5th Semester

INSTRUMENTATION AND CONTROL ENGINEERING

SUBJECT: PROCESS INSTRUMENTATION

SUBJECT CODE : 181554

DISCLAIMER

Process instrumentation

Unit 1: introduction

Various Process Variables are :

•Flow.

•Pressure.

•Temperature.

•Level.

Flow: Any fluids or liquids flowing from one place to another place is called flow and it is defined as volume per unit of time at specified temperature and pressure Conditions, is generally measured by positive-displacement or rate meters.

Units: kg / hr, litter / min, gallon / min, m3 / hr, Nm3 / hr. (Gases)

Pressure: It is defined as Force per unit Area. P = F/A

Units : bar, Pascal, kg / cm2, lb / in2.\

Level: The height of the water column, liquid and powder etc., at the desired measurement of height between minimum level points to maximum level point is called level. The measurement principle is, head pressure method.

Units: Meters, mm, cm, percentage.

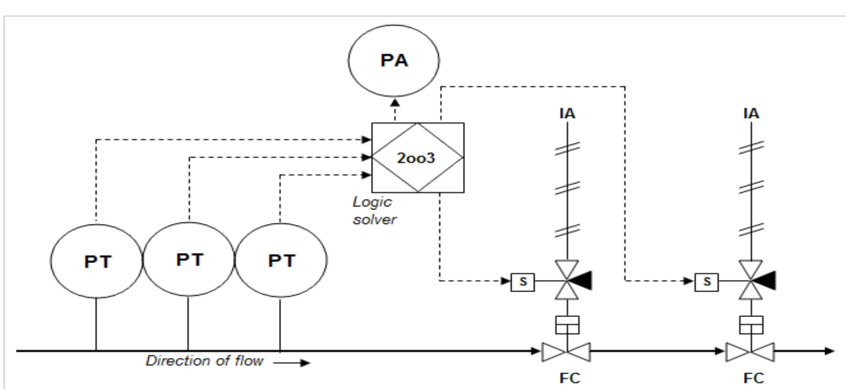
Temperature: It is the degree of hotness or coldness of a body is called temperature. Units : Degree Centigrade, Degree Fahrenheit, Degree Kelvin, Degree Rankin.

Pressure (symbol: p or P) is the force applied perpendicular to the surface of an object per **unit** area over which that force is distributed.

Pressure	
SI **unit**	Pascal [Pa]
In SI base **units**	1 N/m^2, 1 $kg/(m \cdot s^2)$, or 1 J/m^3
Derivations from other quantities	p = F / A
Dimension	$M L^{-1} T^{-2}$

Pressure Variable:

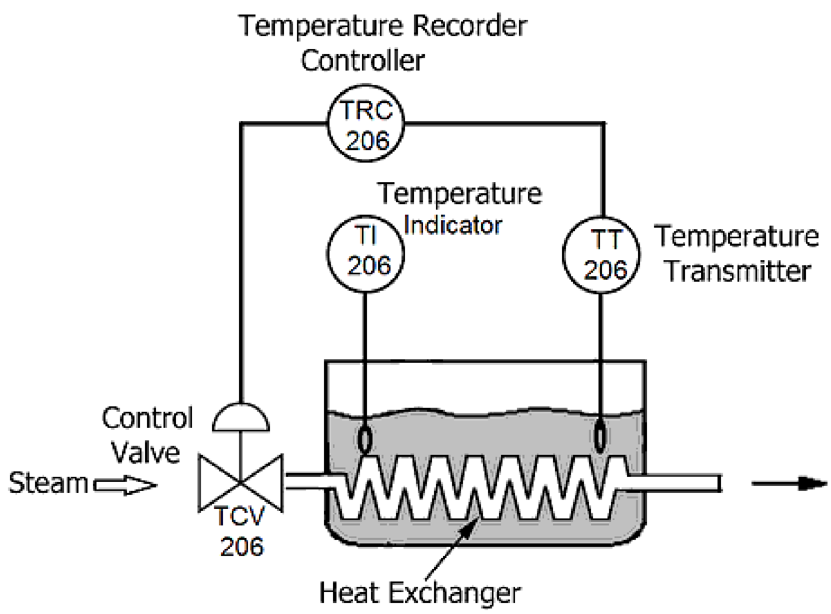
Pressure is a term used to describe the amount of force applied to a specific unit area. Below shows a flow channel of fluid from a compressor.



you open the block valve, air is released to the atmosphere, so the pressure inside the receiver decreases. If you close the control valve, you keep the air inside the receiver and the pressure increases.The process variable that we are controlling is called PRESSURE.

Temperature Variable:

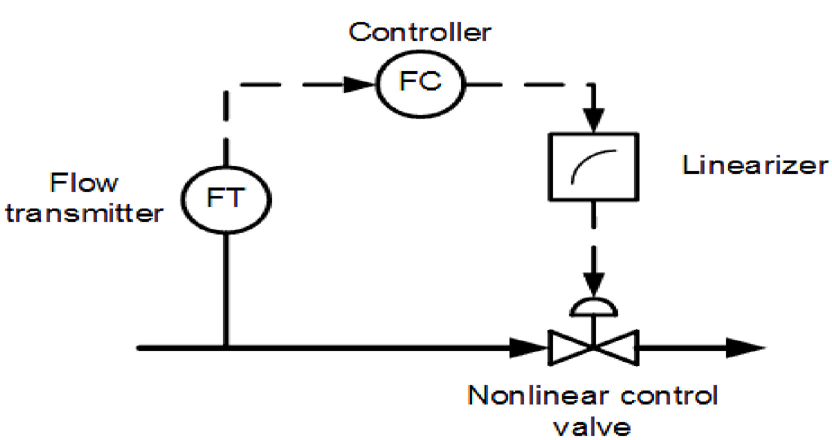
Temperature is a measurement of how hot or how cold an object is. Below figure shows a temperature control unit.



in the vessel is heated by the heat exchanger. Measuring the temperature the steam flow to the exchanger is controlled. Temperature changes when the amount of steam is changed. The process variable is called Temperature.

Flow variable:

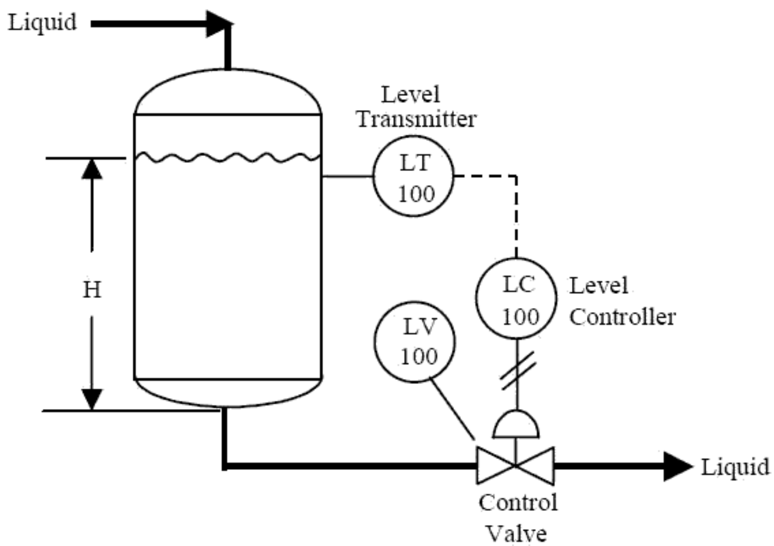
Flow is the movement of fluid inside a pipe in a given direction. Figure below shows the flow control loop.



A valve in the flow channel controls the flow through the pipeline. The greater the valve opening the greater the water flow inside the pipe. Here we are controlling the flow the fluid passing through the pipeline, so the process variable is flow.

