LEVEL MEASUREMENT

TTE TRAINING LIMITED

INSTRUMENT COURSE

SECTION 6

LEVEL MEASUREMENT

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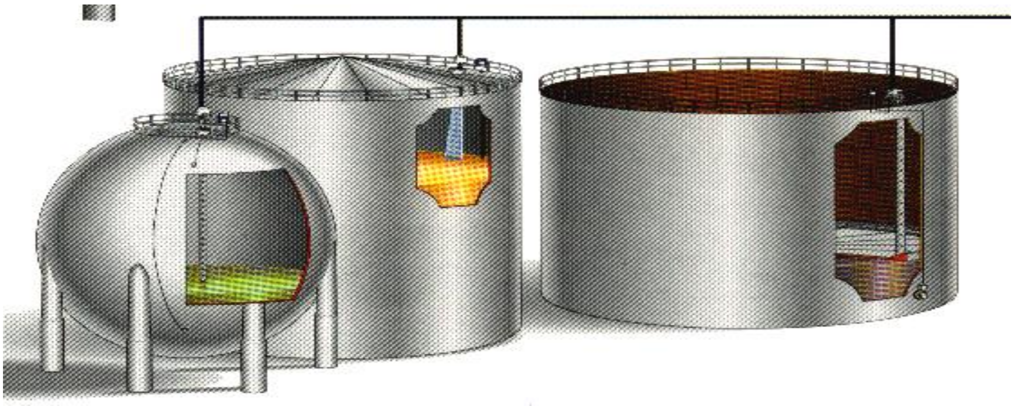
LEVEL MEASUREMENT.

6.1 Need for measurement.

Just as a car needs the petrol level in the tank measured, or the amount of oil in the engine, so too for the successful operation of most process plant operations and manufacturing processes it is essential that the level of products in its tanks and vessels needs to be measured, and where necessary must be controlled or maintained within predetermined limits to ensure safe and economic operation of the plant.



In the early days of industrial development, the methods used to measure level were very primitive and relied heavily on the skill of the process operator or technician, however individual judgements varied thus causing irregularities or inconsistency.

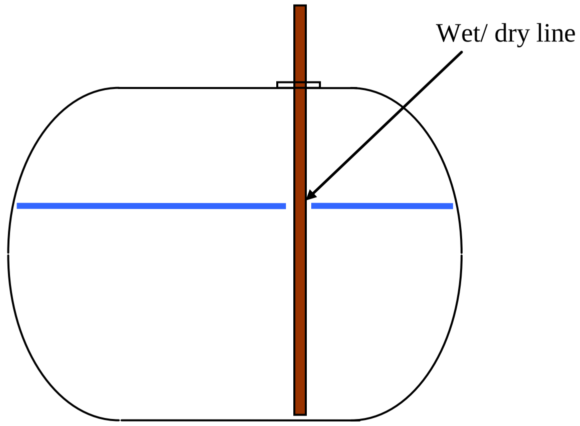
Due to the very nature of some of the chemicals being dealt with, for example, strong acids and toxic gases, where it is essential for these to be contained inside robust vessels and pipelines, such primitive measurement techniques would have proved hazardous. Therefore such conditions may only be monitored and measured by more complex instrumentation.

As a result of continuously changing technology the variety, reliability and functions performed by such instrumentation has increased tremendously. Although some of the early methods still exist most are now obsolete.

6.2 Early techniques

The earliest form of level measurement devices were the dipstick and the sight glass.

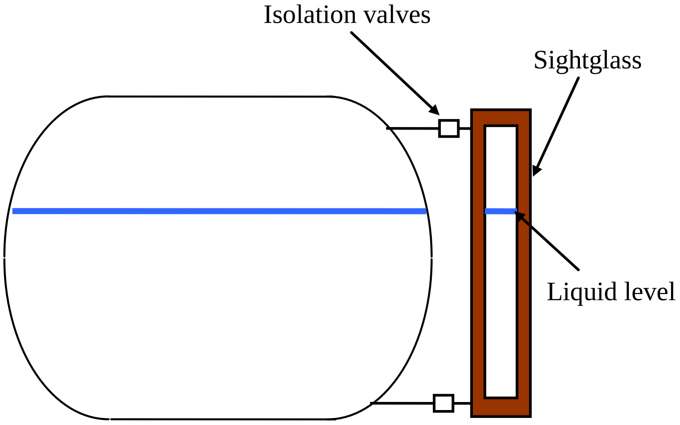
Dipstick - This merely consisted of a rod or stick with graduations marked along its length. The dipstick would be inserted into the liquid being measured to the bottom of the tank or vessel, the point at which the wet/ dry line appeared being an indication of the level. Whilst this method is very simple there are some particular hazards involved particularly where the liquid being measured is hazardous, for example strong acids or alkalis. A still commonly used derivative of this method is that used to measure the oil level in a car engine. Some petrol stations still use this method as a means of determining the stocks in their underground storage tanks.



Sightglass - The sightglass is merely a glass tube attached to the side of the tank, with an entry top and bottom. As the level in the tank rises in the main vessel so to does the liquid level in the sight glass tube. Again this is a simple method that has some problems attached, for example if the liquid is a dirty one it is likely that the glass will become stained and eventually the level changes will be unreadable, equally these are not suited to high pressures or thick clogging substances. It is still possible to find sight glasses in use, however these tend to be as back up to other devices. A simple household version of this can be seen on most electric kettles, on process plants a common use for this is on a plant item known as a steam drum.

Some sight glasses have been modified for use and it is possible to see them with a thick metal frame surrounding it.

