INDUSTRIAL PROCESS MEASUREMENT – Industrial Transducer Systems.

The aim of this unit is to introduce the learner to principles and techniques related to the Performance, Operation and Application of a range of Industrial Transducer Systems.

2 APPLICATION, SELECTION AND OPERATION OF TRANSDUCER TYPES.

Pressure *– diaphragm capsule, bellows, bourdon tube, piezo-electric, manometers;*

What is pressure?

Pressure can be generated naturally, and it can be generated artificially. A natural example of pressure, for example is the atmospheric pressure, which is all around us. On the other hand pressure may be generated, ie, by the use of pumps or compressors.

One way of defining pressure, is the force acting on a specified area, such that:

Pressure equals:

Force per unit area, *or* $\frac{\text{Pressure (or Force)}}{\text{Area}}$ *or* $P = \frac{F}{A}$

The Common units of pressure based on this are:

- Lbs/sq. inch (or P.S.I.)
- Bars (1000 mB = 1 Bar)
- Pascals

Alternatively, Pressure may be derived from liquid in a confined space (process vessels), such that:

Pressure = Density x Gravity x Height (ρgh)

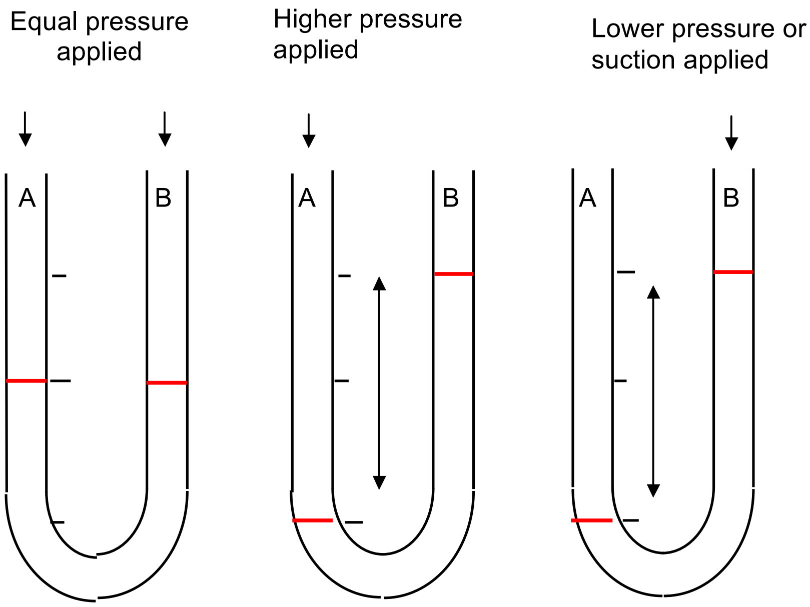
Or in Practice, Pressure = Height x Density

Common units:

- Inches (or mm) of water ('' or mm wg)
- Inches (or mm) of mercury ('' or mm Hg)

Manometers.

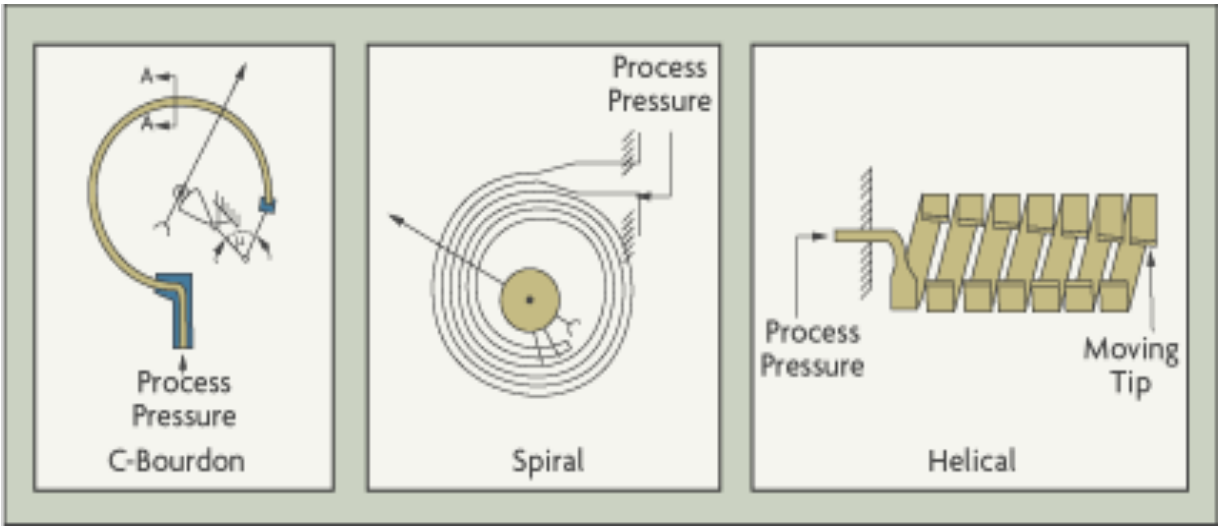
Probably the earliest form of device used to measure pressure would be the u-tube manometer, which is simply a glass or plastic tube formed into a U shape, and then part filled with liquid, with the same pressure applied to both sides the liquid level will balance (i.e.: atmospheric pressure). When a higher pressure is applied to one of the sides the liquid is forced downward pushing up on the other side, the difference in the two levels is an indication of the applied pressure again applying the formula $P = \rho gh$. As shown in the next diagram:-



