TRANSMISSION OF

INSTRUMENT SIGNALS

TTE TRAINING LIMITED

INSTRUMENT COURSE

SECTION 4

TRANSMISSION OF INSTRUMENT SIGNALS

SECTION	CONTENT

TRANSMITTERS/SIGNAL TRANSMISSION.

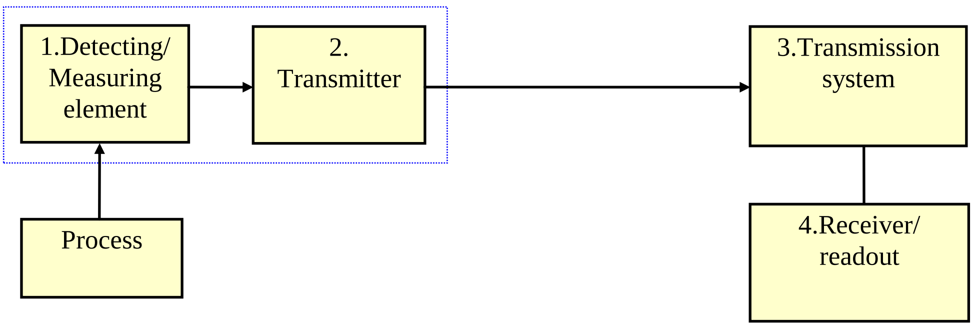
4.1 Introduction.

The driver of a motor vehicle has in front of them, a ‘dash board’, which presents the driver with an array of dials to give them such information as speed, engine rpm, water ‘temperature’, fuel ‘level’ and even a red alarm for oil ‘pressure’. These dials are what we call ‘instruments’, in-particular they are ‘*indicators*’. These indicators need to have information supplied to them. If we take for example the fuel level indicator, it would be unreasonable to believe that fuel is fed directly to the indicator, as this would present a major safety hazard, so, a device is put into the fuel tank which measures the level of fuel, and then converts this information to an electrical ‘signal’, which is sent to, and read by the display indicator. The devices which do this are called transmitters.

At the heart of most petrochemical plant operations and manufacturing processes is a plant control room, this is a centralised panel room where the conditions of the plant or process are monitored and controlled, by plant process operators using various types of controlling and display instrumentation. The more modern of processes being controlled by high powered computer systems and the older plants by individual instruments mounted on a control panel. However, for the information to be displayed, just as in a car, the process conditions need to be measured, and this is done by a multitude of transmitters.

Whilst local indications are necessary, there needs to be methods to send the measured information, this is the function of the transmitter and the transmission system. In a typical system there could anywhere between 100 and 500m between the measuring device and the control room indicator.

The next block diagram shows the main components of a simple transmission system



1. **Detecting/ measuring element:-** This is the part of the system which comes into direct contact with the process being measured. The measured value is often termed as the process (or measured) variable.

2. **Transmitter: -** The part of the system which converts the measured process variable into a transmittable signal (output). *It is more common to refer to the transmitter as a single unit combining the detecting element and the conversion unit* and will continue to do so from now on.

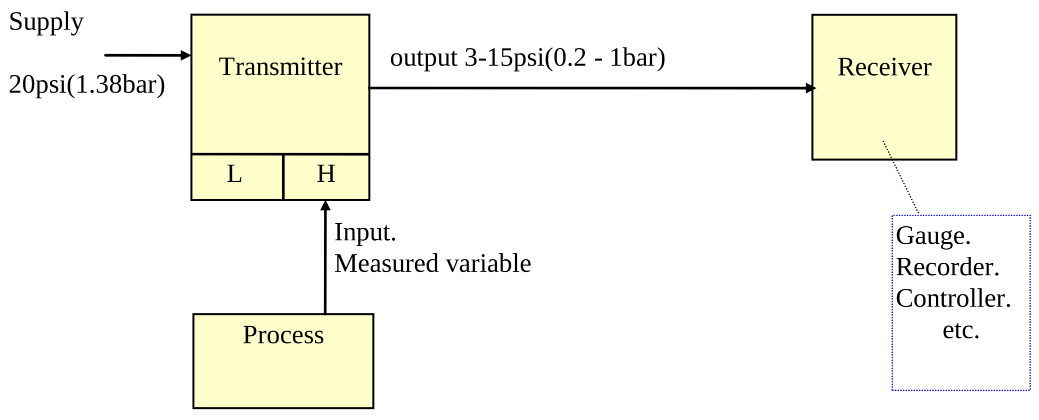
3. **Transmission system: -** The part of the system which carries the output from the transmitter via pipelines or wires to the control room. Within this part of the system there may be a need to convert the signal from one form to another ie;- pneumatic to electrical. The device which carries out the function of signal conversion is more commonly known as a transducer or signal conditioner, these devices are covered in the next section (6)

4. **Receiver / or readout: -** This is the part of the system which reads/ interprets the transmitted signal and displays it accordingly. The types of device used for this function can be as simple as a gauge or as complex as a computer system.

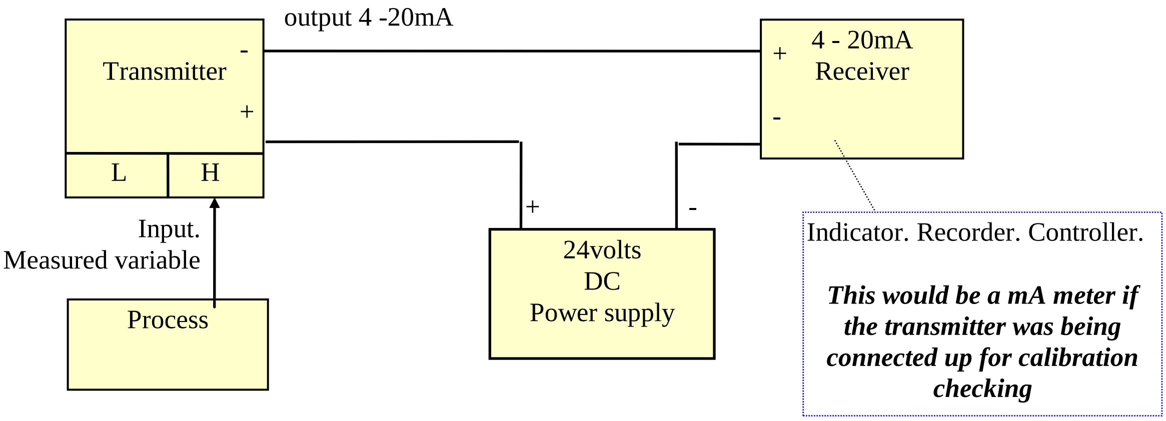
A simple everyday example of a transmission system is the fuel gauge in a car, which contains a level sensor (transmitter), transmission system consisting of interconnecting wires and a power supply, and finally a readout on the car dash board which can be a simple needle moving over a scale, or a digital readout.