Sight Glass arrangement

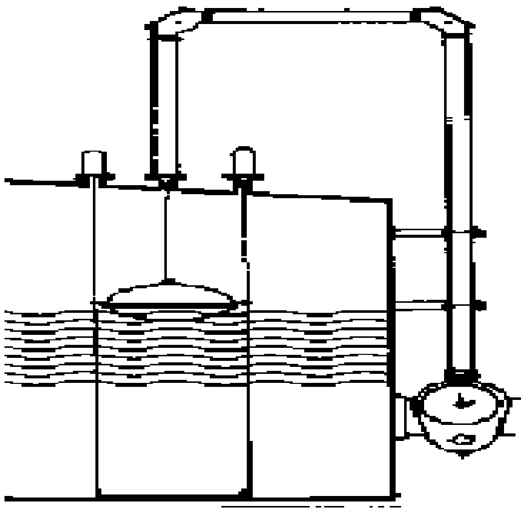


6.3 Buoyancy devices

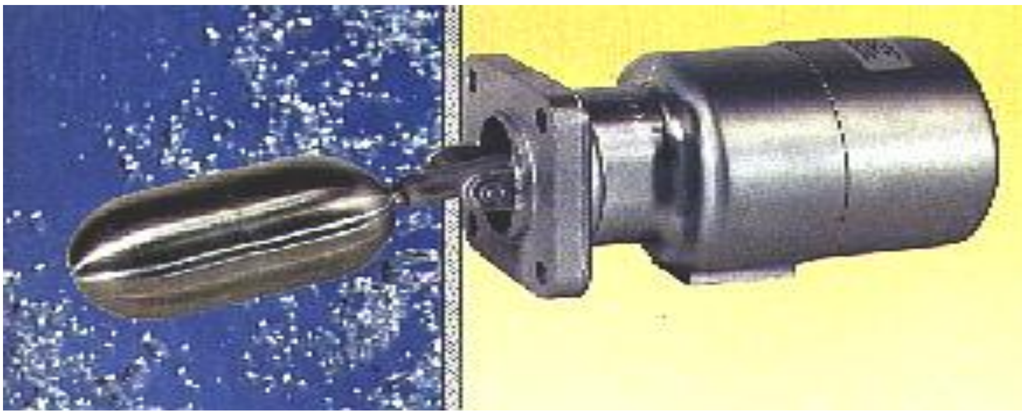
The simplest way to describe the operation of devices in this section, are those which rely on the ability of an object to float on the liquid surface or those which rely on the displacement of the liquid.

Floatation devices.

There are several different devices in this section, for ease we will concentrate on only a few. The first example is of a continuous float level indicator. With this device as the level rises and falls, the float stays with the surface and it inturn is connected via a tape to an external indicator, which could be something very simple or even a precision measurement device. The operating principle, being similar to that of a tape measure. The diagram shows an indicator board however this could be replaced by an analogue gauge style geared indicator or precision device. The diagram opposite shows an example of this:-

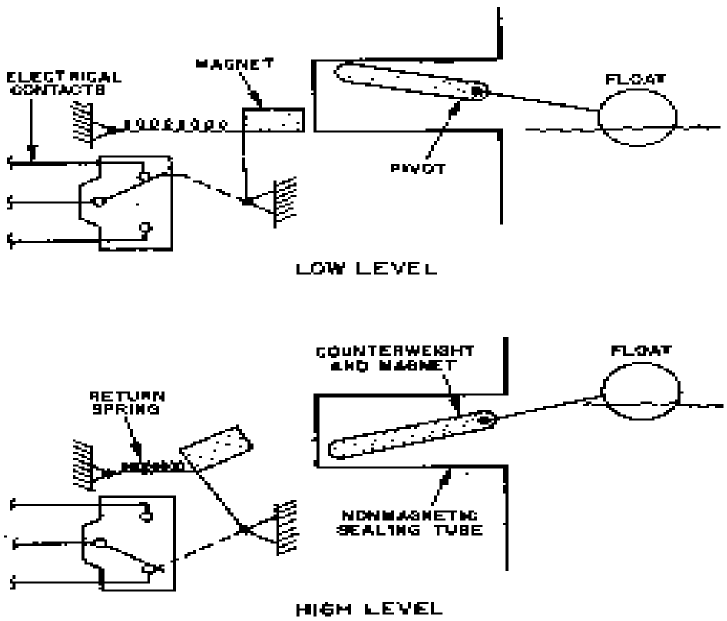


Float switches. The next device in this section is the float switch, as shown in the diagram below-



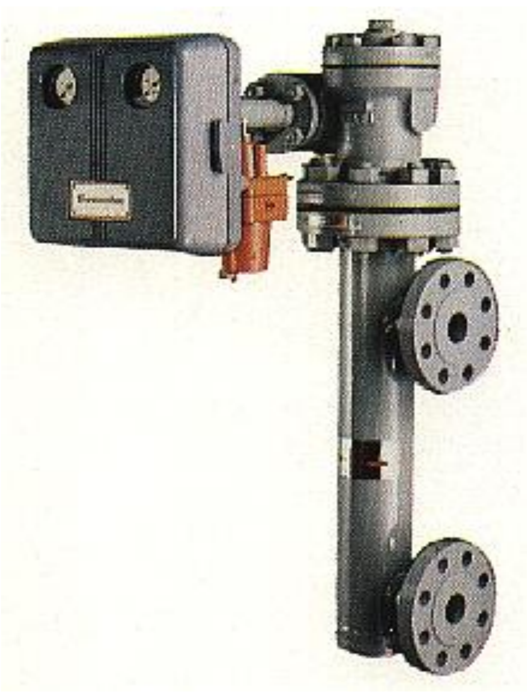
One type of device is manufactured by a company called *Mobrey* and hence is called the Mobrey switch, these can be either pneumatic or electrical and consist of a float which is inserted into the tank, an arm is attached to the float which connects via a pivot to a magnet, then via a magnetic coupling a switch can be operated.

The next diagram shows an example of the two positions of operation:-



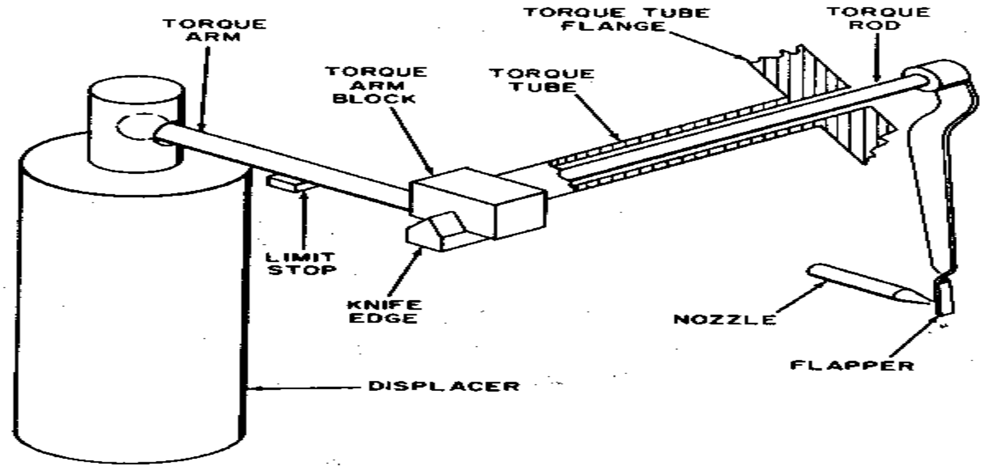
These devices are limited to the point at which the are inserted into the tank and the length of the connecting arm.