Level variable:

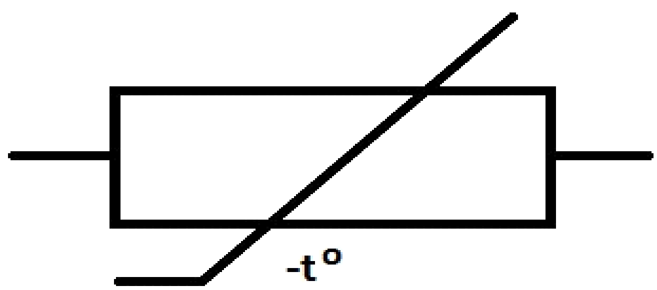
The level in the tank change up and down depending up the fluid in the tank. A control valve is installed in the output line to control the level of the tank.



the process variable is level. You can change the level by closing or opening the control valve. If you close the valve, the level increases. If you open the valve, the level decreases.

Unit2: temperature measurement

Thermistors: The thermistor is a device that changes its electrical resistance with temperature. In particular materials with predictable values of change are most desirable. The original thermistors were made of loops of resistance wire, but the typical thermistor in use today is a sintered semiconductor material that is capable of large changes in resistance for a small change in temperature.



NTC Thermistor Symbol - IEC Standard

www.CircuitsToday.com

These devices exhibit a negative temperature coefficient, meaning that as the temperature increases the resistance of the element decreases.

These have extremely good accuracy, ranging around 0.1° to 0.2°C working over a range of 0 to 100°C. These are still the most accurate transducers manufactured for temperature measurement, however thermistors are non-liner in response. This leads to additional work to create a linear output and significantly adds to the error of the final reading.

A typical thermistor can be less than a tenth of an inch in diameter and cost around fifteen dollars in single quantities, and less than a dollar in production quantities.

A linear response device will cost a few dollars more. In addition to the non-linear response, careful attention must be paid to the circuit design, or an undesirable effect called self heating will significantly affect the reading. Since the device is a resistor, the only viable method of measuring the sensed temperature is to apply a small known current across the device and measure the resulting voltage. If the current flow is too high, the resistor will dissipate energy in the form of heat. This heat, generated by the resistor can significantly affect the temperature that is being sensed. The total heat dissipated by the thermistor in the circuit should be 1mw/°C or less

in air, but can be as high as 8mw/°C in liquid. While the resistance values for thermistors vary greatly across manufacturers and models of devices, a table is provided in the appendix showing the resistance vs temperature values for the non-linear thermistors available from Omega Engineering.

What is a Thermocouple?

The thermocouple can be defined as a kind of temperature sensor that is used to measure the temperature at one specific point in the form of the EMF or an electric current. This sensor comprises two dissimilar metal wires that are connected together at one junction. The temperature can be measured at this junction, and the change in temperature of the metal wire stimulates the voltages.

The amount of EMF generated in the thermocouple is very minute (millivolts), so very sensitive devices must be utilized for calculating the e.m.f produced in the circuit. The common devices used to calculate the e.m.f are voltage balancing potentiometer and the ordinary galvanometer. From these two, a balancing potentiometer is utilized physically or mechanically.

Thermocouple Working Principle:

The **thermocouple principle** mainly depends on the three effects namely Seebeck, Peltier and Thompson.

See beck-effect

This type of effect occurs among two dissimilar metals. When the heat offers to any one of the metal wire, then the flow of electrons supplies from hot metal wire to cold metal wire. Therefore, direct current stimulates in the circuit.

Peltier-effect

This Peltier effect is opposite to the Seebeck effect. This effect states that the difference of the temperature can be formed among any two dissimilar conductors by applying the potential variation among them.

Thompson-effect

This effect states that as two disparate metals fix together & if they form two joints then the voltage induces the total conductor's length due to the gradient of temperature. This is a physical word that demonstrates the change in rate and direction of temperature at an exact position.

Construction of Thermocouple

The construction of the thermocouple is shown below. It comprises of two different metal wires and that are connected together at the junction end. The junction thinks as the measuring end. The end of the junction is classified into three type's namely ungrounded, grounded and exposed junction.

Ungrounded-Junction

In this type of junction, the conductors are totally separated from the protecting cover. The applications of this junction mainly include high-pressure application works. The main benefit of using this function is to decrease the stray magnetic field effect.

Grounded-Junction

In this type of junction, the metal wires as well as protecting cover are connected together. This function is used to measure the temperature in the acidic atmosphere, and it supplies resistance to the noise.

Exposed-Junction

The exposed junction is applicable in the areas where a quick response is required. This type of junction is used to measure the gas temperature. The metal used to make the thermocouple basically depends on the calculating range of temperature.

In the above diagram, the junctions are denoted by P & Q, and the temperatures are denoted by T1, & T2. When the temperature of the junction is dissimilar from each other, then the electromagnetic force generates in the circuit.

Advantages & Disadvantages of Thermocouple

The advantages include the following.

- Accuracy is high
- It is Robust and can be used in environments like harsh as well as high vibration.
- The thermal reaction is fast
- The operating range of the temperature is wide.
- Wide operating temperature range
- Cost is low and extremely consistent

The disadvantages include the following.

- Nonlinearity
- Least stability
- Low voltage
- Reference is required
- least sensitivity
- The thermocouple recalibration is hard

Thermocouple Applications

Some of the applications of thermocouple include the following.

- These are used as the temperature sensors in thermostats in offices, homes, offices & businesses.
- These are used in industries for monitoring temperatures of metals in iron, aluminum, and metal.
- These are used in the food industry for cryogenic and Low-temperature applications. Thermocouples are used as a heat pump for performing thermoelectric cooling.
- These are used to test temperature in the chemical plants, petroleum plants.
- These are used in gas machines for detecting the pilot flame.

Thus, this is all about an overview of the thermocouple. From the above information finally, we can conclude that the measurement of thermocouple output can be calculated by using methods like a multimeter, potentiometer, and amplifier by output devices. The main purpose of the thermocouple is to build consistent & direct temperature measurements in several different applications.

What is Thermistor :

The thermistor is a word formed by combining thermal with a resistor. Thermistors such as RTDs are temperature – sensitive resistors. Thermistors are non-linear devices. Their resistance will decrease with an increase in temperature but at a much faste/rate than that of RTDs. The resistance can change by more than 1000 times. As a result, thermistors can sense minute changes in temperature which are undetected RTDs and thermocouples. The basic equation is given by

$$R_t = R_0 \, e^{\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)}$$

where R_0 is the resistance at a reference temperature T_0°C,
R_t is the resistance at a measured temperature T°C and
β is the constant

The equation uses a reference temperature and resistance with a constant for the device to predict the resistance at another temperature. The expression can be rearranged to calculate the temperature given the resistance.

$$T = \frac{\beta T_0}{T_0 \ln\left(\frac{R_t}{R_0}\right) + \beta}$$

Basic Principle of Thermistors :

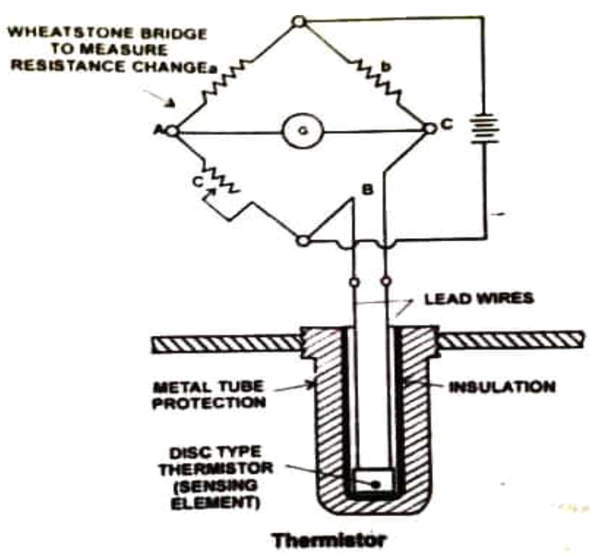
- Thermistors are non-metallic resistors that is semiconductors of a ceramic material having a negative coefficient of resistance.
- When the thermistor is subjected to a temperature change, the resistance of the thermistor changes. This change in resistance of the thermistor becomes a measure of the change in temperature when calibrated.
- The resistance of the thermistor decreases with an increase in temperature and vice-versa.