4.2 Transmission systems.

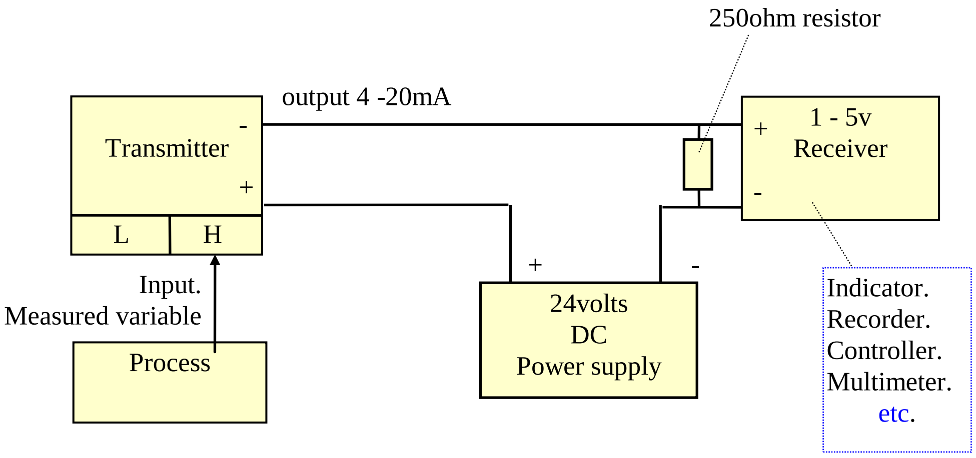
The type of transmission system used is dictated by the area in which the transmitter is located, the type of transmitter, the distance between transmitter and receiver, and finally the type of receiver. Transmission systems can be purely pneumatic, purely electrical, or a combination of both. The next series of block wiring diagrams show the common systems in use with some variations. These diagrams may be used later as the basis for calibration set-ups. The first diagram shows the set-up of a pneumatic system (loop):-



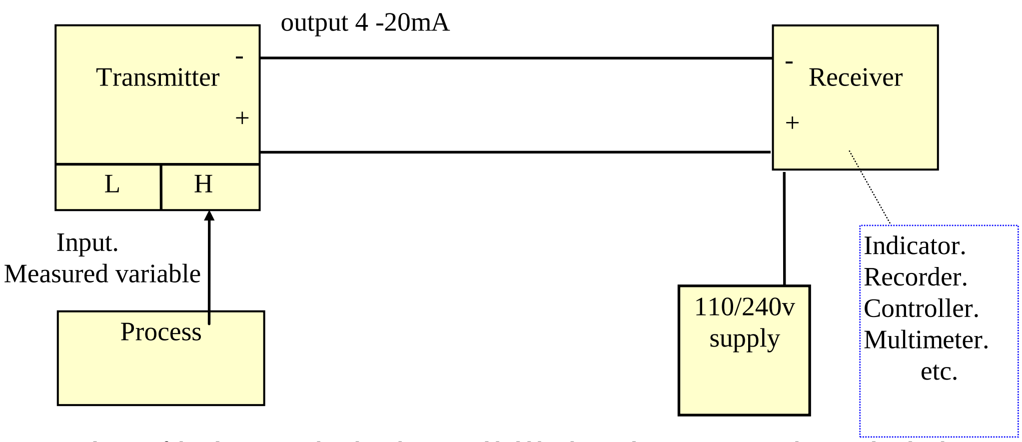
The next diagram shows a typical electronic transmission loop, with external power supply:-



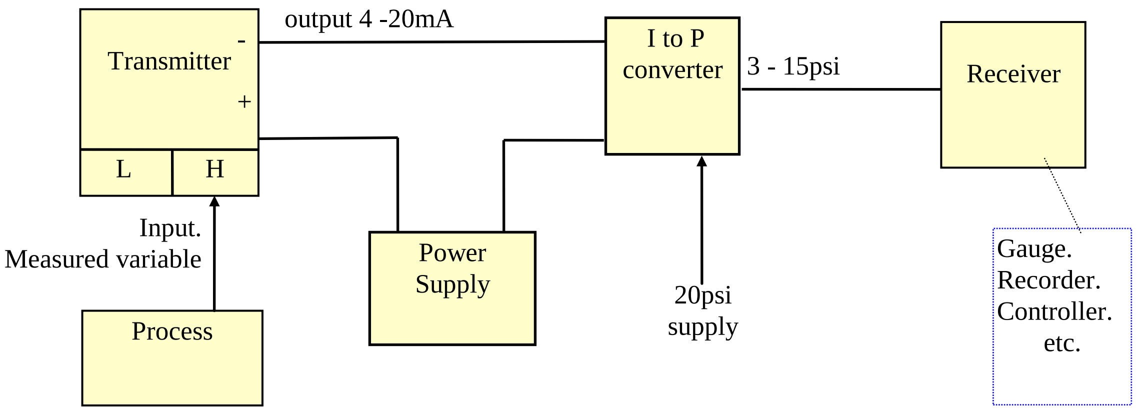
The next diagram is an electronic loop, however the receiver in this system is a 1 - 5volt type and so there needs to be a 250ohm resistor added across its input terminals as the diagram shows:-



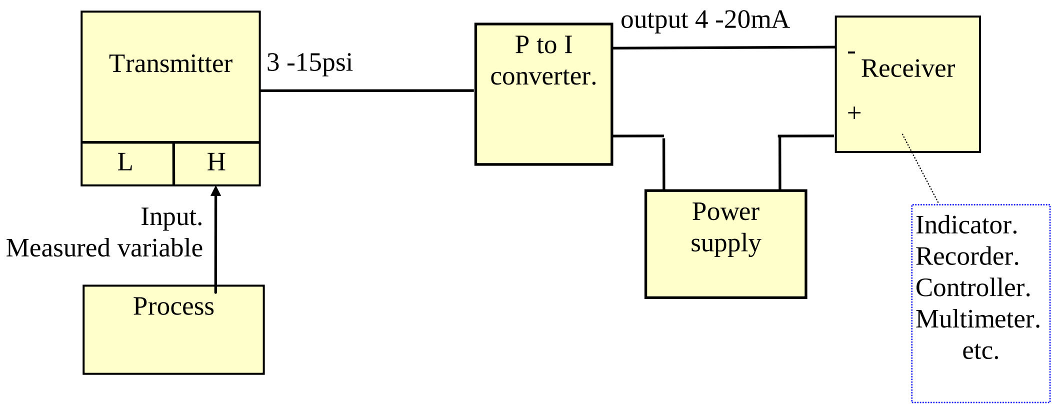
The next diagram shows an electronic control loop but this time the receiver is mains powered and capable of delivering the 24volt supply, again the 1- 5volt input option is available by inserting the resistor across the input terminals. This is often known as a loop powered system:-