Displacement devices.

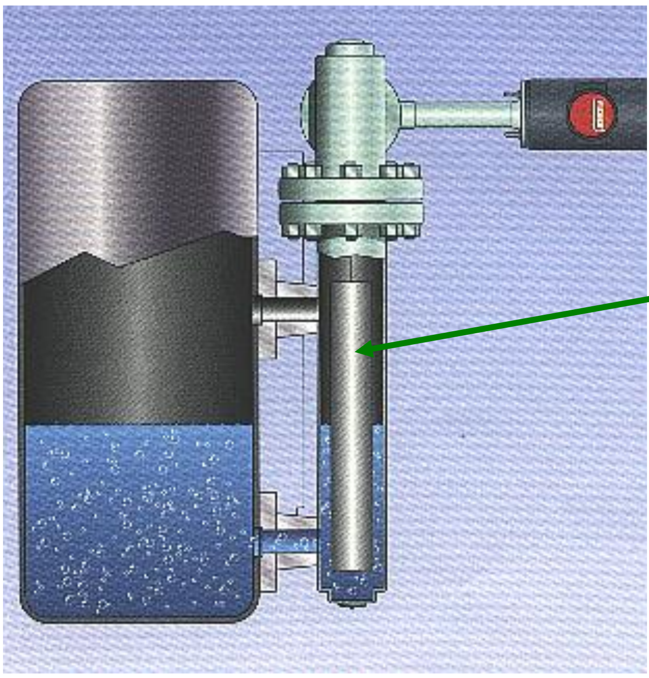


Devices in this section rely on ‘Archimedes principle’ of displacement which states that when an object is partially or wholly immersed in a fluid it experiences an upthrust force equal to the weight of the fluid displaced by the object. Just as when a person swims their body weight is apparently absorbed by the water thus making them feel lighter and also causing them to rise to the surface, this is the same principle use in the device known as the buoyancy tube. The common manufacturers of these devices are Masoneilan and Fisher.

The next diagram shows an example of the principle of operation of a pneumatic Buoyancy tube displacer system:-



bove diagram, as the level rises the displacer weight is absorbed thus making it float higher than if the level surrounding it was low. This movement is transmitted by the torque arm to the torque tube which converts the movement from up/ down to angular (rotational), at the other end of the torque tube is a flapper/ nozzle arrangement which can be used to generate a pneumatic output. This same device can also be set up to generate an electrical output. The next diagram shows a cut-away diagram of the buoyancy level transmitter:-



These devices can be used to measure level from approx 10″ to about 15 ft, this being determined by the length of the displacer tube.

This same device can also be used for the measurement of liquid density by keeping the level constant, or more normal to keep the displacer immersed according to the formula P= ρgh.

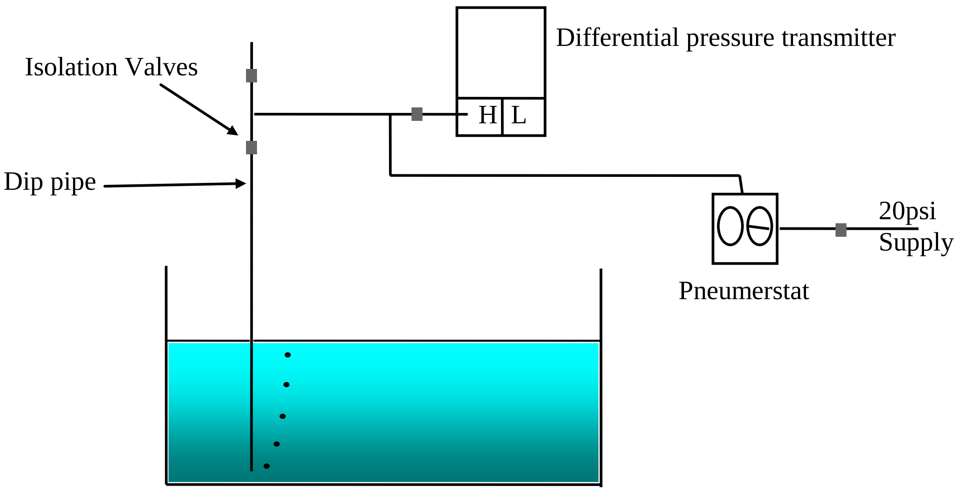
In addition to the pneumatic version an electronic version is also available

6.4 Hydrostatic level devices.

This is the name that is commonly applied to differential pressure type systems. These systems have 3 main components, A gas purge device commonly a Pneumerstat (bubbler), Differential pressure transmitter and a single or double Dip pipe arrangement.

Open tank systems.

The following diagram shows a basic open tank dip pipe system:-



Air (or nitrogen) is fed to the system via the pneumerstat. The pneumerstat provides a constant flowrate of air to the dip pipe such that when there is no level in the tank the air can freely escape thus not creating a pressure build. When the level in the tank rises it becomes increasingly more difficult for the air to escape and a pressure builds up in the dip pipe equal to the height of liquid, according to the formula $P = \rho gh$. Air bubbles will be seen escaping as the pressure in the dip pipe is kept equal to the pressure created by the liquid level. This build up of pressure is detected by the transmitter and as the level rises and falls so to will the output of the transmitter.