Parts Of Thermistors :

The main parts of a thermistor are as follows:

- A metal tube which houses a thermistor sensing element.
- An insulation separates the thermistor sensing element from the metal tube.
- Lead wires are drawn out from the thermistor sensing element as shown in the diagram.
- The metal tube, sensing element, and leads together become a thermistor used to measure temperature.
- The leads of the thermistor are connected to a wheat stone bridge as shown in the diagram.

Thermistor Diagram ;



Thermistor diagram

Working Of thermistor:

The procedure for measuring temperature in an as follows:

- A known constant current is passed through the thermistor sensing element and the initial resistance of the thermistor sensing element is measured using the wheat stone bridge.
- Now the thermistor is introduced into the medium whose temperature is to be measured. Due to a change in temperature (assume the change is in the positive direction), the sensing element changes (decreases). (It should be noted that the same constant current is passed through the sensing element during measurement).
- Now this change in resistance of the sensing element of the thermistor is measured using the wheat stone bridge. This change in resistance becomes a measure of temperature when calibrated.

Types of Thermistors:

There are two types of thermistors based on the lead attachment:

1. Beads

2. Metallized surface-contact.

Bead types have platinum wires sintered into a ceramic body (bead) as shown in figure . (a) Metallized surface-contact thermistors are called chips or flakes. In contrast to bead types, leads are not sintered directly into the ceramic. Instead, the sintered ceramic is coated with a metallic contact shown in Figure 1.43(b). Either the chip manufacturer or user attaches leads to this contact. One advantage of chip thermistors over bead types is that chips are easily trimmed by cutting or grinding. Thus, they are easy to match and therefore, they are interchangeable. While matched bead thermistors are available, they cost more than interchangeable chips.

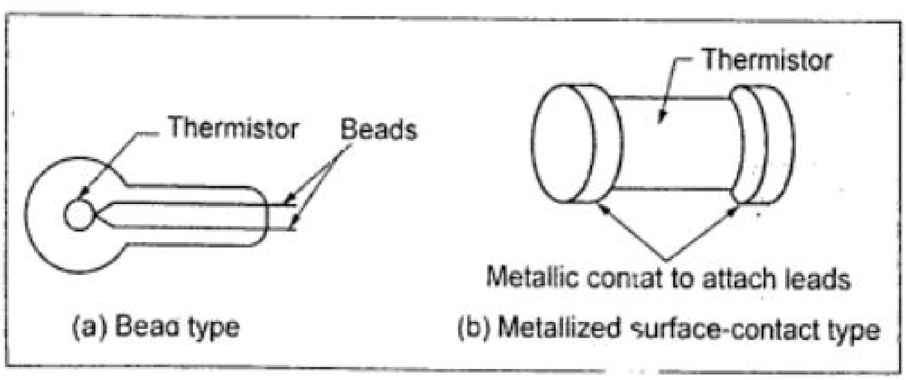


Figure 1.43 Thermistors

Advantages of thermistors

- It produces more accurate output and fast.
- It is suitable for the usage in remote location.
- It can be manufactured in almost any shape and size.
- A high degree of accuracy is obtained.
- Good stability and repeatability are ensured.
- It has the ability to withstand mechanical and electrical stresses.

Disadvantages of thermistors

- It produces highly non-linear behavior over its range of operation.
- It has a limited measuring range.
- Self-heating may occur.
- A power supply is required.
- It is fragile in nature.

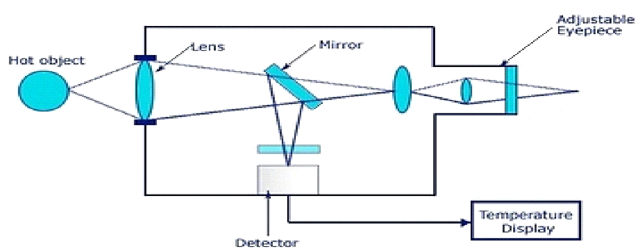
Applications of thermisters :

- As the thermistors have good sensitivity, they are used for measuring varying temperatures.
- They are used for temperature compensation in electronic equipment.
- They are used in time delay circuits.
- They are used to measure thermal conductivity.
- They are used to measure the pressure and flow of liquids.
- Used in precision temperature measurement (in the range of 100 degrees C to 300 degrees C).

Pyrometers:

Pyrometers are used to measure the temperature which is difficult to measure. They are non-contact devices, used to measure temperature above 1500 degree Celsius, contact devices may melt at this temperature.

Construction:



The pyrometer has an optical system, including a lens, mirrors and adjustable eyepiece and a detector circuit.

An optical system collects the visible and infrared energy from an object and focuses it on a detector.

Working:

The heat energy emitted from the hot body is allowed passed on to the lens. Which collects it and focused on to the detector with the mirror and eyepiece arrangement.

Now the detector converts the radiation energy into an electrical signal. Thermophiles and photon multipliers are commonly used detectors. Detectors produce the reading and shows in the temperature display.

Advantages:

- Low cost
- N need of contact

Fast response speed

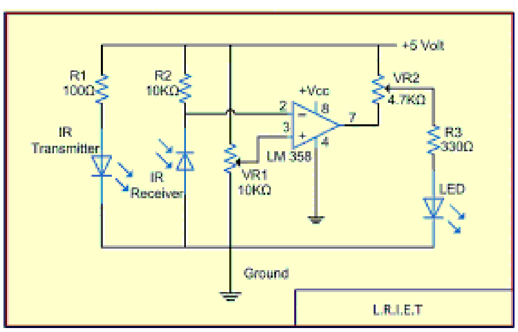
Disadvantages:

- Emissitive error are introduced
- Error due to the obsortion of the radiation by the carbon dioxide , water or other apparently transparent gases

.What is Infrared Sensor:

IR sensor is a simple electronic device which emits and detects IR radiation in order to find out certain objects/obstacles in its range. Some of its features are heat and motion sensing.

IR sensors use infrared radiation of wavelength between 0.75 to 1000µm which falls between visible and microwave regions of electromagnetic spectrum. IR region is not visible to human eyes. Infrared spectrum is categorized into three regions based on its wavelength i.e. Near Infrared, Mid Infrared, Far Infrared.



Wavelength Regions of Infrared Spectrum

- Near IR – 0.75µm to 3 µm
- Mid IR – 3 µm to 6 µm
- Far IR – > 6 µm

Working Principle of Infrared Sensor

Infrared Sensors works on three fundamental Physics laws:

- **Planck's Radiation Law**: Any object whose temperature is not equal to absolute Zero (0 Kelvin) emits radiation.
- **Stephan Boltzmann Law**: The total energy emitted at all wavelengths by a black body is related to the absolute temperature.
- **Wein's Displacement Law:** Objects of different temperature emit spectra that peak at different wavelengths that is inversely proportional to Temperature.

Key Elements of Infrared Detection System

The key elements of Infrared Detection System are:

IR Transmitter

IR Transmitter acts as source for IR radiation. According to Plank's Radiation Law, every object is a source of IR radiation at temp T above 0 Kelvin. In most cases black body radiators, tungsten lamps, silicon carbide, infrared lasers, LEDs of infrared wavelength are used as sources.

Transmission Medium

As the name suggests, Transmission Medium provides passage for the radiation to reach from IR Transmitter to IR Receiver. Vacuum, atmosphere and optical fibers are used as medium.

IR receiver

Generally IR receivers are photo diode and photo transistors. They are capable of detecting infrared radiation. Hence IR receiver is also called as IR detector. Variety of receivers are available based on wavelength, voltage and package.

IR Transmitter and Receivers are selected with matching parameters. Some of deciding specifications of receivers are photosensitivity or responsivity, noise equivalent power and detectivity.

How Infrared Sensor Works:

An Infrared Sensor works in the following sequence:

- IR source (transmitter) is used to emit radiation of required wavelength.
- This radiation reaches the object and is reflected back.
- The reflected radiation is detected by the IR receiver.
- The IR Receiver detected radiation is then further processed based on its intensity. Generally, IR Receiver output is small and amplifiers are used to amplify the detected signal.