The next diagrams show how the loops may be interconnected, if a signal conversion is required. Firstly, from electronic to pneumatic:-



The following diagram shows pneumatic to electronic system:-



Transmission systems used in instrument systems are not just confined to the examples we have just dealt with, in temperature measurement the measured variable would be either millivolts or resistance. Equally there are devices for converting analogue signals into digital formats, and frequency units.

4.3 Standard transmission signals.

From the diagrams we have seen and also section 3, the most common signals used are 3- 15psi (0.2- 1bar) for pneumatic systems, 4- 20mA and 1- 5v for electronic systems.

In each case, the lower value represents when the transmitter has no input signal applied to it (known as *zero*), whereas the higher value represents the maximum input value. It can be clearly seen that with no applied input the transmitter (or transducer) there is an actual output response above zero (ie;- 3psi, 4mA), this is known as a *live zero*. This live zero can be used to indicate loss of supply.

The following table shows a comparison of some of the more common instrument signals.

%	PSI	BAR	mA	Volts
100	15	1	20	5
75	12	0.8	16	4
50	9	0.6	12	3
25	6	0.4	8	2
0	3	0.2	4	1

Other signal types are available, such as frequency and digital.

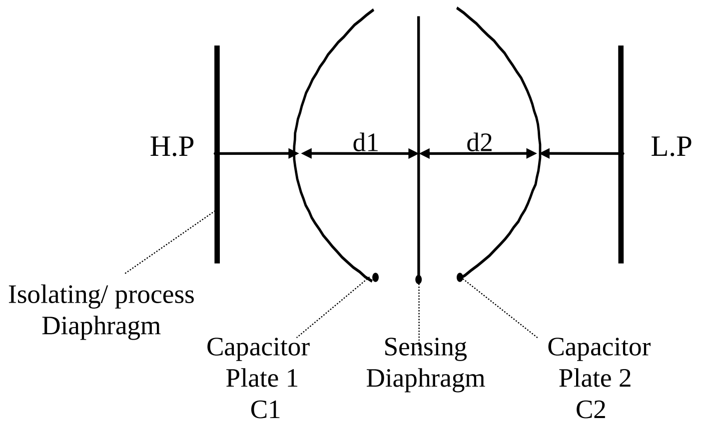
4.4 Electronic Transmitters.

Earlier electronic transmitters were similar in design to the pneumatic versions, however instead of the forcebar being connected to a pneumatic force balance (flapper/ nozzle) unit, they were instead connected to a coil which was moved in and out of a permanent magnetic field, and in accordance with Faradays laws, via electromagnetic induction an emf would be induced into the coil dependant upon how far the coil was inside the field, this small emf would be amplified and converted to 4 - 20mA or other suitable output signal. As a standard the supply for electronic transmitters is 24Vdc.

With advancements in technology, more modern electronic transmitters moved towards the use variable capacitance as their measurement operation.

The most common transmitter in this field is probably the one manufactured by Rosemount, with another being manufactured by Honeywell. Both of these transmitters have the same basic principle of operation, that is the measurement of a difference in value of two identical capacitances, but it is the Rosemount that we will look at in more detail.

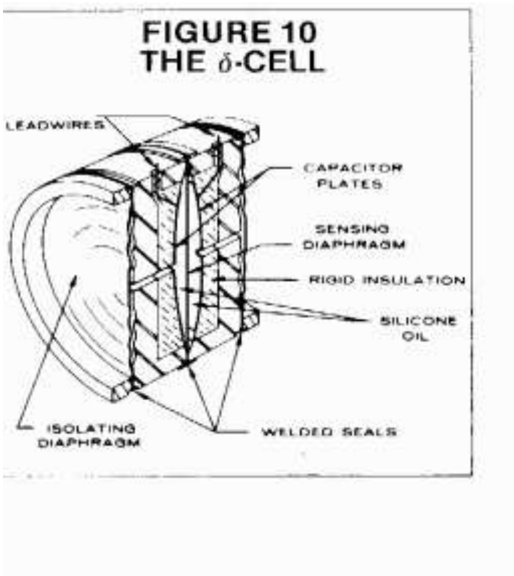
The next diagram shows the basic principle of operation:-



From the diagram previous, it can be seen that the process fluid is separated from the sensing diaphragm by two isolating diaphragms. The inside faces are hydraulically connected to the capacitor plates with silicone oil, with these being separated by the sensing diaphragm, thus producing a differential capacitor. The value of capacitance being a product of

1. The plate surface area
2. The distance between the plates
3. The dielectric strength of the material between the plates.

The next diagram shows a cross section through the measurement cell:-

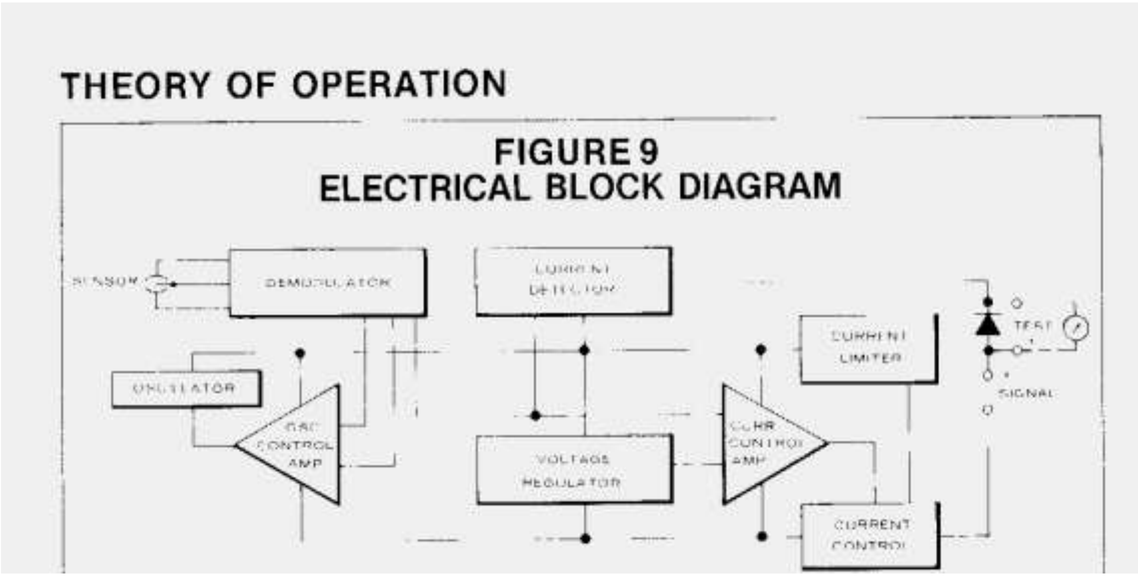


When an equal pressure is applied to each isolating diaphragm the distances D1 and D2 are equal, and therefore the capacitance's C1 and