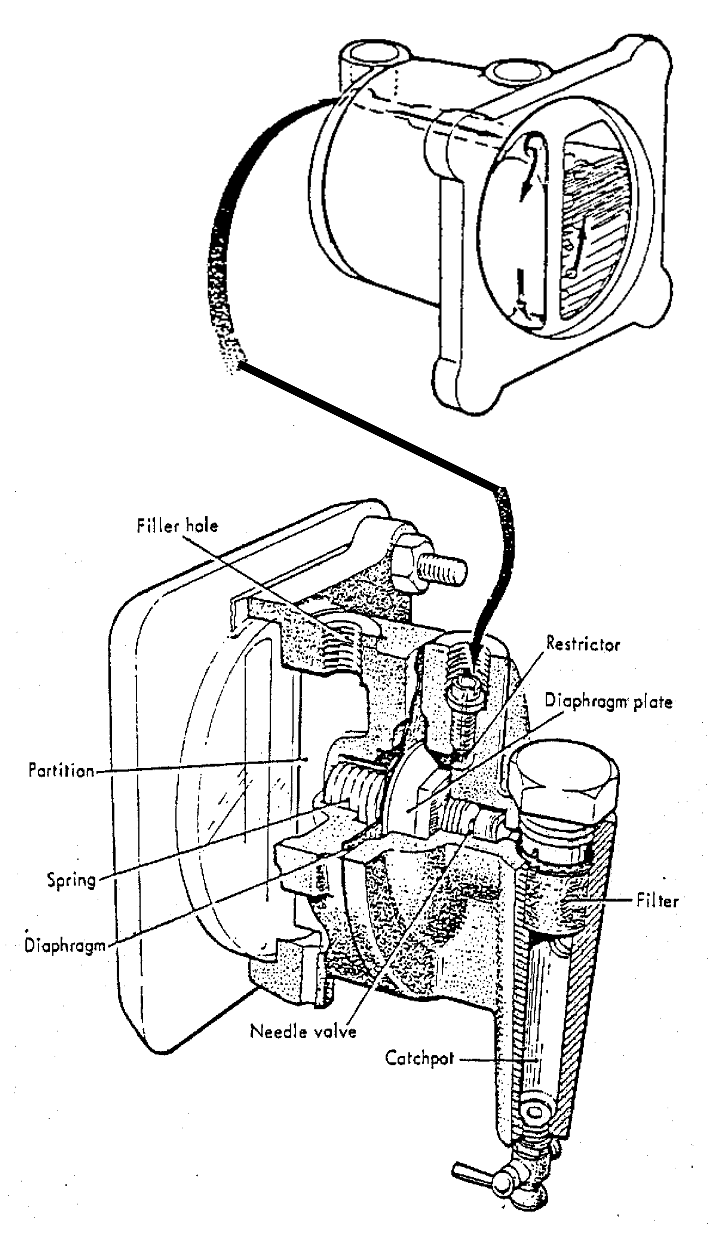
Differential pressure transmitter - can be either pneumatic or electrical, the HP side is connected to the dip pipe arrangement and the low pressure side open to atmosphere. As a general guide, what ever pressure acts on the top of the liquid the same pressure must act on the low pressure side of the transmitter. Calibration of the transmitter is determined by the maximum height of liquid x the density of the liquid.

Dip pipe – this is a pipe which is inserted into the tank through which air (or other purge gas) is blown down to create pressure build up. Material needs to withstand chemical attack and diameter must be small yet large enough to minimise blockage (1/4 or 1/2 inch diameter). The bottom of the dip pipe normally has a 45° mitre at the end and the end off the dip pipe is situated to the point at which the lowest point of level is to be measured, the dip pipe would normally be installed approx 1/2 to 1 inch of the bottom of the tank to minimise the chance of blockage due to silt build up. The most common problems with this part of the installation are leaks and blockage for which isolation valves provide a suitable means of access for rodding out and high pressure(level) simulation.

Pneumerstat - A device used to provide a constant purge gas flow rate into the dip pipe. The operation of this being centred around a restrictor (0.011, 0.017 or 0.022″) and force balance diaphragm arrangement. The diagram below shows this:-

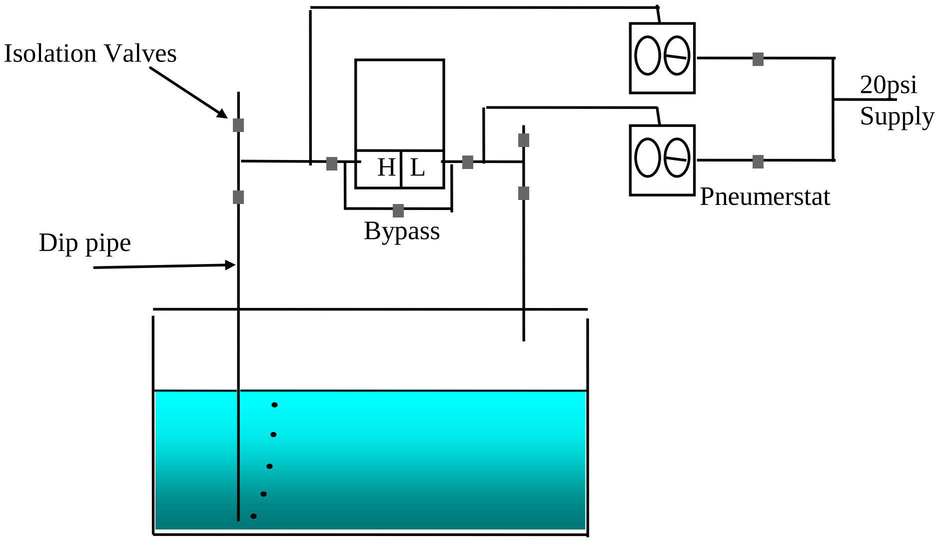
As the air escapes from the restrictor it travels into the front left chamber and via a small hole at the bottom pushing the oil into the right chamber and exit to the dip pipe. The oil merely provides visual indication of the flow. On its way to the front chambers the air also feeds to the other side of the diaphragm and when the pressure increases the pilot valve is closed to minimise and control the air flow.

The larger size restrictors are for long length dip pipes or dense liquids.



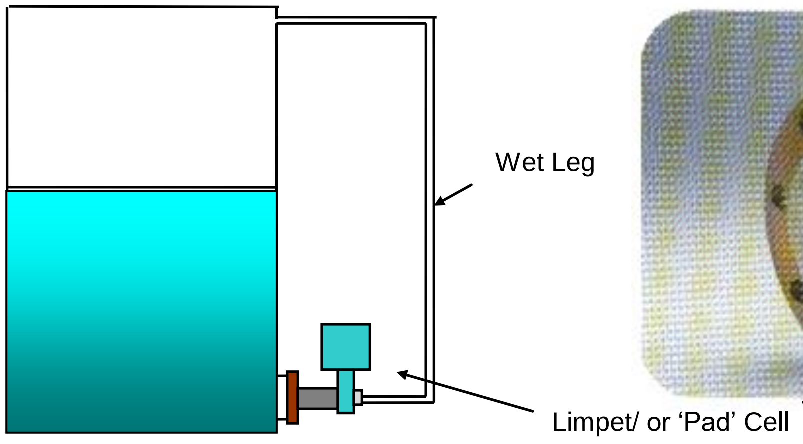
Closed tank installations

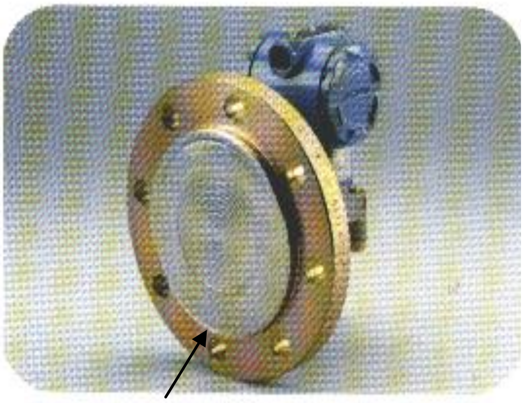
The basic principle of operation of the closed tank level system, can be seen in the next diagram :-



From the previous diagram, when the tank is empty the same pressure acts on both sides of the transmitter therefore creating a zero reading, when the level rises only the high pressure side is affected . If the pressure inside the vessel changes the effect is automatically compensated for. Care should be exercised when operating the isolation valves as the vessel may be under pressure.