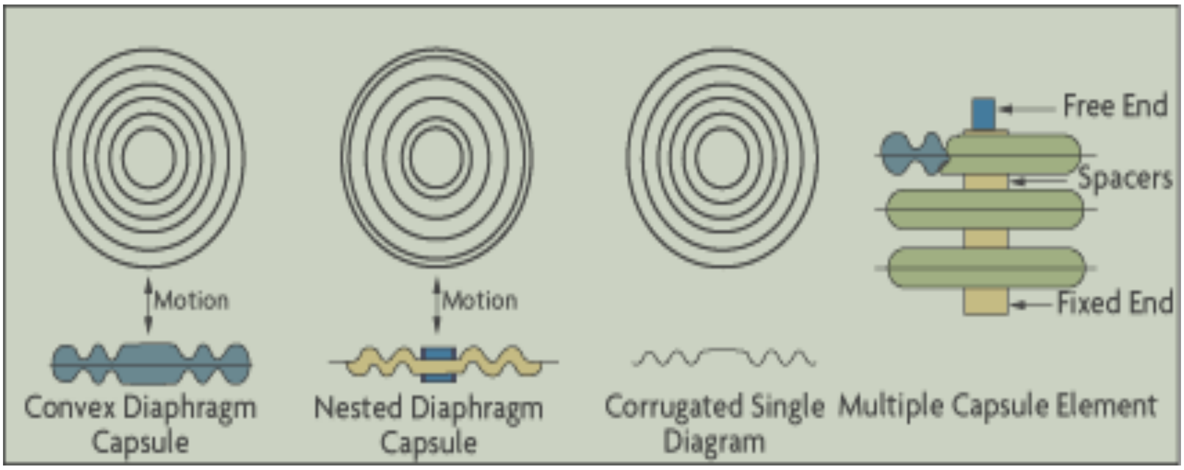
The use of manometers today is limited due to, several limitations, firstly the materials they are made from, second they are restricted to low pressures and third hazardous substances and temperatures would be unsuitable. The normal liquid inside is water, however mercury is used for higher pressures (being 13.6 times more dense than water and thus requiring 13.6 times more pressure to get the same amount of movement), although care must be taken due to the toxic nature of mercury vapour. Because these devices follow the formula $p = \rho gh$, the height is always vertical height and so to get a greater degree of accuracy the limb can be inclined. This elongates the scale, providing a greater degree of accuracy, but significantly increases its length.

Pressure sensing elements

Before we can go about measuring any process variable, firstly we need to be able to sense it. The first element in any measuring system is the primary *sensor*, this gives an output that is a function of the measured process variable, which in this case is pressure. There are several devices which can do this, the most common being, those based around the bourdon tube, and the other being based around the operation of a diaphragm. The first set of diagrams show elements based around the tube design. The tube's, rather than being round in shape, are an elliptical shape.



The second set of diagrams show primary sensing elements based around the operation of a diaphragm. A diaphragm is normally a circular disc, which is corrugated to provide flexibility. It is common to see a series of diaphragms together, these are known as either a bellows, diaphragm stack, or capsule.



In all cases, the operation of these devices relies on the small amount of flex in the metal, or its 'elasticity'. Eventually though, after constant use, and chemical attack, this elasticity reduces, and the measuring elements require replacement.

Probably the most commonly used device for indicating pressure is the pressure gauge, there are two main types of gauge in use, these are the Bourdon tube gauge and the diaphragm gauge. There are other gauges in use however the basis of these gauges is similar to the operation of either 1 of the above.

Application of pressure sensing elements

The simplest form of tube gauge is the C type tube. This gauge consists of a c shaped oval tube which is fixed at 1 end, to the connecting block. The other end of the tube is free to move, attached to this end is a linkage which connects to a pivoted quadrant with a rack and pinion arrangement which in turn is connected to the pointer.

As pressure is introduced to the gauge via the connecting block and fed into the tube, it tries to straighten out with increase of pressure, the free end of the tube moves outward pulling the quadrant via the connecting linkage, thus in turn turning the pointer via the rack and pinion. The movement of the pointer being linear to the pressure increase. A hairspring is attached to the pointer and gears to remove slackness.