C2 are equal. If an increase of pressure is applied to the H.P side, then the distance D1 will reduce thus changing the capacitance C1, this information is fed to the electronics which will detect the difference in the two capacitance values and convert this into a 4 - 20mA output signal.

With the same pressure applied to both sides, distances D1 and D2 therefore being equal the output will be 4mA this again is otherwise known as zero, and with the maximum calibrated range pressure being applied the output will be 20mA. The transmitter can be recalibrated using the zero and range adjusters so that input range may be altered.

This next diagram shows in block diagram form the components of the electronic circuit:-



Unlike the pneumatic transmitter or the earlier electronic transmitter, when a fault occurs if it can not be easily corrected then an exchange of circuit board card may be required taking merely a few minutes. The P.C.B cards tend to only be serviceable by the original manufacturer, as the time and cost it takes to repair them in-house normally exceeds the cost of sending them away for repair.

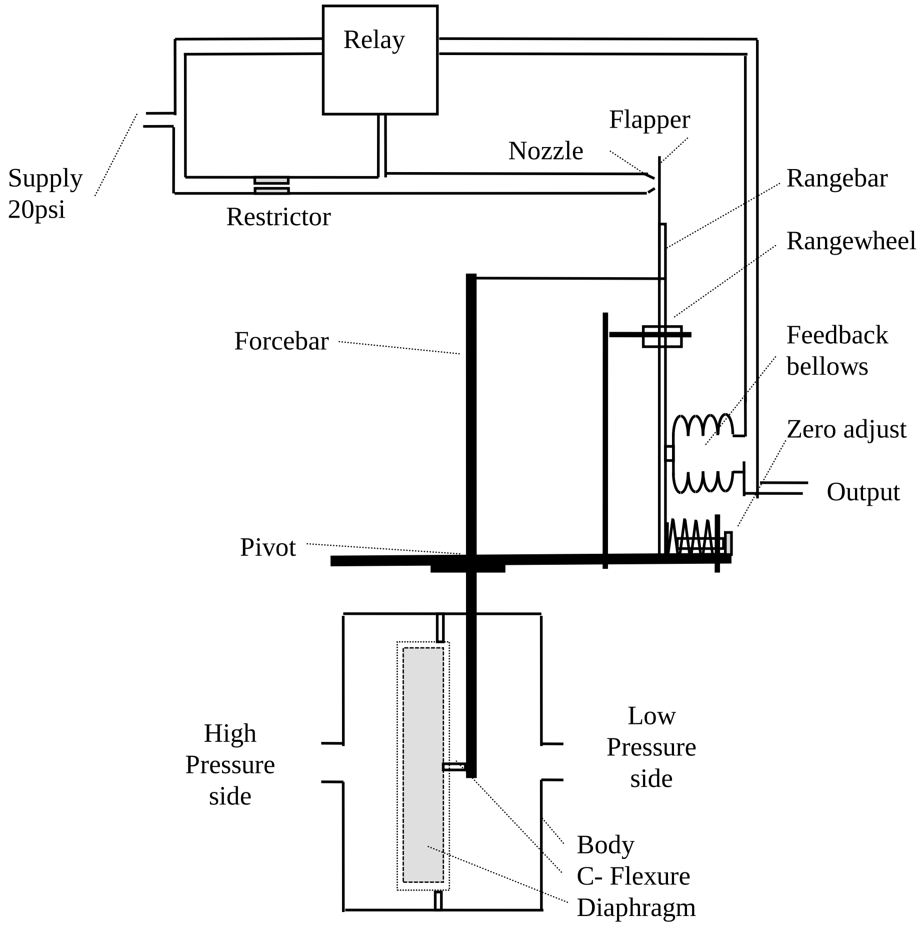
4.5 Pneumatic Transmitters.

Pneumatic transmitters are probably the oldest ones; however there are still many commercially available. Probably the most common of all being the *Foxboro* types, and in-particular their model 13A and 15A. Other companies such as Moore, Taylor, and Fisher/ Porter are other common manufacturers.

For ease this section will concentrate mainly on the Foxboro type. It is probably true to say that there are alot of common items within the principle of operation of all the types mentioned. The fundamental operation of all of these is based around the force balance principle

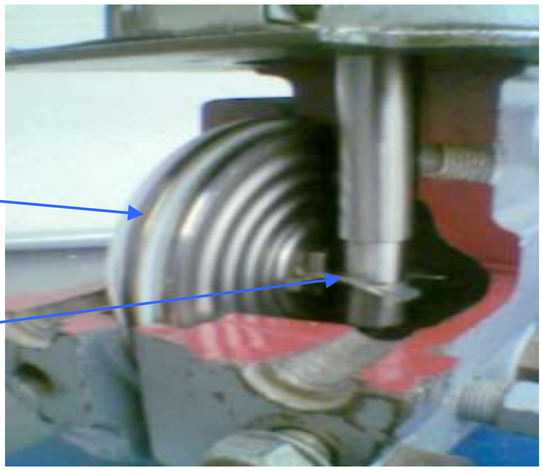
Transmitters can be manufactured to measure absolute pressure, static pressure and differential pressures, with the most common probably being the differential pressure transmitter. You will no doubt hear of the differential pressure transmitter referred to as a *d.p cell* and the pressure transmitter referred to as a *pressure cell.* These terms are commonly used and can be applied to both the pneumatic and electronic types.