When the liquid in the tank is prone to creating blockage of dip pipes (ie:- slurries, viscous etc) the liquid may act directly onto the transmitter diaphragm in a specially designed transmitter known as a **limpet/ or 'Pad' cell.** The following diagram shows a simple limpet cell installation, an isolation valve may be fitted between the 'cell' and the tank:-

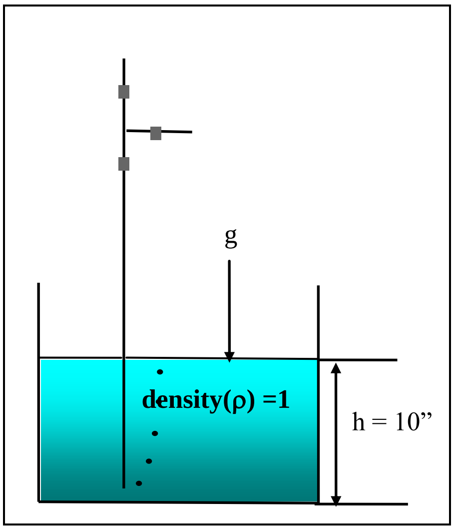




The use of the limpet cell is not restricted to closed vessels only, it may also be used on open tank installations or it may be used to measure density if the level in the tank is kept constant.

Calibration for special installations.

In order to calibrate the transmitter for level measurement the formula P= ρgh needs to be applied. Therefore the calibration range of the transmitter would be:-



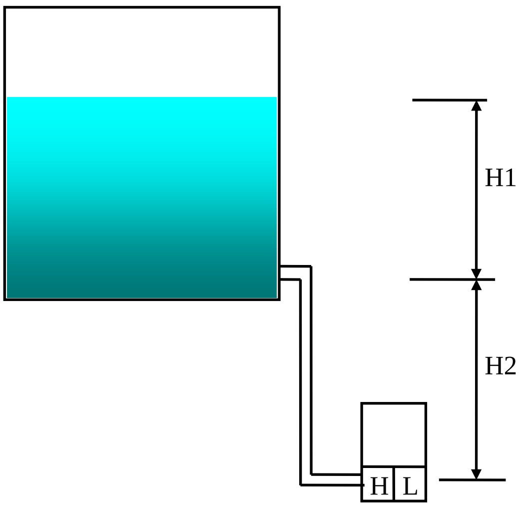
From the diagram:-

P=ρgh therefore

P= 1 x 10 or P= 10 x 1

therefore the calibration of the transmitter would be 0 - 10″wg.

However not all installations are the same particularly when the transmitter is located below the lowest point on the tank and the liquid is acting directly onto the diaphragm rather than via a dip pipe system. In this instance due to the transmitter being located below the point of measurement, liquid build up in the high pressure input leg (static head pressure) would cause the transmitter output to read higher than it should do when the tank is empty effectively creating a raised zero. In order to eliminate this, the output needs to be suppressed (or lowered) this is done via a separate zero adjustment on the transmitter (**elevation/ suppression kit**). The next diagram shows this:-



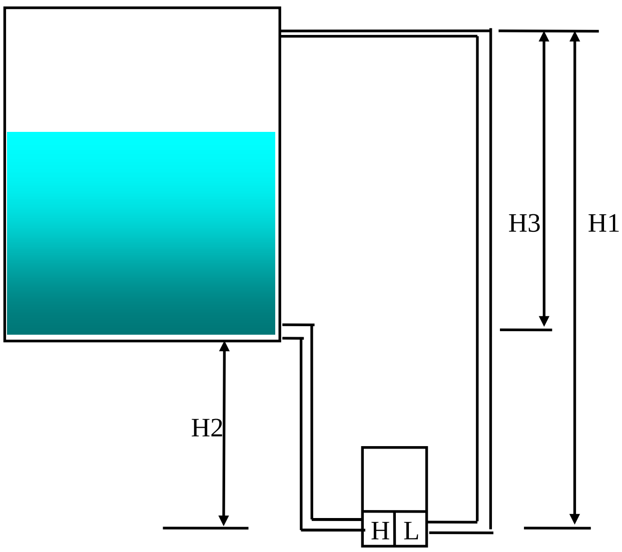
The overall pressure acting on the transmitter is:-
H1 + H2, where H2 is the static head pressure, and H1 is the actual level in the tank. This error (effect of H2) may be eliminated by suppressing the zero.

A further problem exists, that is when the tank is a closed and the gas is a condensable type. A connection between the low pressure side of the transmitter and the top of the tank needs to be made, however any gas going into this low pressure connection would condense and therefore over a period of time there would be a build up of liquid on the low pressure side of the transmitter that would create a negative effect on the indication that would make the indication appear lower than actual. This problem may be eliminated by filling the pipeline with liquid causing a negative zero error when the tank is empty thus would be corrected by *elevating the zero* using the elevation/ suppression kit. This is often referred to as a wet leg system, the liquid filled low pressure side impulse pipeline being called the wet leg. The next diagram shows this:-

