses, the operating costs will be higher. With a large diameter pipe, the reverse is true: fixed costs will be higher, but since frictional losses are smaller, the operating costs will be reduced.

So **correct sizing** of the pipeline is of great importance. Pipe sizing is a complex subject, using highly mathematical methods involving optimum design techniques, but in general, the results are what you would expect from your knowledge of pipelines and what has been said above. Operating costs, as you have seen are directly related to:

(1) The length and diameter of pipe.

(2) To the number of pipeline fittings used, and

(3) The power used to move the pipeline fluid.

Space considerations are important in design. Ample space allows for free straight runs with minimum number of bends. Again, if space is readily available for straight runs of pipe then it is often easier to arrange for cheaper and fewer support and anchorage systems.

Pipeline should be designed so that it can be easily modified, both to deal with increased capacity of plant as production demands increase, and to match improved technology.

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## ACTIVITY 9

For this Activity, we would like you to put yourself in the position of plant inspector! We would like you to inspect ONE area of pipeline to check on efficiency, maintenance, status, safety, etc. Use the guidelines below to help you with this. (You will need to use the blank pages at the end of your workbook.) Once you have compiled your notes, we would like you to write a summary of no more than one page in length on what you have found, under the following 'headings'.

(1) Is the maximum possible amount of straight piping used in the space available? If not, say where there is room for improvement.

(2) Are there any unnecessary gradients in the pipeline? If so, say where.

(3) Are there pipelines where a gradient should exist but doesn't? If so, say where.

(4) Make a list of the kinds of supports and anchors used at bends and on straight runs. In your opinion, are these adequate? If not, say why not.

(5) List the types of joints used. What relationship is there between the joints and the pressure and temperature of the pipe fluid?

(6) List all the ways in which expansion and contraction in the pipelines is compensated or allowed for.

Discuss your comments with your trainer.

---

# SUMMARY

Now you have finished the work in this Section you should be able to:

(1) Make the correct choice of pipe material

(2) Describe how to lay pipes and the various methods used to join pipes

(3) State why adequate support is important

(4) List the main factors affecting pipeline design

## SECTION 5

# WORKING SAFELY ON PIPELINES

Time: 1 hour

Your learning goals for this Section are:

(1) To know how to identify pipeline contents

(2) To know the correct shutdown procedures

(3) To know how to remove pipeline sections

(4) To know how to inspect and replace or renew a pipeline section

(5) To know how to join and seal pipeline sections

## STUDY SESSION 5.1

# HOW TO IDENTIFY THE PIPELINE

The first step when repairing and maintaining a section of pipeline is to identify the **contents and direction of flow** in the pipeline concerned.

You can identify the contents of the pipe by using pipe identification codes and labels, and find out direction of flow using plant layout diagrams, plant functional flow diagrams and by speaking to those who know!

Your trainer may be able to show you examples of these diagrams.

British Standards BS1710 specifies a pipeline contents identification code, based on the use of colours. Also specified are the contrasting colours to be used for letters and figures used to label the pipes.

Table 2 gives these identification colours for your guidance.

**Table 2 Pipeline Contents Identification Colours**

| Pipeline contents | Basic identification colour | Contrasting colour used for letters and figures |
|---|---|---|
| Water | Green | White |
| Steam | Silver/grey | Black |
| Vegetable oil | Brown | Black |
| Animal oil | Brown | Black |
| Gases | Yellow ochre | Black |
| Acid Substances | Violet | Black |
| Alkaline substances | Violet | White |
| Air | Light blue | Black |
| Vacuum | Light blue | Black |
| Other fluid | Black | White |
| Dangerous fluids | Yellow with black diagonal stripes | |

In addition to the above basic colours, pipe contents may be coded using colour bands of the basic colours.

Table 3 gives the colour bands specified for pipeline contents.

**Table 3 Pipeline Contents Colour Bands**

| Pipeline contents | Colour band | Basic colour of pipe |
|---|---|---|
| Cooling water | White | Green |
| Boiler feed water | Crimson/white/crimson | Green |
| Condensate | Crimson/emerald green/crimson | Green |
| Fire extinguishing water | Red | Green |
| Ammonia gas | Diagonal yellow | Yellow ochre |
| Ammonia liquid | Black/crimson/black | Yellow ochre |
| R12 refrigerant | White | Yellow ochre |
| R22 refrigerant | Emerald green | Yellow ochre |
| R502 refrigerant | Brown | Yellow ochre |
| Natural gas | Yellow | Yellow ochre |

Certain colours are associated with safety aspects. Examples are:

(1) **Yellow** with **black diagonal stripes** to indicate dangerous fluids.

(2) Fresh water, suitable for drinking and food processes, is characterized by the familiar **green** for water, but associated with auxiliary **blue**.

(3) Electrical conduits and ducts, which could be mistaken for fluid carrying pipes, are coloured **orange**.

## SAQ 22

A firm uses an identification code for pipes based on the specification of British Standards BS1710. Fig.42 shows the colours used by this firm in the pipe identification code.