The next diagram is a schematic of a pneumatic differential pressure transmitter:-



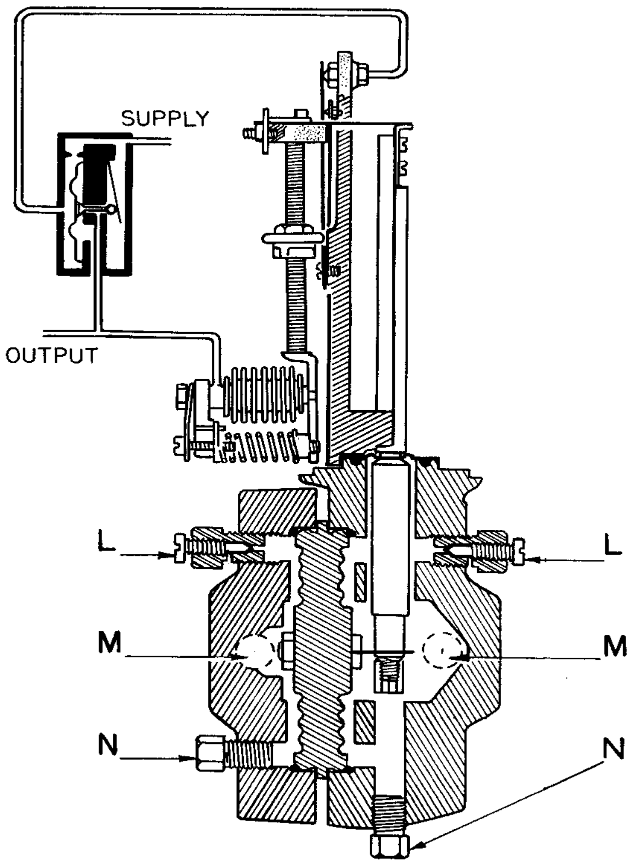
Principle of operation:-

The above diagram shows a schematic representation of a typical pneumatic transmitter. A differential pressure is applied across the diaphragm (or capsule), with the highest pressure being applied to the high pressure side. When this occurs the increase in pressure causes the diaphragm to move the force bar about the pivot via the c-flexure thus pulling the flapper towards the nozzle.



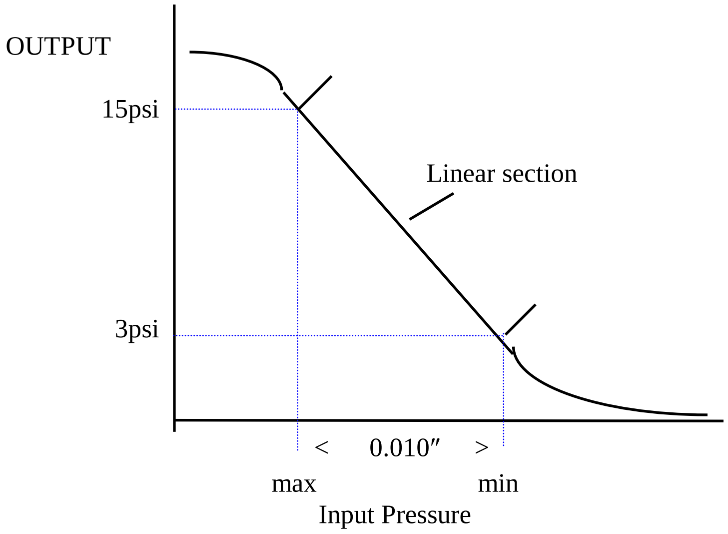
The 20psi supply is passed through a restrictor to the nozzle so that when the flapper moves closer to the nozzle the pressure behind it builds up and feeds back into the relay, where the volume is boosted. The output from the relay feeds the feedback bellows which now expand as the pressure increases thus trying to move the flapper away from the nozzle. When the forces are balanced a constant output will be delivered, with the output being set to 3psi (*zero*) when there is equal or minimum pressure applied across the diaphragm and 15psi being delivered when the input pressure is at its pre-determined maximum (*range*).

In order to set the zero and range the are two adjusters (shown on the diagram). The zero adjustment physically positions the flapper a set distance away from the nozzle either with or without pressure applied, and the range adjustment is a moveable pivot on the range bar, therefore requiring more or less pressure to get the same amount of movement of the flapper towards the nozzle. The letters L, M, and N show the positions of the process connections and vent plugs.



In order to achieve the full output range the flapper merely moves 10 thousandths of an inch in total, towards or away from the nozzle related to the input which could be anything from a few millibar upto several thousand psi (bar). If for example the transmitter was calibrated to measure 0 - 200″wg, for every one inch of change the flapper would move 1/200th of 0.010″ resulting in an output pressure change of around 0.02psi.

This is demonstrated in the displacement curve shown below :-



The same transmitter can be used to measure direct pressure, absolute pressure or differential pressure for the measurement of flow or level. In order to achieve these applications it may be necessary to vacuum the low pressure side in the case of absolute pressure measurement, or to change the size of the diaphragm (large = low pressure and small for high pressures). The diaphragm typically used in differential pressure measurement is known as a medium range diaphragm, this covers a differential pressure range between 10 and 300 inches water gauge but the line/ static pressure can be much higher, these are typically about 100mm in diameter. Using a similar set-up this transmitter can be adapted to measure temperature. The size and shape of the body may vary according to application.

Because of the physical size of the nozzle and restrictor in this transmitter the air supply must be clean and dry. These types of transmitter are still in use today thus demonstrating their overall reliability, however because of the nature of the construction i.e.; - moving parts, potential leaks and small diameter pipes these transmitters do require a moderate amount of maintenance.

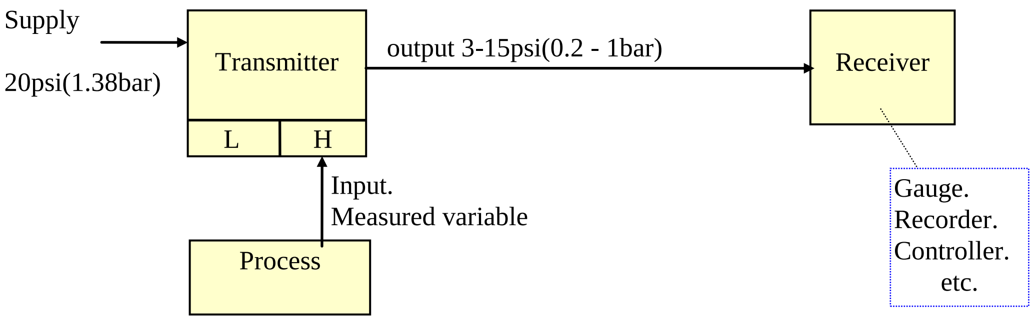
4.6 Transmitter Calibration.