Receiver gauge:- Is a gauge designed specifically to measure the output from pneumatic transmission equipment.

It has a specific range of 3-15 psi (0.2 -1 bar). When purchased they have a clear face so that the user may decide what application it will be put to and is therefore scaled accordingly. At 3 psi (0.2bar) this is referred to as zero.

The receiver gauge will normally be found mounted directly next to the transmitter, or alternatively in control room panels.

Compound gauges:- This gauge is one which measures negative pressure (vacuum) through to positive pressure. Unlike absolute pressure gauges these type tend to show the pressure below atmospheric as a negative (and quite often in red).

Duplex gauges:- This type of gauge is essentially two gauges in one case. Having 2 inlets, 2 tubes and 2 pointers. This type of gauge is not so common, however previously a major use was on steam trains, ships, submarines etc where space was limited.

Differential pressure gauge:- Again this type of gauge is not so common, its operation is based around two tubes operating one pointer. More commonly transmitters are used for this purpose (discussed later).

For some hazardous applications a *diaphragm seal liquid filled bourdon tube* gauge may be used, which keeps the process completely away from the gauge mechanisms, and prevent *any* leakage to atmosphere.

Diaphragm gauges.

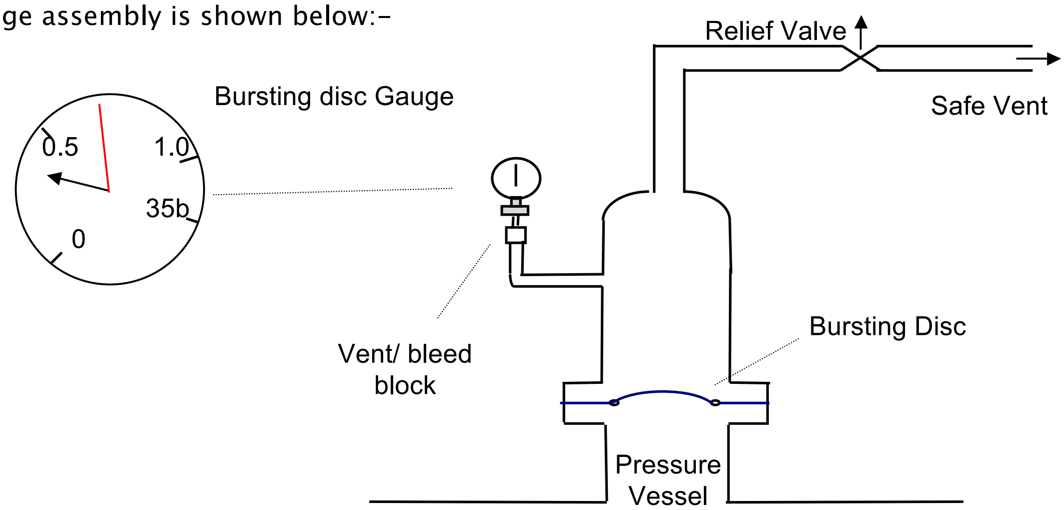
The use of diaphragms, in pressure measurement is now widely used, non moreso than in the operation of the gauge which takes its name. This gauge consists of a heat treated stainless steel corrugated diaphragm (circular disc) about 70mm diameter and held between two flanges.

The unknown pressure is applied to the underside of the diaphragm. The diaphragm flexes in the centre and the resulting movement is transmitted through a linkage to a rack and pinion arrangement to move the pointer over the scale.

The upper flange is shaped to provide protection against over pressurisation, and the flexible section of the diaphragm can be varied in size for low or high pressure applications (small area = high pressure, large area = low pressure), in addition to this for extreme low pressures PVC diaphragms may be used. The major advantage of this gauge over the bourdon tube is that the process is restricted to the underside of the diaphragm, for hazardous or corrosive applications the main stainless steel disc may be coated or lined with P.T.F.E, silver or tantalum for additional protection. The gauges may also be fitted with a blow out disc for safety in the event of diaphragm failure.
This type of gauge may be used for various applications from direct pressure measurement to specific duties (discussed shortly). They are available for measurements 0 – 12"wg and up to 400psi, and depending on type have an accuracy rating of approximately 1%.

Bursting disc gauge:-

Some pressure vessels or systems may be fitted with a particular gauge known as a *bursting disc* gauge this name refers more to the arrangement than the actual gauge itself. A bursting disc gauge assembly is shown below:-



The bursting disc is so designed to rupture when the pressure beneath it exceeds a predetermined safe working limit, prior to this occurring a small pressure may build up, in the space above the disc, due to the disc weeping, however it is more likely for the disc to rupture quite rapidly thus sending the indicated pressure into the overload zone and initiating a high pressure alarm condition via a set of contacts connected to the pointer mechanism.