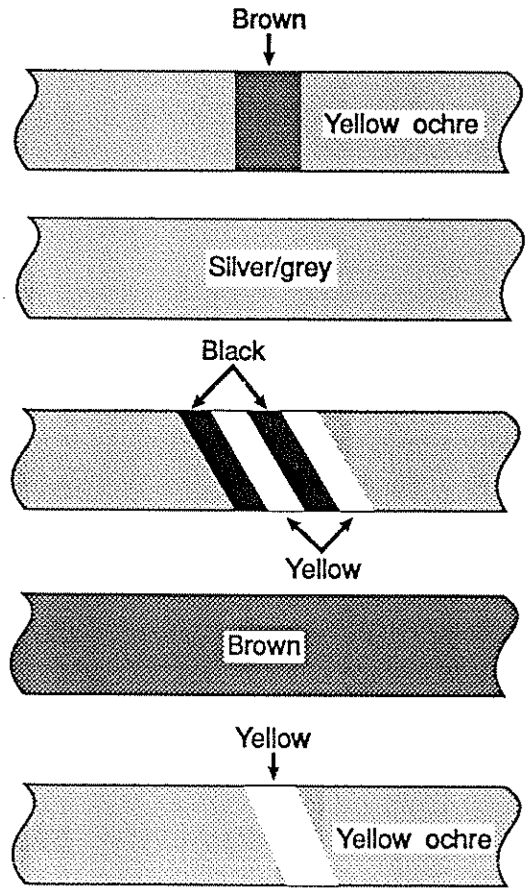



*Fig.42*

Write down the contents of each pipe below.

Check your answer with ours at the end of the module before continuing.

## ACTIVITY 10

You will need to go out into the plant to carry out this Activity.

Activity 10 concentrates on your ability to identify the contents of each pipeline, either for maintenance/repair purposes, or for dealing with emergencies. We would like you to:

(1) Check whether the colour coding used in the plant is the same as that specified by BS1710. If it isn't, don't worry. Many manufacturers use their own colour **names** which may differ slightly from BS1710, although in general they will bear a close resemblance to it. Draw up your own table of the pipe colour code used in your plant on the blank pages at the end of the workbook.

(2) As a self-check, see how you score on the following questions:

(a) Can you easily distinguish electrical conduits and ducts from the fluid carrying pipes?
(b) Would you be confident that you could identify the contents of the pipelines using the pipe identification code of your plan?
(c) Can you point out quickly the pipes which are carrying fluids which may be hazardous in nature?

If you cannot answer 'yes' to all these questions now, your task is to ensure that you **can** do so within a specified timescale. Set this yourself by developing your own action plan, saying what you will do and when you will do it.

Discuss your answers with your trainer.

# STUDY SESSION 5.2

# SHUTDOWN PROCEDURES AND SAFE REMOVAL OF PIPELINE SECTIONS

## 1 SHUTDOWN PROCEDURES ON PIPELINE

In the event of pipeline damage or incorrect functioning when it becomes absolutely necessary to carry our repair and maintenance work on a section of pipeline, the following general procedures should be observed.

- Identify the contents and direction of flow in the pipeline.
- Locate all stop valves.
- Close and lock off stop valves.
- Hang warning notices on shut off stop valves.
- If necessary or appropriate, inserts spades or blanks in pipeline.
- Make sure that any pumps or compressors feeding the pipeline are electrically isolated by putting the local isolator in the off position and locking by padlock.
- Ensure that all steps have been taken to relieve any pressure in the pipeline and drain pipeline.

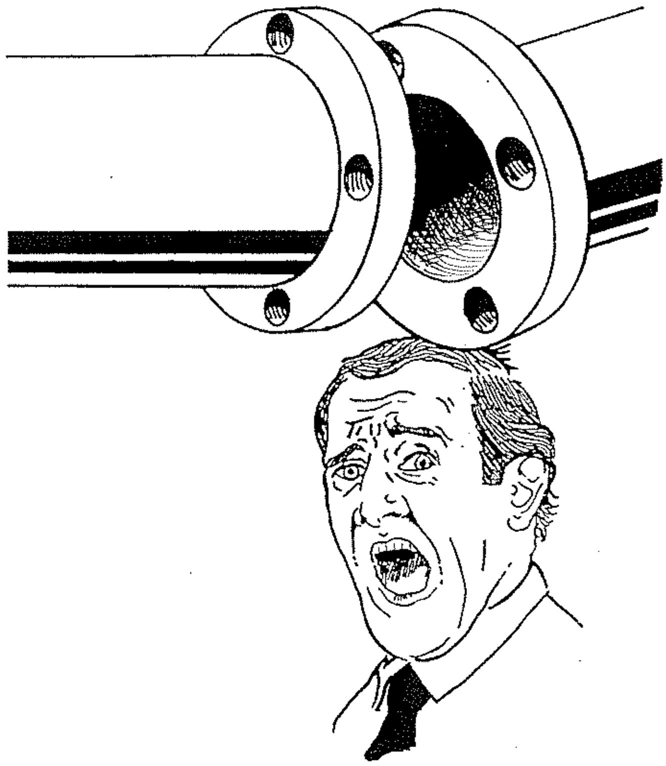
# 2 SAFE REMOVAL OF PIPELINE SECTIONS

Once the pipeline under inspection and repair or maintenance has been SAFELY isolated, it may be approached so that dismantling and removal of pipeline section can be carried out.

Protective clothing should be worn and goggles and eyewash equipment should be on hand.