In order to calibrate a transmitter you first need to decide on the appropriate method of setting it up for calibration. A guide to connection details is in part 2 of this section.

The equipment you will need include:-

EQUIPMENT LIST		
INPUT	PNEUMATIC	ELECTRONIC
'Measured Variable' connected to HP side of transmitter with LP open to atmosphere.	Druck Test panel with regulatable supplies Wallace and Tiernan test box	Druck Test panel with regulatable supplies Wallace and Tiernan test box
SUPPLY	Fixed 20psi (1.38Bar)	24Vdc
OUTPUT	Druck pressure indicator Test panel gauge (0 - 20psi) Receiver gauge	Multimeter 4 - 20mA indicator (analogue or digital)

Once you have selected the appropriate equipment they should be connected together, an example of this is shown below for reference, the example shown being for a pneumatic transmitter. For electronic transmitters refer to the earlier part of this section:-



With the equipment set-up, and no input applied to the HP side turn on the supply and the output should now read 3psi (zero), if it doesn't then adjust the zero screw until it does. Now slowly increase the input pressure until the output reaches 15psi and then make a note of the input, then reduce the input slowly until the output reaches 9psi and the input should be half of the maximum, if this is correct the transmitter response is also linear. However if the input pressure is not as desired to give full output this may be corrected by adjusting the range wheel, however doing so will affect the zero and so this procedure needs to be repeated until the transmitter calibration is accurate.

This procedure would be the same if the transmitter was electronic, the only difference being is the supply and the method of measuring the output which would be between 4 to 20 milli-amps, 4 being zero and 20 being maximum.

The calibration range is expressed normally as;

0 to maximum input pressure (required to produce 15psi output)

ie:- 0 to 100″wg or 0 - 10Bar etc.

Occasionally it may be necessary to work out what the output should be for a given input. The following examples show this:-

Transmitter range = 0 - 100″wg
Input = 25″wg

For a pneumatic transmitter the output would be;

$$\text{Output} = \frac{\text{input}}{\text{input range}} \times \text{output range} + \text{output at zero}$$

$$= \frac{25}{100} \times 12 + 3$$

Output = 6 psi

For an electronic transmitter replace the 12 psi output range with 16, and the zero value to 4mA.

$$= \frac{25}{100} \times 16 + 4$$

Output = 8mA

Calibration may be carried out in the workshop, however it is possible to carry out calibrations in- situ on the plant. Probably the most common on site calibration check is the zero-check, which can normally be done using the block bleed manifold. Important, before carrying out any in-situ maintenance, check the effects this will have on any control systems it may be part of and if necessary have the controller put onto manual.

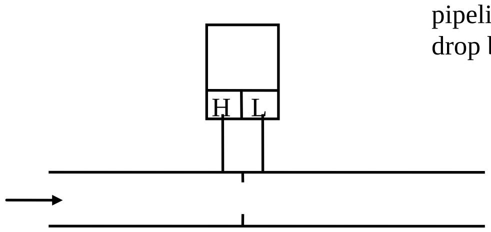
4.7 Transmitter Installations.

The installation of a transmitter is often determined by the type of measurement being made ie;-flow, level or pressure, the body shape and the process being measured.

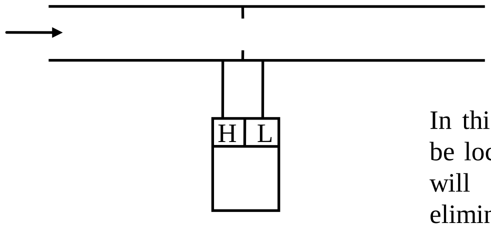
1. The next series of diagrams show some of the installation requirements that are determined by the type of measurement.

Gas Flow

In this installation the transmitter needs to be located above the pipeline, to allow any condensate to drop back into the main pipeline.

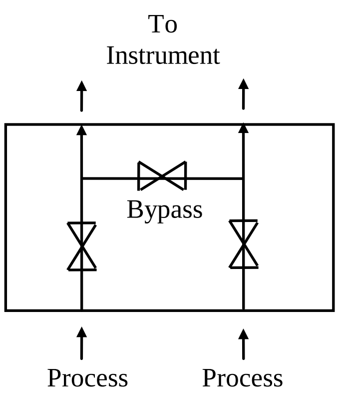


Liquid Flow

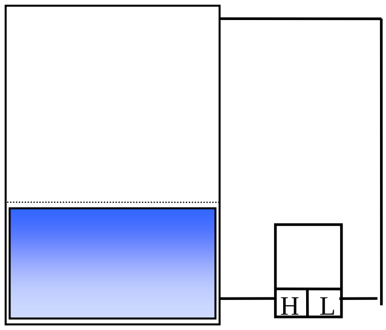


In this installation the transmitter needs to be located below the line so that the liquid will drop into the impulse lines and eliminate any error due to static pressure.

With the two above installations the use of a connection block/ bleed manifold would be employed, the one for this purpose would be slightly different to the pressure type as it would have a built in pressure equalisation (bypass) valve. This modification is shown in the diagram below:-

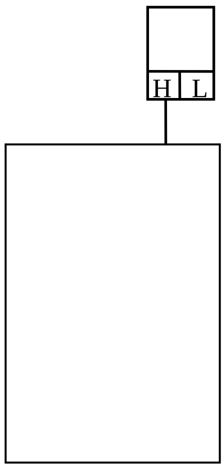


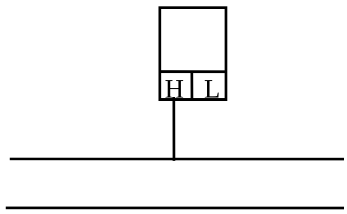
Where the transmitter is to be used for *level measurement* the use of purged dip-pipes may be required in which case the transmitter would be situated at a convenient location near the point of measurement, these systems usually require other pieces of equipment as well. If the transmitter is to have the process act directly on the diaphragm then the transmitter would be located near the bottom of the vessel, if the vessel is sealed then the low pressure side would need a connection to the top of the vessel. The next diagram shows this:-



If the system was using dip pipes as its method a second dip pipe would be required to balance the tank pressure. If the tank was open then only a single dip pipe would be used.

If the transmitter was to be used for measuring direct *pressure*, then it may be fitted as the next diagram suggests:-





Below the line for liquids.

2. Transmitters which are designed sole for pressure measurement normally have a slightly different style body in that it is smaller than the differential pressure type. The same is also true for transmitters designed for the measurement of absolute or vacuum pressure.