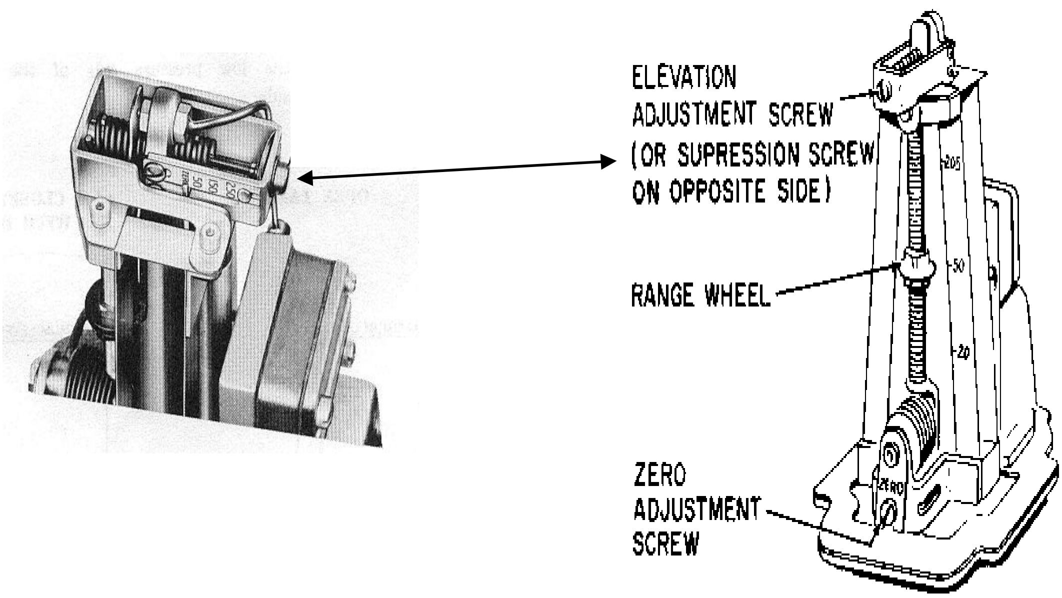
The calibration range of the transmitter (H3) being:-

H3 = H1 - H2

The appropriate pressures would need to be applied to the transmitter during the zero check. The level H3 would be applied afterward to H2 to check the full output.

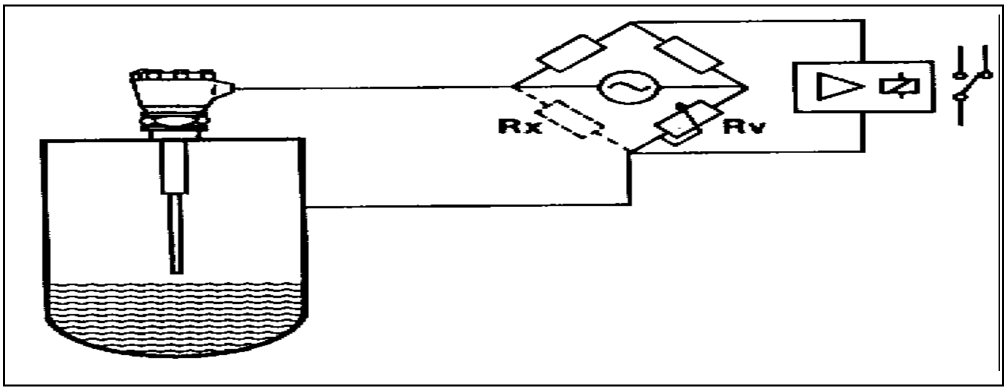


The following diagram shows an example of a suppression/ elevation kit, as fitted to the Foxboro range of pneumatic transmitters:-

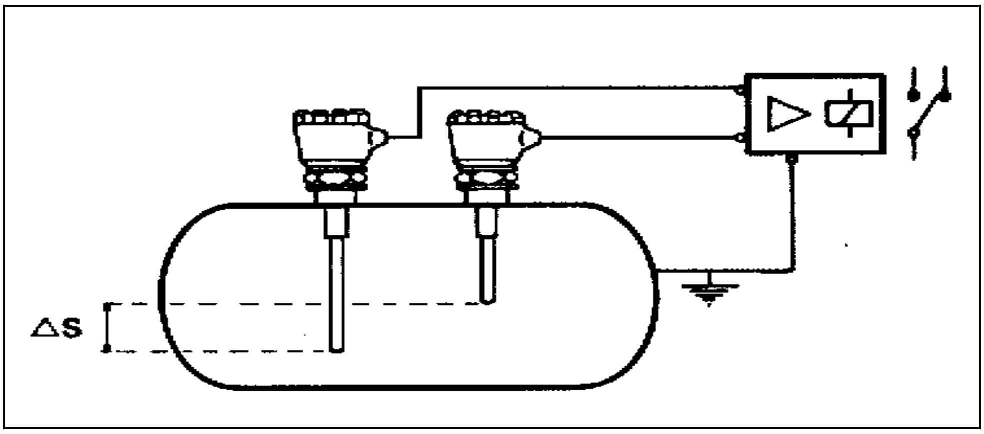


6.5 Conductive level devices.

The basic principle of operation of these systems is that the presence of a product will cause a change in the resistance between two conductors. The conductors in this system would be either (1) a probe inserted into the tank and the tank wall as the other conductor. For measurement to take place the tank wall must be a conductor (ie:- metal), or (2) measurement between two probes if the wall is a non conductor or is internally lined. When the product is not in contact with the wall and the probe, there is a very high or even infinite resistance between them, when the conductive fluid bridges the gap between them the resistance will lower. The change in resistance between the conductors is therefore an indication of the change or presence of liquid level. The power supplies for these system must be A.C to prevent electrolysis taking place. The diagram below shows the principle of operation:-



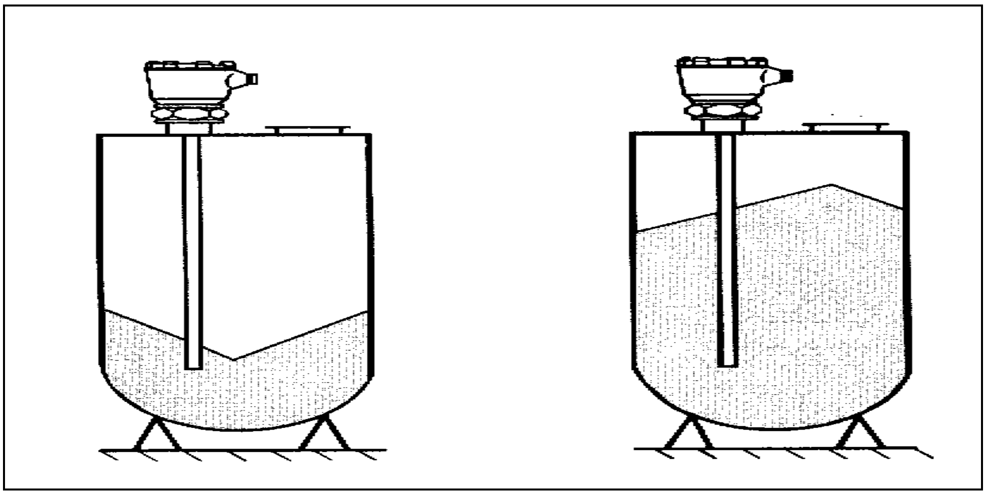
The addition of second and third probes may allow the user to determine the level between the probes. The majority of these systems are used purely for high or low level alarms. The diagram below shows this:-