Typical working of IR sensor detection system can be understood by Figure 2 below.

Incidence in an IR Detection System may be direct or indirect. In case of Direct Incidence, there is no hindrance in between transmitter and receiver. Whereas, in Indirect Incidence IR Transmitter and Receiver are kept side by side and the object is in front of them.

Types of Infrared Sensor

IR sensors can be classified in two types based on presence of IR source:

- Active Infrared Sensor
- Passive Infrared Sensor

Active Infrared Sensor

Active Infrared Sensor contains both transmitter and receiver. Most of the cases LED or laser diode is used as source. LED for non-imaging IR sensor and laser diode for imaging IR sensor are used.Active IR Sensor works by radiating energy, received and detected by detector and further processed by signal processor in order to fetch information required.

Examples of Active IR Sensor: Break Beam Sensor, Reflectance Sensor.

Passive Infrared Sensor:

Passive Infrared Sensor contains detectors alone. There won't be a transmitter component.

These type of sensors use object as IR source/ transmitter. Object radiates energy and it is detected by IR receivers. A Signal processor is then used to interpret the signal to fetch information required.

Example of Passive IR Sensor: Thermocouple-Thermopile, Bolometer, Pyro-Electric Detector, etc.

There are two types of Passive Infrared Sensor:

- Thermal Infrared Sensor
- Quantum Infrared Sensor

Thermal Infrared Sensor

Thermal Infrared sensors are independent of wavelength. They use heat as energy source.

Thermal detectors are slow with their detection time and response time.

Quantum Infrared Sensor:

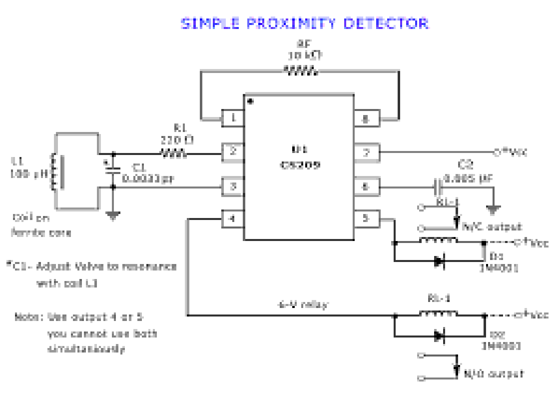
Quantum Infrared Sensor are dependent on wavelengths. They have high detection time and response time. These type of IR sensors require frequent cooling for precise measurement.

Applications of Infrared Sensor:

IR sensors have found their applications in most of today's equipment. Following are the list of sensors which are named after its usage.

Proximity Sensor:

These are used in smart phones to find distance of object. They use principle called Reflective Indirect Incidence. Radiation transmitted by transmitter is received by receiver after being reflected from object. Distance is calculated based on the intensity of radiation received.



Item Counter:

This use direct incidence method to count the items. Constant radiation is maintained in between transmitter and receiver. As soon as object cuts the radiation, item is detected and count is increased. The same count is shown on display system.

Burglar Alarm

This is one of widely and commonly used sensor application. It is another example for direct incidence method. It works similar to item counter, where transmitter and receiver are kept on both the sides of door frame. Constant radiation is maintained between transmitter and receiver, whenever object crosses path alarm starts off.

Radiation Thermometers:

It is one of key application of Infrared sensors. Working of radiation thermometer depends on temperature and type of object.

These have faster response and easy pattern measurements. They can do measurement without direct contact of object.

Human Body Detection

This method is used in intrusion detection, auto light switches, etc. Intrusion alarm system sense temperature of human body.

If the temperature is more than threshold value, it sets on the alarms. It uses electromagnetic system which is suitable for human body in order to protect it from unwanted harmful radiations.

Gas Analyzers:

Gas Analyzers are used to measure gas density by using absorption properties of gas in IR region. Dispersive and Non Dispersive types of gas analyzers are available.

Other Applications:

IR sensors are also used in IR imaging devices, optical power meters, sorting devices, missile guidance, remote sensing, flame monitors, moisture analyzers, night vision devices, infrared astronomy, rail safety, etc.

Advantages of Infrared Sensor:

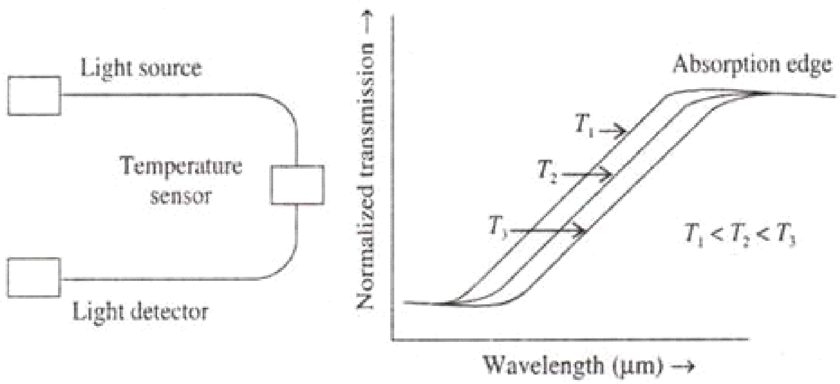
The advantages of Infrared Sensor are:

- Their low power requirements make them suitable for most electronic devices such as laptops, telephones, PDAs.
- They are capable of detecting motion in presence/ absence of light almost with same reliability.
- They do not require contact with object to for detection.
- There is no leakage of data due to beam directionality IR radiation.
- They are not affected by corrosion or oxidation.
- They have very strong noise immunity.

Disadvantages of Infrared Sensor:

The disadvantages of Infrared Sensor are:

- Required Line of sight.
- Get blocked by common objects.
- Limited range.
- Can be affected by Environmental conditions such as rain, fog, dust, pollution.
- Transmission Data rate is slow.



Fiber Optic Temperature System

Figure-1: Non-Interferometric fiber optic temperature sensor

The simple non-interferometric type sensor consists of multi-mode optical fiber and temperature sensitive material. The temperature sensing materials include GaAs, CdTe, Si etc. GaAs is preferred over others due to its better wavelength variation with temperature. These materials exhibit changes in their optical parameters such as absorption, transmission and reflection qualities with variation in the temperature.

The working principle depends on phenomenon of energy bandgap shrinkage with increase in the temperature of such semiconductor materials. The figure-1 depicts schematic of such temperature sensor and its temperature vs wavelength curve.

In this sensor type, thin semiconductor ship is used as active element. This active element is sandwiched between light source (e.g. LED or laser) and photodetector. In this sensor, constant intensity of light signal us modulated by external temperature when it travels through the optical fiber cable. Moreover its wavelength shifts towards higher side due to gradual increase in the temperature. This is due to optical absorption edge.

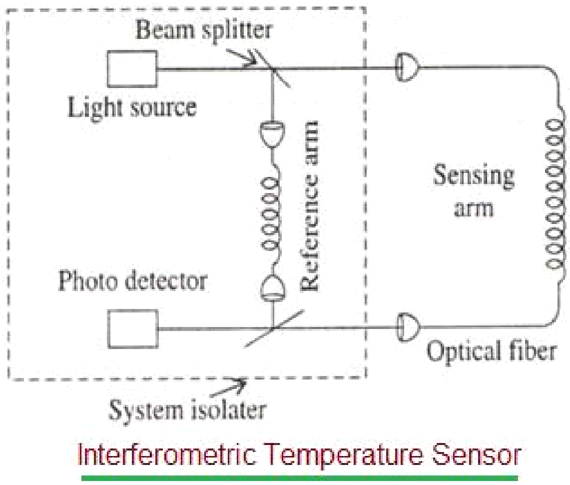


Figure-2: Interferometric fiber optic temperature sensor .

This sensor offers flexible geometry and higher sensitivities. Hence it can be used for measurement of various measuranads such as temperature, pressure, rotation, strain etc.