3. The type of process being measured can affect the installation requirements. The following are some options:-

Steam tracing - Where the process is prone to freeze or solidifying below a certain temperature ie; on water or caustic.

As a general guide ‘***above the line for gases, below the line for liquids’***.

Suitable pressure venting method, this can be achieved with the block bleed manifold or isolation valves.

Suitable isolation valves should be fitted between the process tapping point and the impulse lines.

The materials chosen for impulse lines should be non reactive with the process fluid, and suitable diameter to avoid blockages also with a minimum number of joints and bends.

Transmitter should where possible be located away from excessive vibration.

4.8 Advancements in technology.

Recent developments in technology have made use of the 'Hart communications interface' or *Smart* as it is commonly known. (HART – Highway Addressable Remote Transducer). Smart transmitters as well as having the usual electronics also have a small memory chip inside that can be communicated with from a central computer or hand held terminal. The Rosemount smart system is one that is commonly used, however the Honeywell Company use a similar system.

Essentially, 'smart' equipment is the same as before, except that electronics make use of addition digital electronics, therefore giving a wider range of functions.

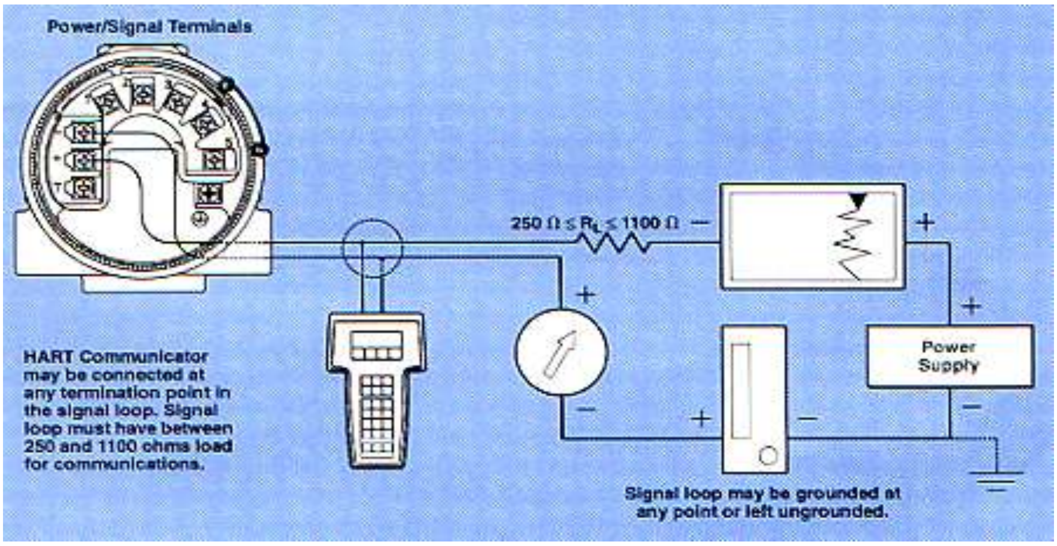
The advantage of this system is that it allows the technician to communicate with the transmitter to 'programme it', for such things as zero and range, it can also give the transmitter identification numbers and tell the technician precisely what components/ materials the transmitter is made up of. This system also allows the operator to carry out remote loop simulations from/ via the handset. Other benefits include greater fault finding ability.

Because Smart uses digital signals more than 1 transmitter can be connected to the same wiring loop.

The handset may be connected directly to the transmitter, or it can be connected to part of the wiring loop inside the control panel area. Newer breeds of handsets are capable of storing information on upto 100 individual transmitters. Most standard electronic transmitters can be fitted with replacement smart electronics. The transmitter itself will have push button zero and range adjustment rather than traditional potentiometers.

The diagram left shows a typical smart handset:-

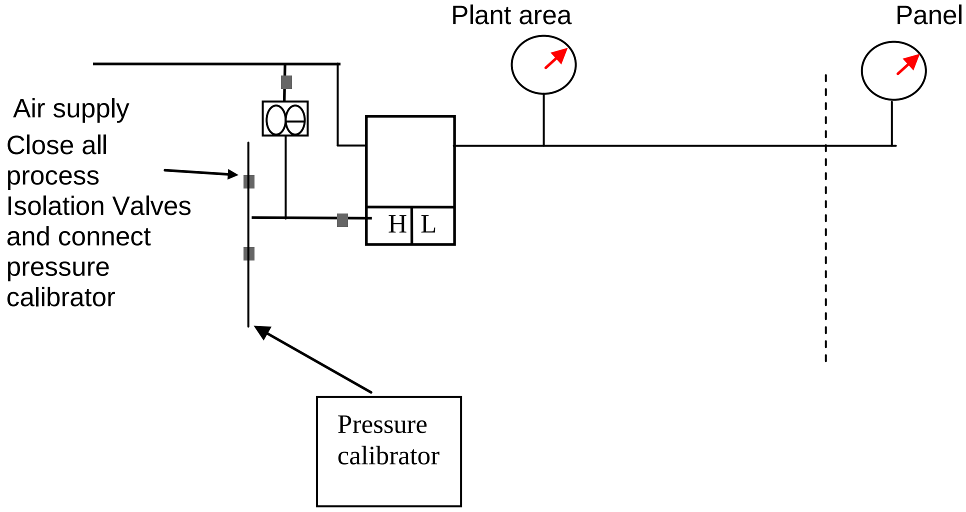
The diagram below shows a typical wiring arrangement.



4.9 Fault diagnosis from local or panel indications, and basic maintenance.

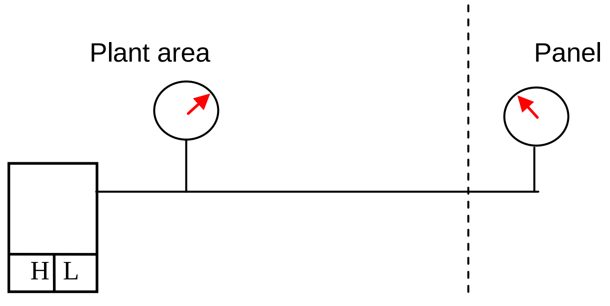
Initial recognition or diagnosis of faults can come from local or panel indications, accurate diagnostic skill may prevent the need to carry out further detailed calibration checks.