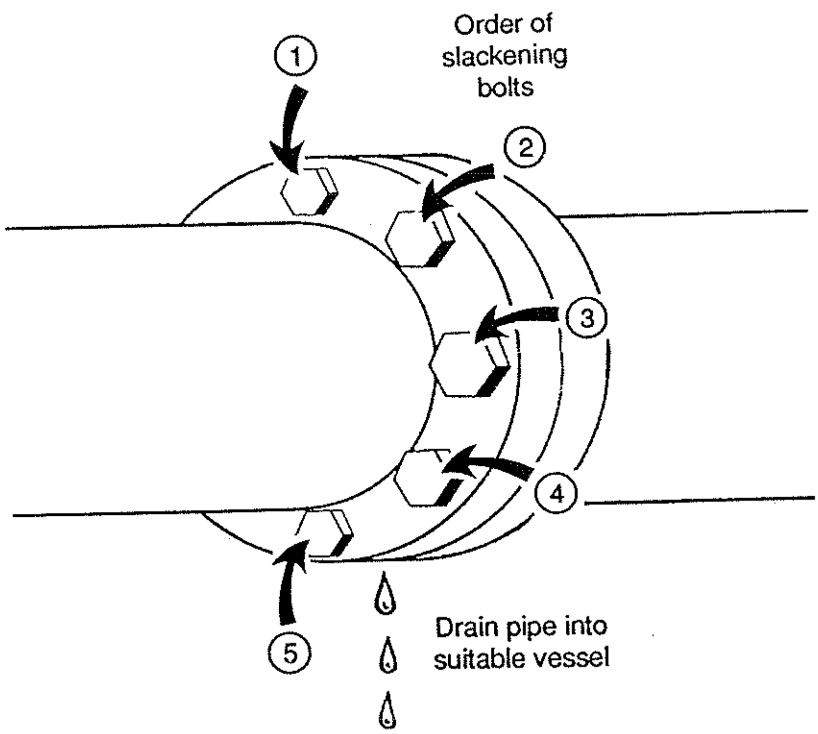
Where possible work should be carried out on the pipe from above.

When breaking a joint make sure the pipeline is adequately supported, by checking position and type of pipe supports before slackening any bolts.



NEVER REMOVE ALL NUTS AND BOLTS BEFORE PARTING A FLANGE.
The golden rule is work with caution:

- Always assume the pipeline is full!
- Slacken bolt furthest from you first!
- Last bolt should not be slackened till a wedge has been used to open joint and the line has been completely drained.




When a joint has finally been broken, allow the pipeline to drain into a suitable container. Never allow spillage onto the floor as this will make a slippery, dangerous walking surface.

If the line is blocked and steam or air under pressure is needed to remove the blockage, use hessian sacking or some other safe deflector placed over the open end of the joint.

When breaking a joint ALWAYS BE ON YOUR GUARD FOR SUDDEN SPRINGING OF THE JOINT.

**SAQ 23**

List the safety precautions you should take when breaking a joint in a pipeline.

Check your answer with ours at the end of the unit before continuing.

## STUDY SESSION 5.3

# PROCEDURES FOR INSPECTION AND REPLACING OR RENEWAL OF PIPELINE SECTION

Once the faulty pipeline section has been broken and removed, you should inspect both the removed section and the adjacent sections of pipeline. If the removed section of pipeline is cracked or damaged, or if heavily corroded, it must be replaced. This is particularly true of plastic pipe which can become cracked and brittle with age.

If the pipe has integral flanges which are distorted or physically deformed in a way that renders leak-free recoupling impossible or doubtful, then the pipe section must be replaced.

In some cases the pipe section may have become blocked with sediment or liquid which has solidified. Here, the pipe section can be thoroughly unblocked and cleaned and, if there is no other damage, replaced in the line.

In all circumstances, pipe section, joints must remade.

## STUDY SESSION 5.4

# JOINING AND SEALING PIPELINE SECTIONS

Remaking of joints is the exact opposite of breaking the joints and the same safety factors must be observed. In addition, however:

- The joint faces must be cleaned thoroughly, otherwise leakage will occur.
- Flange bolts should be smeared liberally with grease or thread dope to make them easy to remove at a later stage.
- The correct gasket or sealing material must be employed when making the joint.
- When remaking a sealed joint using a flange and gasket, you should make sure that the correct selection of gasket is made for a particular application. This can be done by reference to manufacturers' technical date or a table of gasket materials found in British Standards BS5500.
- You must make sure that the minimum stress is applied to the gasket so causing the material to flow and fill the surface irregularities of the gasket. In this way, effective sealing is guaranteed.

When the repaired or replaced pipe section is in operation, the internal pressure in the pipe will tend to force the flanges apart. This means that the operating pressure on the gasket is actually less than tightening up pressure when making the joint.

Wherever possible, flange protection should be ensured by using flange shields which afford protection to both plant and personnel:

(1) A band flange is a rubber strip fitted around the full width of the flange and secured by means of band-it and securing buckles.

(2) Flange aluminium shields, are specially used on steam lines and on all pipes carrying fluids containing enzymes or biological material. These shields are made of aluminium and are secured by self-locking buckles. They are filled with insulating material.

Piping that is joined by thread is never sealed by the threads, but by fittings such as O-rings (Fig.43).

O-rings are used in grooves where they are compressed between two surfaces. Make sure that the correct material is chosen for the ring and so avoid possible corrosion.

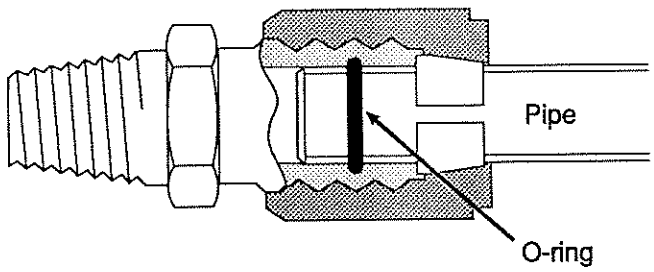



*Fig.43 O-ring*

A flare fitting can be made as shown in Fig.44. As the compression nut is tightened, the flared ends of the tube or pipe squeeze against the seal material. A sleeve extension of the nut supports the pipe and damps any vibration.