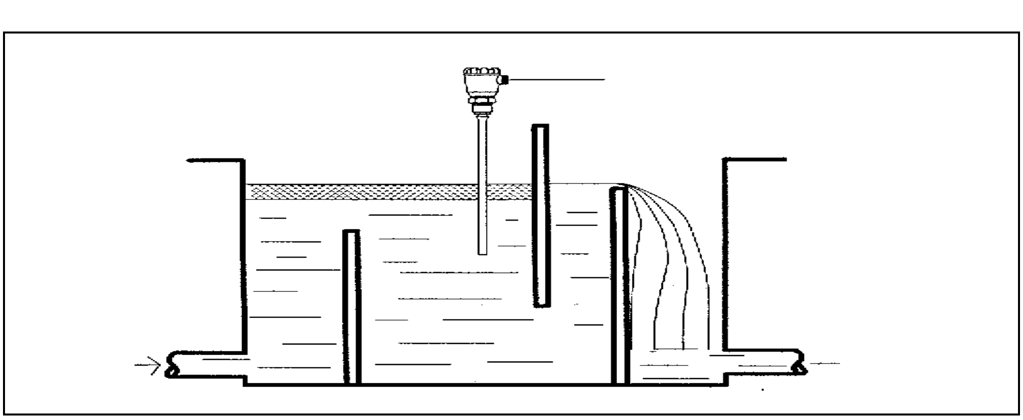
Only about 50mm of conductor at the probe is immersed into the product. The checking of the system merely involves raising the product level between the probe and wall and the lowering it and noting the response. Using the formula R = V/ I the fluid resistance can be found if the applied voltage and current are known. Primarily the main difference between a capacitance and conductivity probe is that none of the inner metal core is exposed with the capacitance probe.

6.6 Capacitance level devices.

The set up of this system is similar to the setup and operation of the conductive type. However in this system it is the capacitance of the fluid which will give rise to the indication of level. Unlike the conductive system this type may be used to constantly monitor the level in the tank rather than just detection at a preset level. The next diagram shows the installation of a capacitance system with the level in its low and high state:-



Because this system works on capacitance, the capacitance between the probe and tank wall will vary as the level rises and falls. Capacitance is described as the ability to store and discharge electrical energy. With a simple capacitor consisting of two plates separated by an insulator known as the dielectric. In these systems the process fluid acts as the dielectric. Again if the tank wall is non conductive a second probe of the same length as the first may be used to act as the second plate. The use of these systems can be similar to the conductive system, however a popular use is to measure liquid interface levels, as the final diagram shows:-



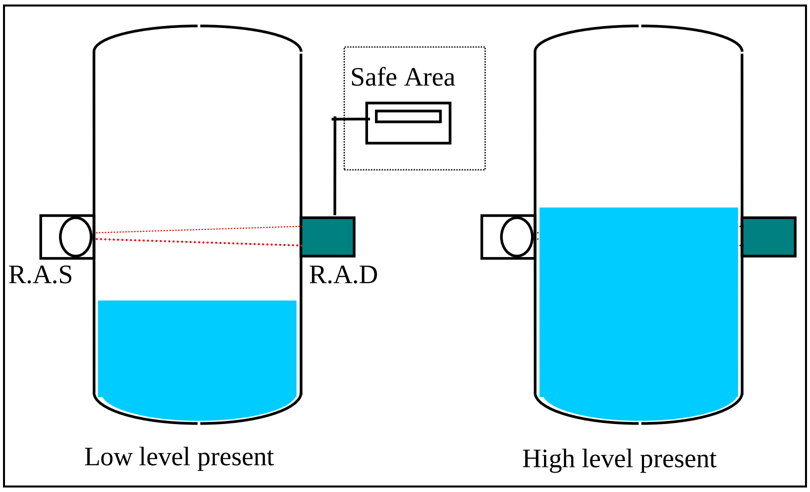
6.7 Radiation level detectors.

The use of radiation as a means of detecting level is particularly advantageous where it is not possible to put probes or sensors into the tank, for example:-

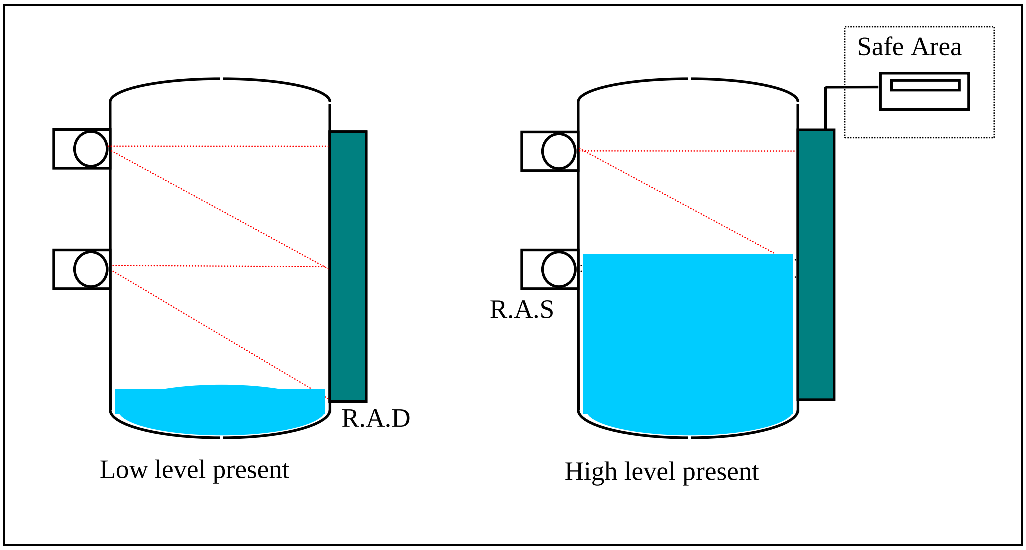
- With very corrosive or viscous substances.
- In reactors or furnaces, at high temperatures and pressures.
- With very coarse and abrasive bulk materials, powders or slurries.