It works based on phase modulation by external measurands. Here phase of the beam through sensing fiber is compared with the reference beam. Beam splitter is used in the design of such Mach-Zehnder Interferometric sensor as shown in the figure. Beam splitter divides the light beam into two parts, one is launched into the sensing part and the other is used as reference.

Benefits or advantages of Fiber Optic Temperature Sensor

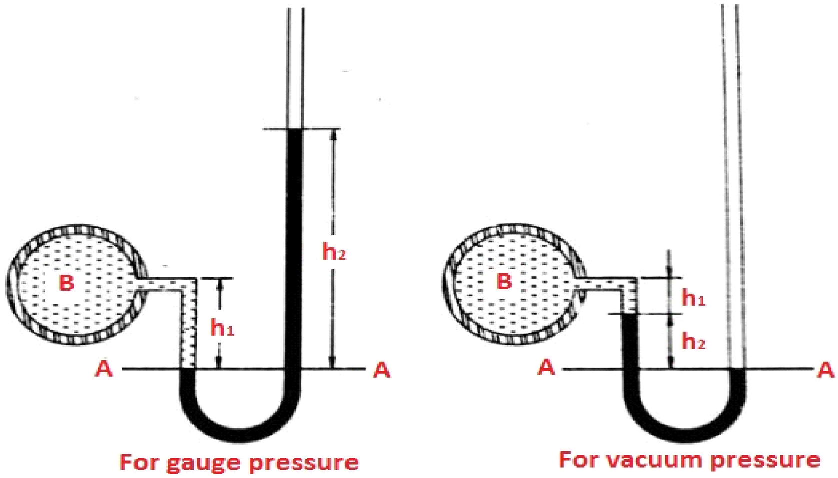
Following are the benefits or **advantages of Fiber Optic Temperature Sensor**:

- ➡ It is immune from nearby EM (electromagnetic) and stray radiation.
- ➡ It can be used in environments where high levels of electrical interference exists or where intrinsic safety is a concern.
- ➡ It (i.e. non-interferometry type) offers greater accuracy (+/- 1º) and faster response time (~2 sec).
- ➡ It is light in weight and compact in size.
- ➡ It is cheaper due to low manufacturing cost.
- ➡ It supports wide temperature range of measurement from -10 ºC to 300 ºC. The GaAs offers better wavelength variation with temperature.

Unit 3:

. U-tube Manometer

As shown in the figure it consists of a glass tube bent in V-shape, with one end is connected to a point at which pressure is to be measured and the other end remains open to the atmosphere.



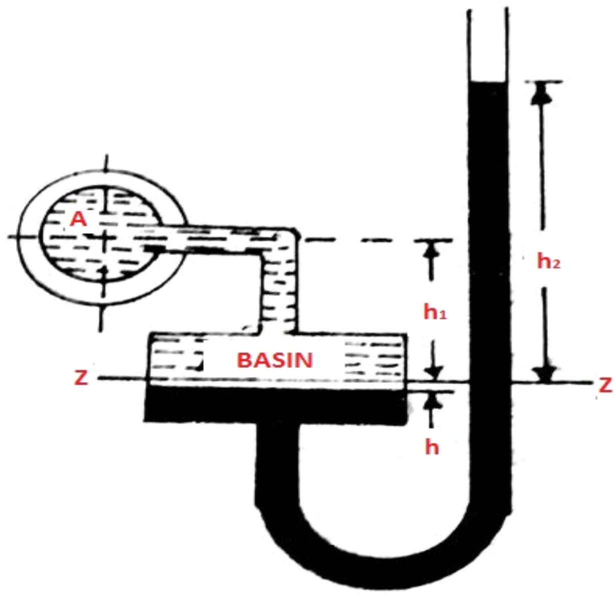
U-tube Manometer

The tube carries mercury or any other liquid or fluid whose specific gravity is much higher than the specific gravity of the liquid whose pressure is to be measured.

- For gauge pressure
- For vacuum pressure

3. Single Column Manometer

Consider a vertical tube micromanometer connected to a pipe containing light liquid under very high pressure. The pressure in the pipe will force the lighter liquid in the basin to push the heavier liquid downwards.

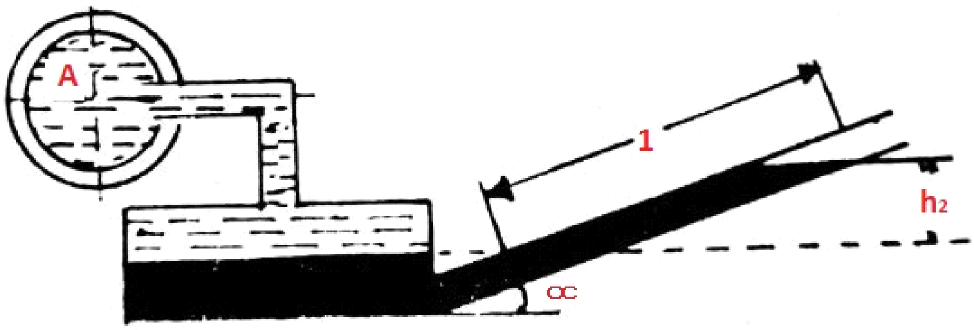


Single Column Manometer

Due to the larger area of the basin, the fall of a heavy liquid level will be very small. This downward movement of heavy liquid into the basin will result in a significant rise of heavy liquid in the right limb.

4. Inclined Tube Manometer

If the vertical tube of the micromanometer is made inclined as shown in figure then it is called inclined tube micromanometer.



Inclined Tube Manometer

This type of inclined micromanometer is more sensitive than the vertical tube type. Due to inclination, the distance moved by the heavy liquid in the right limb is comparatively more. Thus it can give a higher reading for the given pressure.

Differential Manometer

The differential manometer is a device used to measure the pressure difference between two points in a pipe or in two different pipes.

A differential manometer consists of a U-tube, containing a heavy liquid, with two ends connected by points whose pressure difference is to be measured:

Types of differential manometers are:

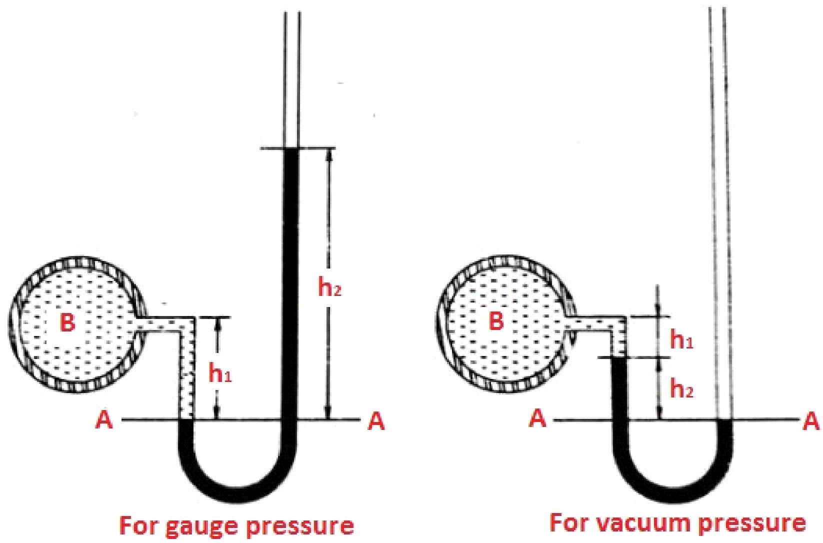
- Two piezometer manometer
- U-tube differential manometer
- Inverted differential manometer

1. Two Piezometer Manometer

It consists of two piezometers mounted at two different gauge points where the pressure difference is to be measured. The pressure difference between two points can be simply measured by the difference in the level of liquid between the two tubes. It possesses some limitations in the form of piezometers.

U-tube Manometer

As shown in the figure it consists of a glass tube bent in V-shape, with one end is connected to a point at which pressure is to be measured and the other end remains open to the atmosphere.