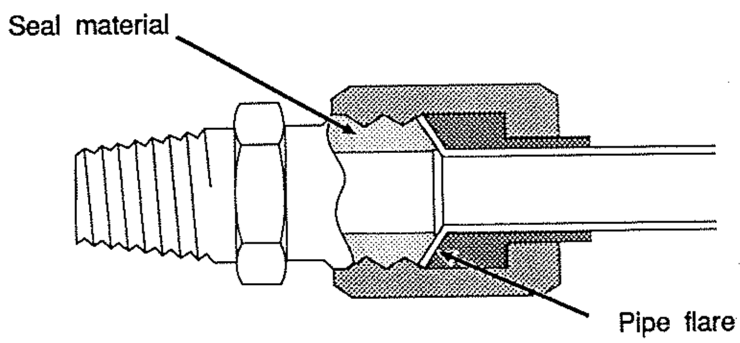



*Fig.44 Flare Fitting*

A ferrule compression fitting is shown in Fig.45.

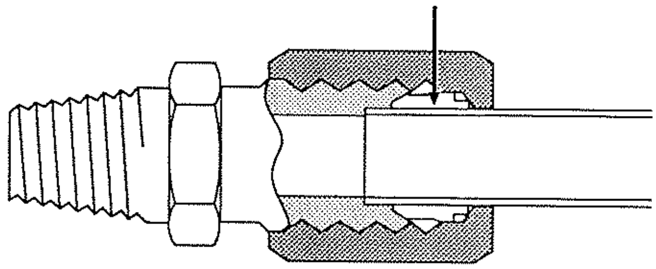



*Fig.45 Ferrule Compression Fitting*

Questions to ask yourself when rejoining or making a pipe joint are:

(1) Will the seal or sealing material be resistant to attack by the pipe fluid?

(2) Is the seal or sealing material able to withstand the temperature and pressure of the pipe fluid?

(3) Will the seal or sealing material wear out too quickly?

If in doubt, follow the manufacturers' instructions and recommendations.

If a bonding material is used for repairing plastic pipe, the correct adhesive should be used for the particular plastic of which the pipe is made, and correct hardening times must be allowed before any valves are opened to return the pipe to use.

Once the joint has been made, a thorough visual inspection should be made and a pressure test carried out on the pipeline section as early as possible. This can be done by filling with water to one and a half times the working pressure. No leakage should be detected.

## ACTIVITY 11

For this Activity you will need manufacturers' details about supplied pipe sections and their associated joints. See your manager or trainer if you have problems finding these. Then carry out the following activities (use the blank pages at the end of this workbook).

(1) Using the manufacturers' data, draw up a table to show the methods for sealing different kinds of joints (i.e. pipe flanged joints, screwed joints and welded joints). Include in the table details of the materials used for each, and any specified operating temperatures and pressures.

(2) Using the information presented in your table, we would like you to comment on any relationships which you have found between the type of joint and method of sealing, and the type of fluid being carried in the pipeline.

(3) If you have not already had the experience of being present at a maintenance overhaul of a pipeline section, make sure that you do so as soon as possible. Bearing in mind what you learned in the last study session, notice especially:

  (a) What safety procedures are adopted at each stage in the maintenance process.

  (b) What methods of joining and sealing are used.

We would like you to record your observations and comments on a separate sheet of paper as you go along and to show these to your trainer during the next training day.

Discuss your answers with your trainer.

# SUMMARY

Now you have finished the work in this Section you should be able to:

(1) Identify pipeline contents from the colour codes used

(2) List the procedures to follow when shutting down pipelines

(3) Remove pipeline sections safely

(4) State how to inspect and replace or renew a pipeline section

(5) Join and seal pipeline sections

## SECTION 6

# TROUBLESHOOTING

Time: 1 hour

Your learning goals for this Section are:

(1) To know the difference between a symptom and a fault

(2) To know how to use your senses and instruments to detect symptoms

(3) To know how to relate symptoms to faults

(4) To know how to find a fault

# STUDY SESSION 6.1

# WHAT IS A SYMPTOM? WHAT IS A FAULT?

A pain in your stomach is a sign or **symptom** that all is not well in your stomach! The pain may be caused by simple indigestion, an infection, such as gastritis, or by your having eaten something which is poisonous or infected.

The indigestion, gastritis, poisoning or infection cause your stomach to behave in a way which is not normal. Your stomach behaving in a faulty way is the symptom, and the indigestion, gastritis, poisoning or infection are **causes** or **faults** which give rise to the symptom of pain.

In the same way, if something goes wrong in the plant then normal plant processes will be disrupted. These disruptions will show up as changes in the normal operating conditions of the plant and will be seen as, most commonly, changes in the normal recorded temperatures, pressure, rates of flow etc. of the plant.

A **FAULT** PRODUCES A **SYMPTOM** THAT ALL IS NOT WELL

Note this very important distinction. Too often, people regard a symptom as the fault itself.

This is summarized in Fig.46.

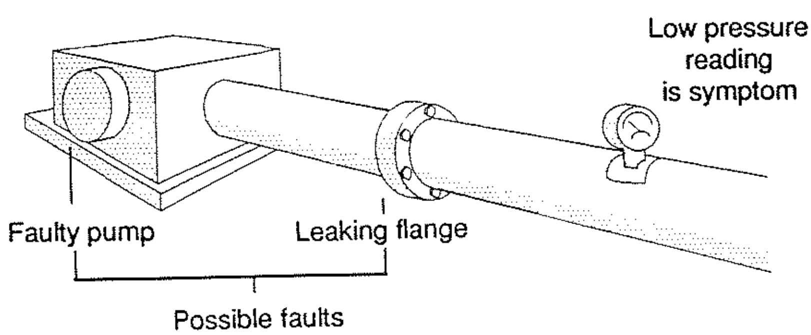



*Fig.46 A Symptom and Possible Faults in a Pipeline*

## STUDY SESSION 6.2

# USING THE SENSES TO DETECT SYMPTOMS

Although there are many recording instruments of great technical complexity in the plant, quite often symptoms can be detected and recognized using your senses of smell, touch, sight, hearing and (possibly unwisely!) taste.