Consider the following diagram:-

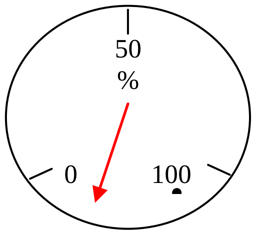


In the previous diagram both of the gauge indications are the same and reflect accurately the calibration pressure. However:-

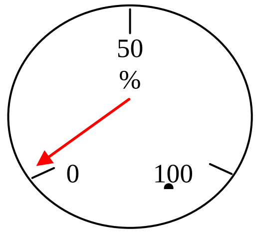
1. **If the panel gauge was lower than the plant gauge -** it is possible that a small hole or leak may exist between the transmitter and the panel indication causing a lower indication on the panel.



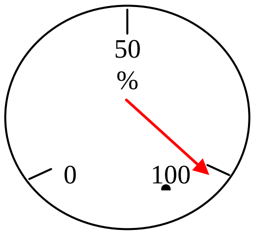
2. **If the Indication on both gauges was well below the zero level on each gauge -** it could be due to an air supply failure to the transmitter.



3. **If the Indications are the same but either slightly above or below the zero point on the gauge - If** the tank was known to be empty this could be due to a zero error on the transmitter. If this was applicable to only one gauge it could be a zero error on that particular gauge.



4. **If the Indications where the same yet above full or just below full reading -** If the tank was known to be full, this could be due to a range error on the transmitter or the individual gauge.



Diagnosis of faulty equipment

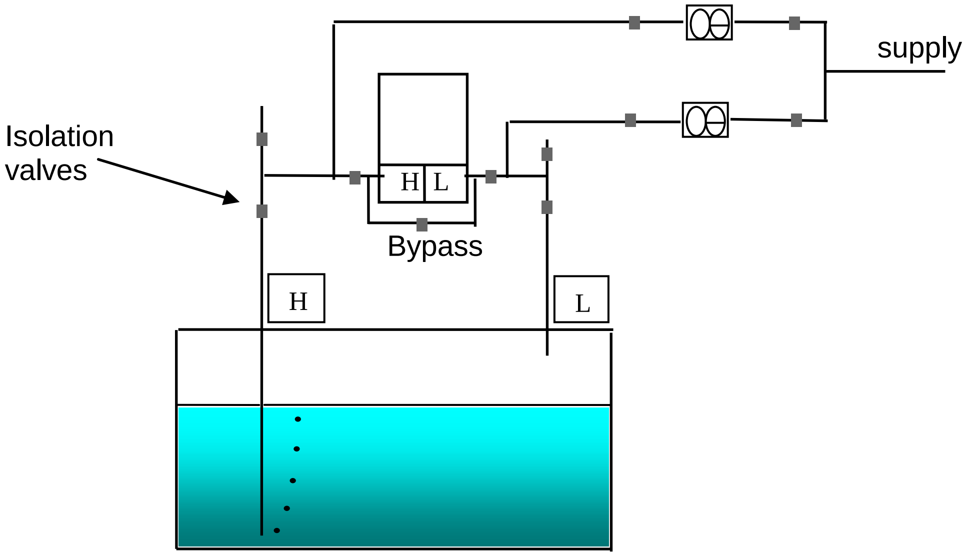
Accurate diagnosis of faults in equipment before the items are removed from plant can minimise valuable downtime. The observations made using the local and panel indications will help speed this process up. In some cases the faults found may be simple calibration errors which can be put right without having to remove equipment.

In order to accurately diagnose faults it may be necessary to carry out some simulation checks or even calibration checks. The next section talks about some of the checks that may be carried out.

1 Basic maintenance activities

Simulation tests

Before carrying out any maintenance activity, it is wise to check whether or not the equipment forms part of a control loop, if so the plant controller will need informing, and were appropriate the process controller may need switching to manual operation. The following diagram will be used to help explain some basic simulation checks:-



1. **Simulation of full output-** it is possible to simulate full output from the transmitter, by simply closing the isolation valve closest to the tank on the high pressure side of the transmitter. Having done this the output should quickly rise to maximum and also the bubbles indicating the airflow through the pneumerstat should also stop. This also indicates that this side of the system is leak free. Whilst this check can be used to check the full output from the transmitter it does not check the calibration.

2. **Simulation of zero output-** it is possible to check the transmitter zero by simulating minimum output (3psi, or 4mA)

This is achieved by having the same pressure on both sides of the transmitter, ie:- By closing the isolation valves closest to the transmitter and opening the bypass valve. In addition the pressure can be vented to atmosphere if the transmitter has vent plugs fitted.

3. Leak checking

The simplest way to leak check is to close the isolation valve closest to the top of the dip pipe. Having closed this valve the pressure in the line is built up to the supply pressure, and when this is achieved the flow of air will stop. This can be seen visually by the bubble flow through the pneumerstat stopping. If the bubble flow fails to stop this indicates that the purge gas is still being allowed to escape and so a leak is present. The use of leak detection spray used around the joints should help to identify where the leak is.

4. Dip pipe rodding

Having identified a blocked dip pipe ‘usually by a full output indication’, the above named process ‘Rodding the dippipe’ is used hopefully to clear the blockage. This involves inserting a piece of wire (or similar) down into the dippipe usually via the vent valve and prodding until the blockage is cleared. If the blockage is solid this may require a new dip pipe to be fitted.

Care must be taken to eliminate the chance of a pressure surge back up the dip pipe once the blockage is clear. Should this be a potential problem the process vessel may require the pressure removing from it first.

5. Replacing faulty equipment

When replacing faulty equipment it must be ensured that you are changing ‘like with like’ ie:- materials, calibration etc.

Before removing equipment, it must be first checked that the equipment is isolated from its supply, and also its connection to the process is safely removed and isolated.

6. Basic calibration on individual system components

Before calibrating equipment, it is firstly important to ensure that the effects of calibration both range and zero will not affect the control of the process. Having had the process controller put to into manual operation, calibration may continue.

Isolating the dippipe for example will only prove the system responds and gives full output, it will not confirm the calibration of the transmitter. In order to do this separate calibration equipment will be required, this must be capable of simulating accurately the process condition, ie:- 0 –100 inches water gauge, this equipment is connected to high pressure side of the transmitter and by raising and lowering the input the output should raise and fall by the same degree.

The pneumerstat for example may be checked by simply blocking the dippipe and waiting for the bubbles to stop.

Having checked the individual components, any faulty items should be repaired, replaced or reported for maintenance.

7. Provide clear definitions for maintenance of faults from simulations and diagnostic checks

Having performed maintenance on the system, most plants now require a record or maintenance log to be completed. This log should provide clear information on what work has been carried out, and may require a before and after detail.

The more information is provided, and the clarity it is provided will help others in future, and may help minimise plant downtime.