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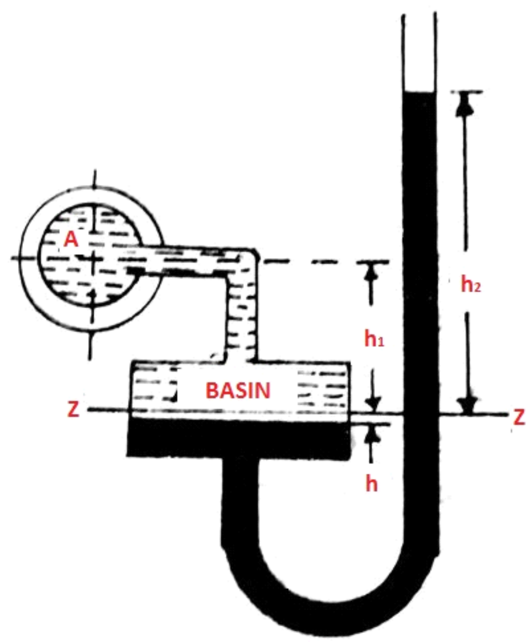

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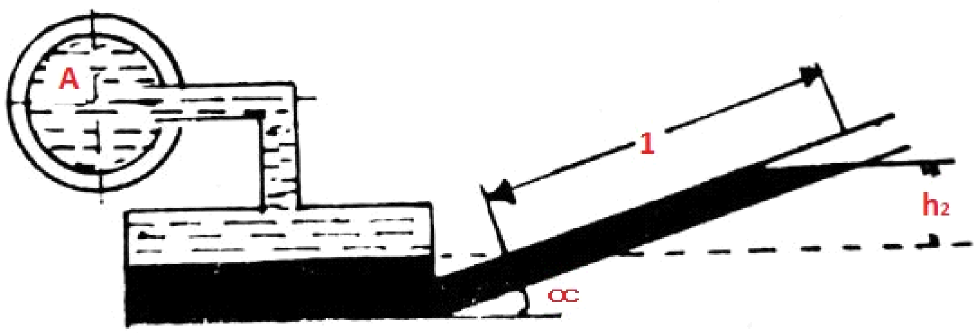


Inclined Tube Manometer

This type of inclined micromanometer is more sensitive than the vertical tube type. Due to inclination, the distance moved by the heavy liquid in the right limb is comparatively more. Thus it can give a higher reading for the given pressure.

Differential Manometer

The differential manometer is a device used to measure the pressure difference between two points in a pipe or in two different pipes.

A differential manometer consists of a U-tube, containing a heavy liquid, with two ends connected by points whose pressure difference is to be measured:

Types of differential manometers are:

- Two piezometer manometer
- U-tube differential manometer
- Inverted differential manometer

1. Two Piezometer Manometer

It consists of two piezometers mounted at two different gauge points where the pressure difference is to be measured. The pressure difference between two points can be simply measured by the difference in the level of liquid between the two tubes. It possesses some limitations in the form of piezometers.

2. *U-tube Manometer*

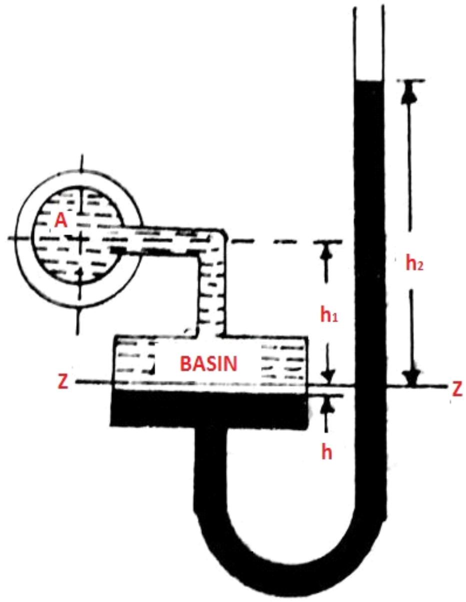
As shown in the figure it consists of a glass tube bent in V-shape, with one end is connected to a point at which pressure is to be measured and the other end remains open to the atmosphere.

The tube carries mercury or any other liquid or fluid whose specific gravity is much higher than the specific gravity of the liquid whose pressure is to be measured.

- For gauge pressure
- For vacuum pressure

3. Single Column Manometer

Consider a vertical tube micromanometer connected to a pipe containing light liquid under very high pressure. The pressure in the pipe will force the lighter liquid in the basin to push the heavier liquid downwards.

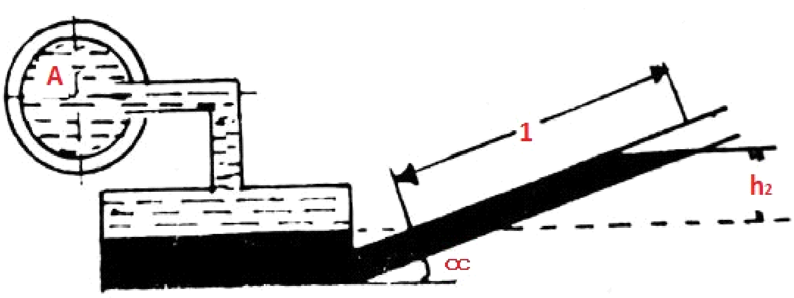


Single Column Manometer

Due to the larger area of the basin, the fall of a heavy liquid level will be very small. This downward movement of heavy liquid into the basin will result in a significant rise of heavy liquid in the right limb.

4. Inclined Tube Manometer

If the vertical tube of the micromanometer is made inclined as shown in figure then it is called inclined tube micromanometer.



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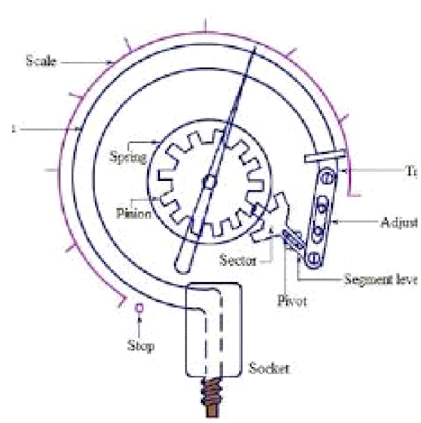
Aneroid gauges are based on a metallic pressure-sensing element that flexes elastically under the effect of a pressure difference across the element. "Aneroid" means "without fluid", and the term originally distinguished these gauges from the hydrostatic gauges described above. However, aneroid gauges can be used to measure the pressure of a liquid as well as a gas, and they are not the only type of gauge that can operate without fluid. For this reason, they are often called **mechanical** gauges in modern language. Aneroid gauges are not dependent on the type of gas being measured, unlike thermal and ionization gauges, and are less likely to contaminate the system than hydrostatic gauges.

The pressure sensing element may be a **Bourdon tube**, a diaphragm, a capsule, or a set of bellows, which will change shape in response to the pressure of the region in question. The deflection of the pressure sensing element may be read by a linkage connected to a needle, or it may be read by a secondary transducer. The most common secondary transducers in modern vacuum gauges measure a change in capacitance due to the mechanical deflection. Gauges that rely on a change in capacitance are often referred to as capacitance manometers.



Membrane-type manometer

The Bourdon pressure gauge uses the principle that a flattened tube tends to straighten or regain its circular form in cross-section when pressurized. This change in cross-section may be hardly noticeable, involving moderate stresses within the elastic range of easily workable materials. The strain of the material of the tube is magnified by forming the tube into a C shape or even a helix, such that the entire tube tends to straighten out or uncoil elastically as it is pressurized. Eugène Bourdon patented his gauge in France in 1849, and it was widely adopted because of its superior sensitivity, linearity, and accuracy; Edward Ashcroft purchased Bourdon's American patent rights in 1852 and became a major manufacturer of gauges. Also in 1849, Bernard Schaeffer in Magdeburg, Germany patented a successful diaphragm (see below) pressure gauge, which, together with the Bourdon gauge, revolutionized pressure measurement in industry.[12] But in 1875 after Bourdon's patents expired, his company Schaeffer and Budenberg also manufactured Bourdon tube gauges.