Suggestions for using your senses are shown on the following page. Look at this before completing SAQ 24.

---

✓ **SAQ 24**

We have mentioned using all 5 senses for detecting symptoms. But there are safety implications. Suggest some sensible safety precautions below. (We have done the first one to start you off.)

| Sense | Precaution |
|---|---|
| Touch | Avoid hot areas, faulty electrical fittings, etc. |
| Smell | |
| Sight | |
| Hearing | |
| Taste | |

Check your answers with ours at the end of the unit..

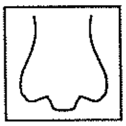
---

### HEARING

| | |
|---|---|
| **Chattering..** | Valve trouble in pipeline. |
| **Banging..** | Water hammer/ faulty pump. |
| **Dripping or trickling..** | Pipe leakage. |
| **Hissing..** | Steam or air leak. |
| **Crackling..** | Electrical fault. |

### SIGHT

| | |
|---|---|
| **Movement..** | Incorrect anchorage or support of pipe (due to turbulent flow in pipe or water hammer, faulty pump). |
| **Surface glistening..** | Pipe leakage. |
| **Smoke/Flame..** | Electrical fault in cables/ motors. |



### SMELL

| | |
|---|---|
| **Too hot metal..** | Temperature of pipe fluid too high. |
| **Chemicals..** | Leakage in pipe. |
| **Burning..** | Overheating of electric motor on pump. |

### TOUCH

| | |
|---|---|
| **Too hot..** | Pipe fluid too hot. |
| **Too cold..** | Pipe fluid too cool. |
| **Too much vibration..** | Water hammer/ turbulent flow/ faulty pump in pipe. |
| **Oily/Wet..** | Leakage in pipe. |

## STUDY SESSION 6.3

# USING INSTRUMENTS TO DETECT SYMPTOMS

As you've seen, the natural senses can help a great deal in the spotting of symptoms of things having gone wrong in the plant, but even more accurate determination and diagnosis of symptoms can be obtained by noting the readings on the instruments which are used to monitor the plant variables such as pressure, temperature, rate of flow, etc. When using instruments to take accurate records of the plant's performance, you have to bear in mind two major points.

These points are:

(1) When recording pressures, you must remember that pressure variations are inevitable in a working pipeline, due to pressure surges caused by back pressure effects from pumps and compressors. Most pressure gauges should be regarded as giving a reliable reading of the average pressure of the pipeline system and you should be looking for marked changes in this average pressure which will indicate a potential or actual fault.

(2) If you are going to use instruments with any degree of accuracy to help you monitor the plant, you should make sure that these instruments are checked regularly and even recalibrated where necessary. For gauges in good condition, you can assume a degree of accuracy of ± 5% for the less expensive instruments used in pipeline. Instruments which are not periodically checked can develop errors way outside the range of accuracy just mentioned, and so give a false indication of a fault.

What you will be looking for in your instrument readings will be either:

TOO HIGH or TOO LOW READINGS FOR:

(1) PRESSURE

(2) TEMPERATURE

(3) RATE OF FLOW.

Let's move on to what you hope to diagnose from this type of reading.

## STUDY SESSION 6.4

# WHAT SYMPTOMS INDICATE WHAT FAULT?

The identification of a symptom and then tracing it back to a fault is called fault diagnosis.

Fault diagnosis is a skill which demands a great working knowledge of the pipeline circuit and its components. The observed symptom may point to an obvious fault, but more often, the symptom or symptoms may indicate many possible faults and then the fault diagnosis becomes a job demanding careful analysis and study of the whole pipe system, so that the main fault can be isolated from a confusion of possible secondary effects.

First of all, however, you must be able to recognize symptoms and let these suggest to you possible faults. This is the first step in fault diagnosis.

---

✓ **SAQ 25**

As a taster, let's ask you a question.

Suppose the pressure gauge in a pipeline is consistently reading a low pressure. Can you suggest which of the following faults could give rise to this symptom? (*Tick the correct answer/s.*)

(1) A faulty pressure gauge ☐

(2) Blocked line upstream of gauge ☐

(3) Blocked line downstream of gauge ☐

(4) Faulty pump ☐

(5) Leakage from the pipeline ☐

Check your answer with ours at the end of the unit.

---

For your convenience, Table 4 summarizes (very simply) the symptoms you may encounter and the possible faults which produce those symptoms.

**Table 4 Faults and Symptoms**

| Symptom | Possible fault(s) |
|---|---|
| Loss of pressure in pipeline | Leakage in pipe<br>Pump failure<br>Failure of relief valve to reseat |
| Loss of pressure in pipeline plus delay in actuation of control valves | As above plus<br>Badly adjusted or faulty relief valve<br>Damaged or worn valve actuator |
| Pipeline pressure high | Partial blockage of pipe<br>Failure of relief valve<br>Failure of control valve or its actuator<br>Faulty pump or pump setting |
| Variable pipeline pressure | Faulty pump failing to produce maximum demand<br>Intermittent fault signals to valve actuator<br>Sticking valve |
| Normal pipeline pressure BUT loss of actuation in control valve | Control valve not receiving signal<br>Control valve actuator failure<br>Mechanical obstruction in control valve |
| Normal pipeline pressure BUT delay in actuation of control valve | Faulty relief valve<br>Partially blocked control valve<br>Worn or damaged actuator |
| Too high a temperature in pipeline | Thermostats of temperature control system not working or set incorrectly.<br>Damage, kinks or blockages in pipe, causing energy losses through friction<br>Insufficient normal cooling of pipe<br>Faulty pump becoming overheated and transferring heat to fluid in pipe<br>Excessive rate of flow, giving rise to high friction losses. |

Too high and too low rates in the pipeline may often be registered in terms of the pressure in the pipeline. Possible faults may lie with the pump, control valves and their actuators and possible partial blockage of the pipe.