In application a beam of gamma radiation (usually from Cobalt 60 or commonly Caesium 137) is emitted from a source holder, which is often referred to as the *R.A.S* RadioActive Source. Opposite the source is a radiation detector or *R.A.D* (normally a Geiger Muller tube or Geiger counter). When there is no level present the radiation strength at the detector will be just less than at the source (due to distance). When the level rises it absorbs the radiation and blocks it from the detector. The next diagrams/ explanations show the two most common applications of level measurement with this technique:-

High/ Low level alarms-



As the diagrams show when the radiation beam is interrupted by the product, no radiation hits the detector, and as a result the output to the electronics would initiate a high level alarm warning. In addition to alarm use, this system may also be used for indicating the actual level as the next diagrams show:-



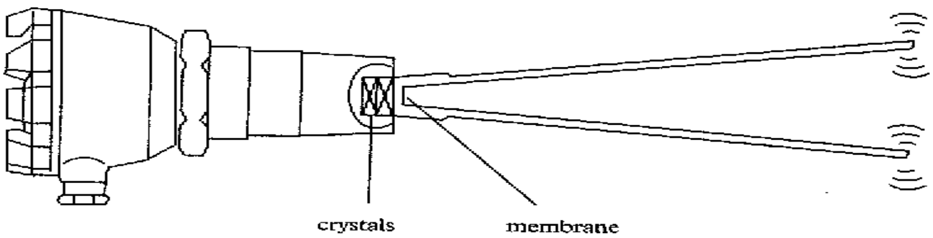
In the diagrams above the first would show a low level near 5%, whereas the second diagram would be indicating a level in the region of 60%, therefore the reduction of radiation intensity creates a higher output level and level reading.

It is important to note that use of these systems is safe, and that strict guidelines must be followed when carrying out any maintenance. The user of the equipment (the company) must also be licensed to do so.

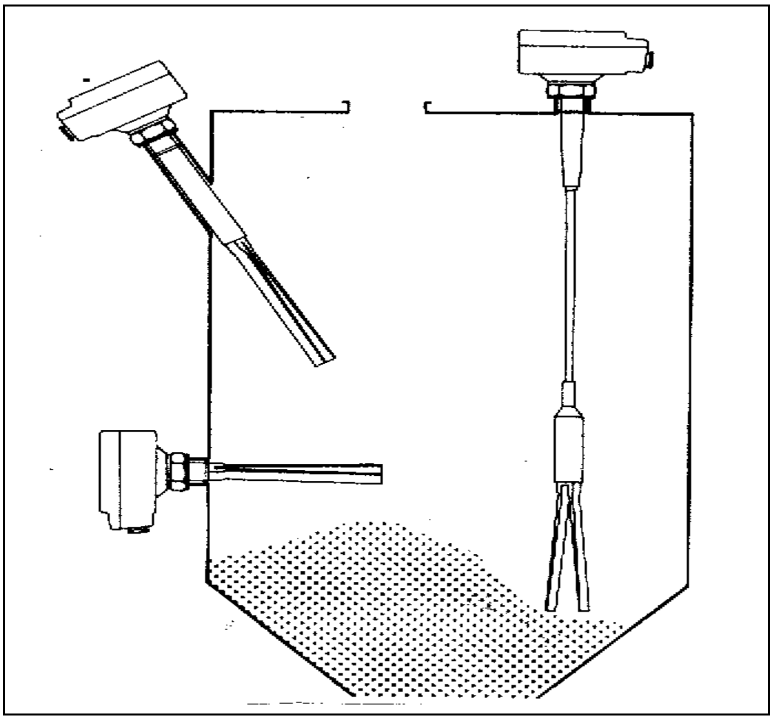
Also important to note is that using gamma radiation in no way affects the product and is thus safe for use afterward, it can also be used on foodstuffs without risk.

6.8 Electromechanical level devices.

By far the most common device in this section is the tuning fork. This device consists of a tuning fork whose natural vibration frequency is set by electronics, without the presence of product the device is set to vibrate freely, with the frequency of vibration being monitored. As the liquid level or more particularly powder, rises between the vibrating



forks the natural vibration is dampened or stopped, this is detected within the electronics and a switched output may be generated to create or initiate an alarm. The diagram below shows typical uses of this system:-



In some systems it is common to see a series of these units mounted up/ into the vessel wall this detects rising and falling product between the sensors, or alternatively the sensor may be suspended into the tank from the top, this is common for high level alarms in large silo's or storage tanks.

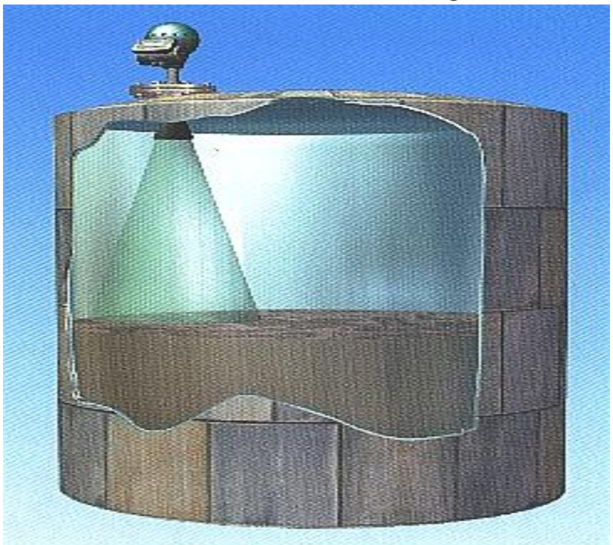
6.9 Miscellaneous level detection techniques.

Weighing.

This method is becoming unpopular as technology changes. It was first necessary to weigh the vessel without contents to create a zero reading, and then filling the tank to gain the maximum weight when the tank is full. From this determinations of contents could be gauged by weight. The systems to this were often quite large depending on the size of the tank or vessel, this would immediately make the systems very costly. By far the most common use for this method is in road tanker loading bays, where the truck and trailer would be weighed with the trailer empty and then filled. Whereas early systems would have resembled a large weighing scale, modern equivalents would use strain gauges.

Ultrasonic and radar level detection.

The principle of operation of these devices is based on the measurement of the travel time of a sound or microwave signal transmitted and received from the same sensor after reflection off a liquid or semi solid product within a process vessel. The time of travel of the signal pulse being a direct measure of the height as the distance travelled by the sound /microwave pulse is equal to the travel time in seconds multiplied by the speed travel ie: speed of sound(in metres per second). With sound travelling at 331m/s in air @ 0 degrees C. It is a similar principle to a radar on an aircraft determining its height above ground or sea level.



One particular example of the use of this method is in the paper industry, where the paper pulp is held and moved through plant vessels. A this is a non – invasive method is use is ideal in these circumstances. Other uses could include in storage tanks, tank farms, and on products such as powders or even petrol and oil

'Smart' level measurement.

As with all instrumentation techniques, the use of Hart communication protocol easily allows modern devices to be incorporated into the latest of plant control and monitoring systems.