The bursting disc gauge has a calibrateable range of *0 –1bar with an overload pressure rating of around 35bar (500psi),* having this overload pressure facility prevents the gauge from being destroyed if the bursting disc ruptures, and once normal pressures are regained the gauge is re-usable.

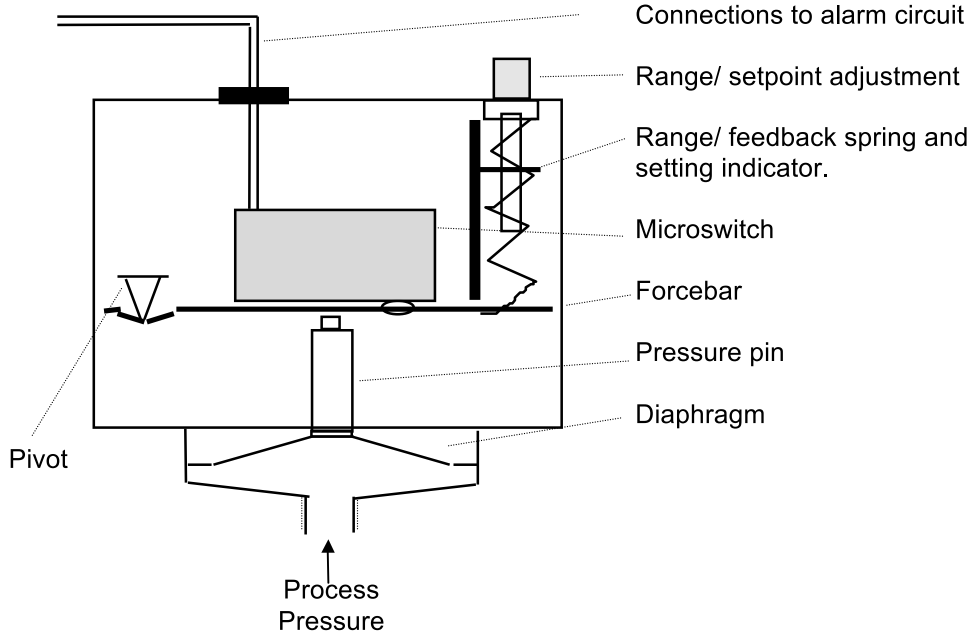
Pressure Switches.

Pressure switches may be used as an alternative to an alarm gauge. While its function is the same, pressure switches do not indicate the detected pressure merely producing an activated signal when a predetermined limit is reached, as a consequence they tend to have slightly fewer moving parts therefore increasing reliability.

There are three main types of pressure switch, either the bellows, diaphragm or the tube operated. By far the most common are the diaphragm or bellows types. The bourdon tube pressure switch's tend to be used on extreme high pressures, ie; above say 1000psi.

Diaphragm pressure switches:-

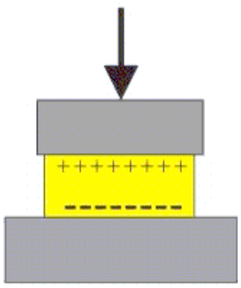
The following diagram shows a diaphragm operated pressure switch. As the process pressure is increased the diaphragm flexes upward and via the pressure pin and pivot the forcebar is moved towards the microswitch. Once the tension of the spring is overcome the micro switch will be operated changing the condition of its internal contacts. To change the set position merely adjust the tension of the spring.



Piezo-electric transducers

Piezoelectricity is the ability of some materials (notably crystals and certain ceramics) to generate an electric potential in response to applied mechanical stress.

A piezoelectric sensor is a device that uses the piezoelectric effect to measure pressure, acceleration, strain or force by converting them to an electrical signal.



Piezo-electric crystals are man-made or naturally occurring crystals that produce a charge output when they are compressed, flexed or subjected to shear forces. The word piezo is a corruption of the Greek word for squeeze. In a piezo-electric transducer a mass is attached to a piezo-electric crystal which is in turn mounted to the case of the transducer. When the transducer is subjected to force, this compresses or stretches the piezo electric crystal. This force causes a charge to be generated and due to Newton's law. The charge output is either is converted to a low impedance voltage output by the use of integral electronics. This forms the basis of operation of several pressure transmitters.

PRESSURE TRANSMITTERS

Pressure transmitters make use of different types of pressure transducers. These devices not only sense and measure pressure, they also produce a safe output, representative of the pressure measured. The output is then fed to other devices, such as display and control equipment.

The typical types of transmitter include:

Pneumatic,  using the pressure diaphragm capsule

Electronic using Piezo effect

Electronic using variable capacitance

One of the newest transmitters available uses a principle called DP HARP ((High Accuracy Resonant Pressure) , that uses silicon resonators.

More on transmitters will be covered in other sections of this unit.