✓ **SAQ 26**

A pipeline registers too low a pressure. A plant engineer diagnoses a leak at a joint. Which of the following might have caused it? (*Tick the correct answer/s.*)

(1) Gasket worn ☐

(2) Using a water hammer ☐

(3) Thermal expansion ☐

(4) Excess pressure ☐

Check your answer with ours at the end of the unit before continuing.

## STUDY SESSION 6.5

# SIMPLE FAULT FINDING TECHNIQUES

Actually, the above title is misleading! Fault-finding is the process by which, after studying the symptoms and deciding on the possible faults, a search is made to discover the actual fault.

This **fault-finding search** is far from simple, but in the hands of a skilled engineer it may appear so.

A fault-finding search has one major aim: to find the fault as quickly and efficiently as possible, so it can be corrected or remedied, and downtime cut to a minimum.

To do this, the fault-finding technician or engineer must organize a logical and systematic search.

The search is usually organized to make use of all data relating to the plant or pipeline, including circuit diagrams, functional block or functional phase diagrams (diagrams based on the sequence of functions or operations of the plant, rather than the physical layout of the plant components), manufacturers' manuals and actual reports of the symptoms shown.

If you are not familiar with this kind of data, ask your manager or your trainer to show you examples.

The progress of the search is shown in the diagram in Fig.47.

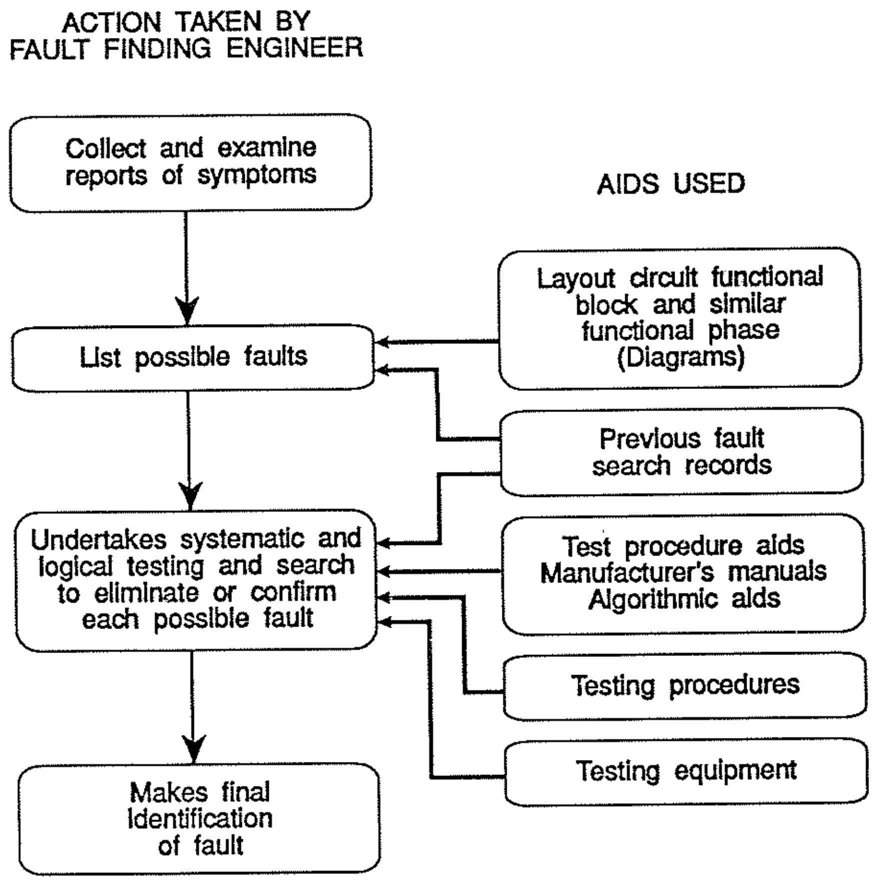



*Fig.47 Fault Finding Search*

The search for the fault involves the fault-finding technician or engineer using his own knowledge of the plant or pipeline, together with the available aids, to develop a strategy of testing which will identify the fault as quickly as possible. He will then test the operation or parts of the system using test equipment, particularly testing signals between control systems and control components.

## SAQ 27

Let's see if you can develop your own search strategy.

(1) The pressure in a pipeline is too high. Which of the following faults may apply? (*Tick the correct answer.*)

(a) Blocked line downstream of the point. ☐

(b) Blocked line upstream of the point. ☐

(c) Faulty relief valve on positive displacement pump. ☐

(d) Valve closed when it should be open. ☐

(e) Valve open when it should be closed. ☐

(2) The pipeline is a long one and has to be tested for pressure at sectional points along the pipe.

A diagram of the pipe is shown below. Each circle represents a sectional point along the pipe.

The pipe flow direction is indicated by the arrow.

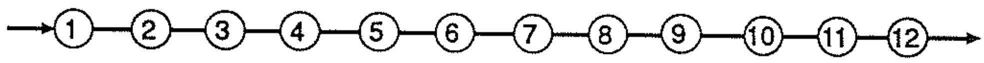



*Fig.48*

(a) How many tests would you have to make if you tested the pressure at each of the entries and exits to the pipeline points shown?

(b) How can you cut down this number of pressure tests?

(3) Now show the method by which you can pinpoint the location of the fault exactly by carrying out the minimum number of pressure tests.

Check your answer with ours at the end of the unit before continuing.

In SAQ 27 the search strategy was an extremely simple, but effective one. It can be used on more complex pipelines with multiple branching. The strategy is called the **half split** method, for obvious reasons.