An original 19th century Eugene Bourdon compound gauge, reading pressure both below and above ambient with great sensitivity

In practice, a flattened thin-wall, closed-end tube is connected at the hollow end to a fixed pipe containing the fluid pressure to be measured. As the pressure increases, the closed end moves in an arc, and this motion is converted into the rotation of a (segment of a) gear by a connecting link that is usually adjustable. A small-diameter pinion gear is on the pointer shaft, so the motion is magnified further by the gear ratio. The positioning of the indicator card behind the pointer, the initial pointer shaft position, the linkage length and initial position, all provide means to calibrate the pointer to indicate the desired range of pressure for variations in the behavior of the Bourdon tube itself. Differential pressure can be measured by gauges containing two different Bourdon tubes, with connecting linkages.

Bourdon tubes measure gauge pressure, relative to ambient atmospheric pressure, as opposed to absolute pressure; vacuum is sensed as a reverse motion. Some aneroid barometers use Bourdon tubes closed at both ends (but most use diaphragms or capsules, see below). When the measured pressure is rapidly pulsing, such as when the gauge is near a reciprocating pump, an orifice restriction in the connecting pipe is frequently used to avoid unnecessary wear on the gears and provide an average reading; when the whole gauge is subject to mechanical vibration, the entire case including the pointer and indicator card can be filled with an oil or glycerin. Tapping on the face of the gauge is not recommended as it will tend to falsify actual readings initially presented by the gauge. The Bourdon tube is separate from the face of the gauge and thus has no effect on the actual reading of pressure. Typical high-quality modern gauges provide an accuracy of ±2% of span, and a special high-precision gauge can be as accurate as 0.1% of full scale.

Force-balanced fused quartz bourdon tube sensors work on the same principle but uses the reflection of a beam of light from a mirror to sense the angular displacement and current is applied to electromagnets to balance the force of the tube and bring the angular displacement back to zero, the current that is applied to the coils is used as the measurement. Due to the extremely stable and repeatable mechanical and thermal properties of quartz and the force balancing which eliminates nearly all physical movement these sensors can be accurate to around 1 PPM of full scale.[14] Due to the extremely fine fused quartz structures which must be made by hand these sensors are generally limited to scientific and calibration purposes.

In the following illustrations the transparent cover face of the pictured combination pressure and vacuum gauge has been removed and the mechanism removed from the case. This particular gauge is a combination vacuum and pressure gauge used for automotive diagnosis:

- The left side of the face, used for measuring manifold vacuum, is calibrated in centimetres of mercury on its inner scale and inches of mercury on its outer scale.
- The right portion of the face is used to measure fuel pump pressure or turbo boost and is calibrated in fractions of 1 kgf/cm HYPERLINK "https://en.wikipedia.org/wiki/Square_centimeter"2 on its inner scale and pounds per square inch on its outer scale.

Stationary parts:

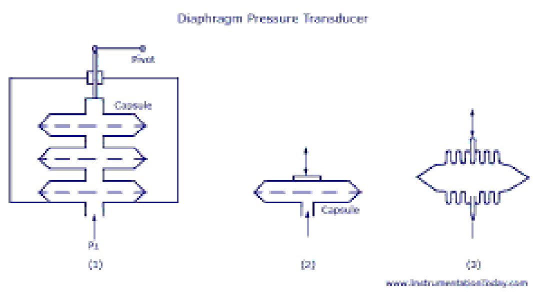
- A: Receiver block. This joins the inlet pipe to the fixed end of the Bourdon tube (1) and secures the chassis plate (B). The two holes receive screws that secure the case.
- B: Chassis plate. The face card is attached to this. It contains bearing holes for the axles.
- C: Secondary chassis plate. It supports the outer ends of the axles.
- D: Posts to join and space the two chassis plates.

Moving parts:

- Stationary end of Bourdon tube. This communicates with the inlet pipe through the receiver block.
- Moving end of Bourdon tube. This end is sealed.
- Pivot and pivot pin
- Link joining pivot pin to lever (5) with pins to allow joint rotation
- Lever, an extension of the sector gear (7)
- Sector gear axle pin
- Sector gear
- Indicator needle axle. This has a spur gear that engages the sector gear (7) and extends through the face to drive the indicator needle. Due to the short distance between the lever arm link boss and the pivot pin and the difference between the effective radius of the sector gear and that of the spur gear, any motion of the Bourdon tube is greatly amplified. A small motion of the tube results in a large motion of the indicator needle.
- Hair spring to preload the gear train to eliminate gear lash and hysteresis

Diaphragm:

A second type of aneroid gauge uses deflection of a flexible membrane that separates regions of different pressure. The amount of deflection is repeatable for known pressures so the pressure can be determined by using calibration. The deformation of a thin diaphragm is dependent on the difference in pressure between its two faces. The reference face can be open to atmosphere to measure gauge pressure, open to a second port to measure differential pressure, or can be sealed against a vacuum or other fixed reference pressure to measure absolute pressure. The deformation can be measured using mechanical, optical or capacitive techniques. Ceramic and metallic diaphragms are used.



Useful range: above 10^{-2} Torr [15] (roughly 1 Pa)

For absolute measurements, welded pressure capsules with diaphragms on either side are often used.

shape:

- Flat
- Corrugated
- Flattened tube
- Capsule

Knudsen gauge:

There are some devices such as micro Knudsen gauge and microscale radiometric actuator that applied this technique for industrial applications.

Knudsen gauge is a type of manometer that works with the interaction of particles with a surface. Particles that interact with a hotter or colder surface will exert a force on that surface. Radiometric actuator is a measurement device that is used for the evaluation of the thermal radiation with mechanism of Knudsen force. In this device, there are vanes in which one side is dark and other side is bright in the vacuum domain. Under the radiation, the temperature of two sides of the vanes varies and induces thermally driven gas flow and this causes the rotation of the blades.

As shown in Fig. 1, the hot wire is the source of thermal Knudsen force and it induces approximately uniform force on the string (shuttle arm) which could deflect under Knudsen force. All of these elements are confined in the narrow micro channel and the pressure of the domain is reduced by the vacuum pump. In fact, the string is fixed in the right side and it is similar to cantilever beam.

As the Knudsen force exerts on the string, the deflection occurs and its value is proportional with the operating conditions such as pressure, temperature difference and the gap between hot wire and string.

1% which is within acceptable range (see Table 1).

Table 1. Uncertainties of the parameters.

Parameter	**Uncertainty**
Force	±1μN
Shuttle length	±0.1 mm
Young Modulus	±0.5 Gpa
Moment of inertia of area (I)	±5e−16 m^4

In order to visibly demonstrate the main effective term on the model, Fig. 8 illustrates the temperature distribution and streamline inside the domain for various pressures. Obtained results clearly confirm that the temperature gradient declines as the pressure of the domain is increased. Moreover, the streamline patterns are significantly influenced by the temperature gradient.

. Comparison of the flow feature and temperature distribution of the model in various pressures.The strain gauge is generally glued (foil strain gauge) or deposited (thin-film strain gauge) onto a membrane. Membrane deflection due to pressure causes a resistance change in the strain gauge which can be electronically measured.

Piezoresistive strain gauge

Uses the piezoresistive effect of bonded or formed strain gauges to detect strain due to applied pressure.

Piezoresistive Silicon Pressure Sensor:

The Sensor is generally a temperature compensated, piezoresistive silicon pressure sensor chosen for its excellent performance and long-term stability. Integral temperature compensation is provided over a range of 0–50°C using laser-trimmed resistors. An additional laser-trimmed resistor is included to normalize pressure sensitivity variations by programming the gain of an external differential amplifier. This provides good sensitivity and long-term stability. The two ports of the sensor, apply pressure to the same single transducer, please see pressure flow diagram below.

This is an over simplified diagram, but you can see fundamental design of the internal ports in the sensor. The important item here to note is the “Diaphragm” as this is the sensor itself. Please note that is it slightly convex in shape (highly exaggerated in the drawing), this is important as it effects the accuracy of the sensor in use. The shape of the sensor is important because it is calibrated to work in the direction of Air flow as shown by the RED Arrows.