There are many other search strategies and many other fault-finding aids. You can obtain more information on fault-finding techniques by reference to material in your own plant and by looking at copies of 'Institute of Plant Engineers Journal.'

## STUDY SESSION 6.6

# REMEDIAL ACTION

This is the action taken once the fault in the plant or pipeline has been located. It involves repair or replacement of faulty components giving rise to the fault. The pipeline or any other system is then activated and operated to test that the fault has actually been cleared.

You should remember that when undertaking a fault diagnosis and fault search, ALL SAFETY PRECAUTIONS RELATING TO SHUT DOWN OR ISOLATION OF ANY PIPELINE SECTION MUST BE STRICTLY OBSERVED.

During remedial action ALL SAFE WORKING PROCEDURES MUST BE OBSERVED.

Testing for clearance of the fault means OBSERVING ALL SAFETY PRECAUTIONS RELATING TO RECONNECTION, START UP AND REACTIVATION OF PIPELINE OR PLANT.

## ACTIVITY 12

For this Activity, you will need access to block diagrams used to show:

(1) Physical location of pipelines and fittings.

(2) Functional flow and operating sequences.

You may have access to a number of different types of chart. These might include:

- Flow charts showing operational sequences and diagnosis.
- Algorithms showing methods for tracing faults.
- Maintenance dependency charts showing the interdependency of all the operating elements in a pipeline or other plant system.
- Symptom charts.
- Procedures cards.

You need to make sure that you are familiar with the different charts and diagrams available to you, and to be aware of what information they can give you.

Make a note of the charts which you have studied, with a short comment noting how useful you think each is for tracing faults. You will discuss this during your next training day.

Discuss your answers with your trainer.

## SUMMARY

Now you have finished the work in this Section you should be able to:

(1) State that a symptom is a sign that there is a fault in the pipeline

(2) Use your senses and instruments to detect symptoms

(3) Relate symptoms to the faults that produce them

(4) Describe a simple fault finding procedure

# ANSWERS TO SELF ASSESSMENT QUESTIONS

SAQA 1 Any liquid or gas is a fluid. So your answer should include air, water and steam. The others are solids, although all of them can be liquified given the right conditions, e.g. molten iron.

SAQA 2 (1)

SAQA 3 With difficulty, plastic, heated, lagged

SAQA 4 Yes

SAQA 5
(1) False
(2) True

SAQA 6 (2)

SAQA 7 (2)

SAQA 8

(1) The pressure exerted by 15 m of oil:

$= \text{Height (depth)} \times \text{density} \times 9.81$
$= 15 \times 813 \times 9.81$
$= 119633 \text{ newtons/m}^2$

Pressure reading of gauge at bottom of tank:

$= \text{Atmospheric pressure} + \text{pressure exerted by liquid}$
$= 101300 + 119633$
$= 220933 \text{ newtons/m}^2$ (221,000 newtons/$m^2$)

(2) Pressure exerted by 3 m of oil:

$= 3 \times 813 \times 9.81$
$= 23927 \text{ N/m}^2$

Reading of lower gauge:

$= 101300 + 23927$
$= 125227 \text{ N/m}^2$

(3) (a)

$$\text{Atmospheric pressure} = 101300 \text{ N/m}^2 = 14 \text{ p.s.i}$$

$$\text{So } 1 \text{ N/m}^2 = \frac{14}{101300} \text{ p.s.i}$$

$$\text{So } 220933 \text{ N/m}^2 = \frac{14}{101300} \times 220933 = 30.5 \text{ p.s.i}$$

$$\text{Similarly } 125227 \text{ N/m}^2 = \frac{14}{101300} \times 125227 = 17.31 \text{ p.s.i}$$

(b)

$$100000 \text{ N/m}^2 = 1 \text{ bar}$$

$$\text{So } 1 \text{ N/m}^2 = \frac{1}{100000} \text{ bar}$$

$$\therefore 220933 \text{ N/m}^2 = 2209333 \times \frac{1}{100000} = 2.209 \text{ bar}$$

$$\text{Similarly } 125227 \text{ N/m}^2 = 125227 \times \frac{1}{100000} = 1.25 \text{ bar}$$

**SAQA 9** Fluid flow, pressure

**SAQA 10** (2)

**SAQA 11** Decreases (or lessens), greater (or more), less, easily

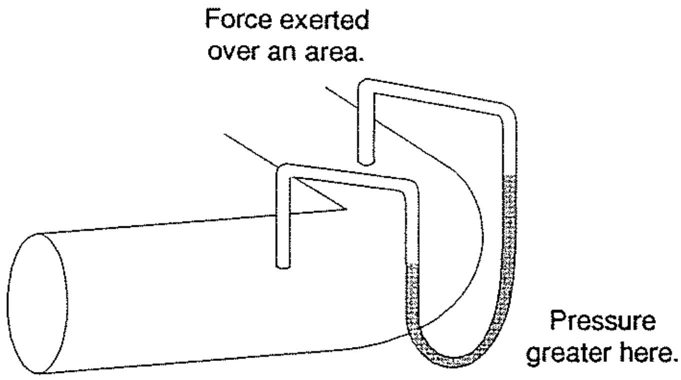
**SAQA 12** Valves, lost, fall

**SAQA 13** (1) and (3)

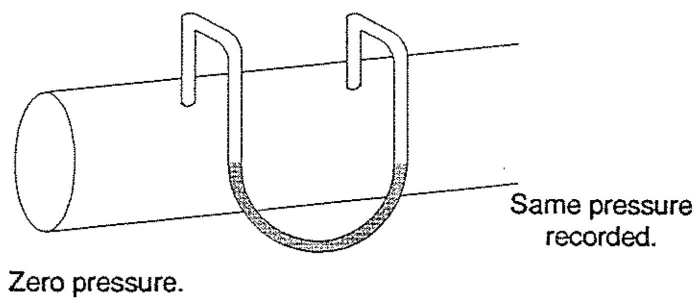
**SAQA 14** The two units are newtons per metre squared ($N/m^2$) and pascals (Pa).

**SAQA 15** (1)

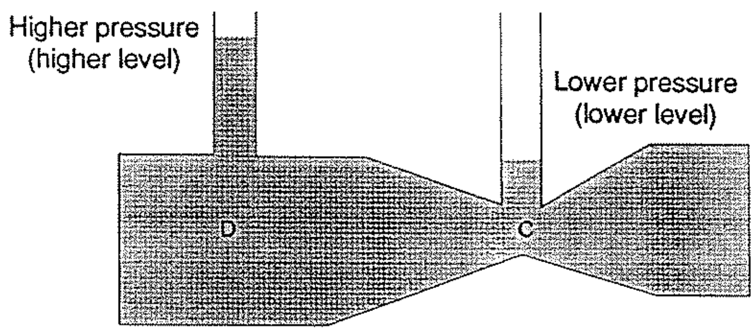
**SAQA 16** (1)




(2)



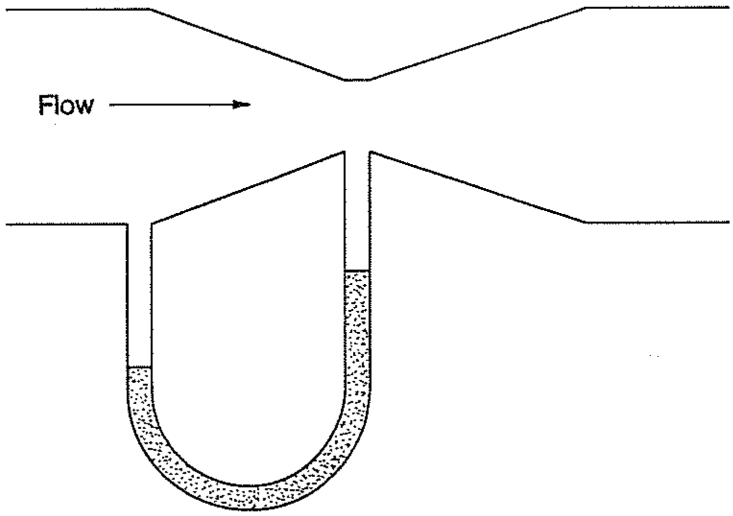

**SAQA 17** (1)




Fluid is moving faster at C.

(2) Fluid is moving faster at C

(3)




**SAQA 18**

| | | | |
|---|---|---|---|
| Gate | Ball | Globe | Diaphragm |
| Plug | Butterfly | Needle | Check |

**SAQA 19**

| | Light | Corrosive resistant | Strong | Easily cleaned |
|---|---|---|---|---|
| Stainless steel | ✓ | ✓ | ✓ | ✓ |
| Aluminium | ✓ | | ✓ | ✓ |
| Cast Iron | | | ✓ | |
| Copper/Brass | | ✓ | ✓ | ✓ |
| Plastic | ✓ | ✓ | | |

**SAQA 20** (1), (2) and (3)!

**SAQA 21**

| Type of joint | Suitability |
|---|---|
| Corrugated expansion joints<br>Loop expansion joints<br>Flexible tube joints<br>Slip type joints<br>Bellow joints | To compensate for expansion in high pressure high temperature steam pipes |
| Screwed connections<br>Brazed or soldered joints | Suitable for low pressure oil flow |
| Welded joints | Suitable for high pressure high temperature steam |
| Flanged joints<br>Compression fittings | Suitable for high pressure gas flow |

**SAQA 22** R502 refrigerant, steam, gases
Vegetable oil, ammonia

**SAQA 23** Wear protective clothing and goggles
Check pipe is adequately supported before breaking a joint
Remove bolts from flange in correct sequence
Use deflectors when removing blockage from line
Never work from underneath a joint
Close and lock off stop valves
Hang warning notices on locked valves
Insert spades or blanks in line if needed
Isolate pumps or compressors electrically and lock off
Relieve pressure in pipeline
Drain pipeline
Tidy work is clearing up as you go and is a must because tools and pipe sections lying about can cause tripping and injury

**SAQA 24** When using the senses avoid too close a contact with dodgy plant and fittings!

| | |
|---|---|
| **Touch** | Do not touch moving machinery or electrical circuits or components. Moving parts may trap your hair or clothing |
| **Smell** | Detection of symptoms by smell is not so good if ammonia or some refrigerants are involved! Similarly with smoke. One sniff is enough! |
| **Sight** | Don't peer too closely at faulty items. A sudden leak might squirt hot or dangerous liquids into your eyes. |
| **Hearing** | Similarly, don't bend your ear to close to faulty items. Avoid over-exposure to loud noise. |
| **Taste** | 'Tasting for leaks' in plant is most unwise for obvious reasons. |

**SAQA 25** All of these can give a low pressure reading. The important thing is to find out which!

**SAQA 26** Again, all of these can cause a leaking joint.

**SAQA 27** (1) The answer is (a), (c) and (d)

(2)(a) 13 tests

(b) Pressure test between each section acts as pressure test at exit of one and entrance of other:

= 11 tests

Plus entry at 1 and exit at 12:

= 2 tests

Total tests = 11 + 2 = 13

(3) Test between 6 and 7. If pressure normal, fault is beyond 7.
Test between 9 and 10. If pressure normal, fault is between 10 and 12 or 11 and 12
If pressure is high, fault is between 1 and 6
Test between 3 and 4. If pressure normal, fault is between 4 and 5 or 5 and 6. This is a maximum of 7 tests.