This is normal operation for the pressure sensor, providing a positive reading on the display of the digital pressure meter. Applying pressure in the reverse direction can induce errors in the results as the movement of the air pressure is trying to force the diaphragm to move in the opposite direction. The errors induced by this are small but, can be significant and therefore it is always preferable to ensure that the more positive pressure is always applied to the positive (+ve) port and the lower pressure is applied to the negative (-ve) port, for normal 'Gauge Pressure' application. The same applies to measuring the difference between two vacuums, the larger vacuum should always be applied to the negative (-ve) port. The measurement of pressure via the Wheatstone Bridge looks something like this....

Application Schematic

The effective electrical model of the transducer, together with a basic signal conditioning circuit, is shown in the application schematic. The pressure sensor is a fully active Wheatstone bridge which has been temperature compensated and offset adjusted by means of thick film, laser trimmed resistors. The excitation to the bridge is applied via a constant current. The low-level bridge output is at +O and -O, and the amplified span is set by the gain programming resistor (r). The electrical design is microprocessor controlled, which allows for calibration, the additional functions for the user, such as Scale Selection, Data Hold, Zero and Filter functions, the Record function that stores/displays MAX/MIN.

Capacitive

Uses a diaphragm and pressure cavity to create a variable capacitor to detect strain due to applied pressure.

Magnetic

Measures the displacement of a diaphragm by means of changes in inductance (reluctance), LVDT, Hall effect, or by eddy current principle.

Piezoelectric

Uses the piezoelectric effect in certain materials such as quartz to measure the strain upon the sensing mechanism due to pressure.

Optical

Uses the physical change of an optical fiber to detect strain due to applied pressure.

Potentiometric

Uses the motion of a wiper along a resistive mechanism to detect the strain caused by applied pressure.

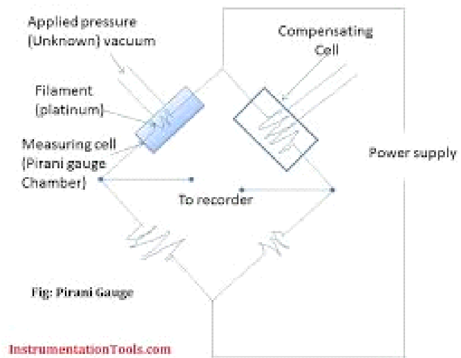
Resonant

Uses the changes in resonant frequency in a sensing mechanism to measure stress, or changes in gas density, caused by applied pressure.

Thermal conductivity

Generally, as a real gas increases in density -which may indicate an increase in pressure- its ability to conduct heat increases. In this type of gauge, a wire filament is heated by running current through it. A thermocouple or resistance thermometer (RTD) can then be used to measure the temperature of the filament. This temperature is dependent on the rate at which the filament loses heat to the surrounding gas, and therefore on the thermal conductivity. A common variant is the Pirani gauge, which uses a single platinum filament as both the heated element and RTD. These gauges are accurate from 10^{-3} Torr to 10 Torr, but their calibration is sensitive to the chemical composition of the gases being measured.

Pirani (one wire)



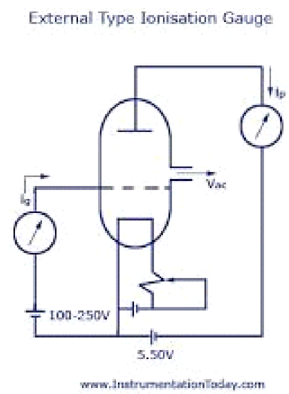
Pirani gauge

A Pirani gauge consists of a metal wire open to the pressure being measured. The wire is heated by a current flowing through it and cooled by the gas surrounding it. If the gas pressure is reduced, the cooling effect will decrease, hence the equilibrium temperature of the wire will increase. The resistance of the wire is a function of its temperature: by measuring the voltage across the wire and the current flowing through it, the resistance (and so the gas pressure) can be determined. This type of gauge was invented by Marcello Pirani.

Two-wire:

In two - wire gauges, one wire coil is used as a heater, and the other is used to measure temperature due to convection. **Thermocoupel gauges** and **thermistor gauges** work in this manner using thermocouple or thermistor, respectively, to measure the temperature of the heated wire.

Ionization gauges are the most sensitive gauges for very low pressures (also referred to as hard or high vacuum). They sense pressure indirectly by measuring the electrical ions produced when the gas is bombarded with electrons. Fewer ions will be produced by lower density gases. The calibration of an ion gauge is unstable and dependent on the nature of the gases being measured, which is not always known. They can be calibrated against a McLeod gauge which is much more stable and independent of gas chemistry.



Thermionic emission generates electrons, which collide with gas atoms and generate positive ions. The ions are attracted to a suitably biased electrode known as the collector. The current in the collector is proportional to the rate of ionization, which is a function of the pressure in the system. Hence, measuring the collector current gives the gas pressure. There are several sub-types of ionization gauge.

Useful range: 10^{-10} - 10^{-3} torr (roughly 10^{-8} - 10^{-1} Pa)

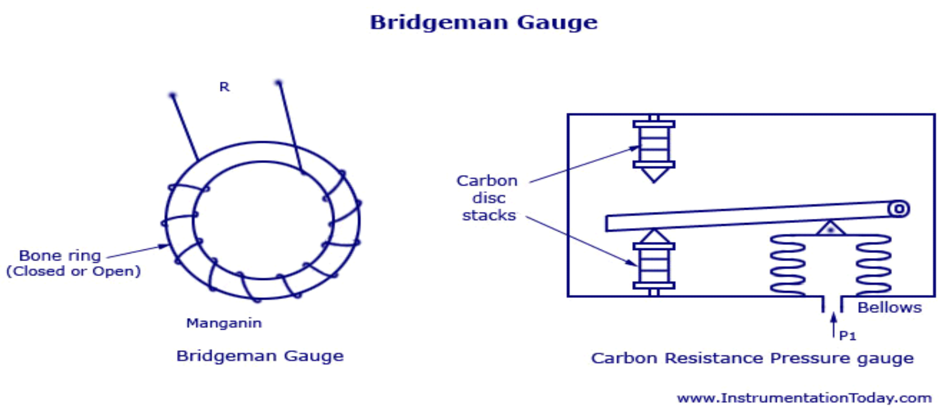
Physical phenomena	**Instrument**	**Governing equation**	**Limiting factors**	**Practical pressure range**	**Ideal accuracy**	**Response time**
Mechanical	Liquid column manometer			atm. to 1 mbar		
Mechanical	Capsule dial gauge		Friction	1000 to 1 mbar	±5% of full scale	Slow
Mechanical	Strain gauge			1000 to 1 mbar		Fast
Mechanical	Capacitance manometer		Temperature fluctuations	atm to 10^{-6} mbar	±1% of reading	Slower when filter mounted
Mechanical	McLeod	Boyle's law		10 to 10^{-3} mbar	±10% of reading between 10^{-4} and $5 \cdot 10^{-2}$ mbar	
Transport	Spinning rotor (drag)			10^{-1} to 10^{-7} mbar	±2.5% of reading between	

					10^{-7} and 10^{-2} mbar 2.5 to 13.5% between 10^{-2} and 1 mbar	
Transport	Pirani (Wheatstone bridge)		Thermal conductivity	1000 to 10^{-3} mbar (const. temperature) 10 to 10^{-3} mbar (const. voltage)	±6% of reading between 10^{-2} and 10 mbar	Fast
Transport	Thermocouple (Seebeck effect)		Thermal conductivity	5 to 10^{-3} mbar	±10% of reading between 10^{-2} and 1 mbar	
Ionization	Cold cathode (Penning)		Ionization yield	10^{-2} to 10^{-7} mbar	+100 to -50% of reading	
Ionization	Hot cathode (ionization induced by thermionic emission)		Low current measurement; parasitic x-ray emission	10^{-3} to 10^{-10} mbar	±10% between 10^{-7} and 10^{-4} mbar ±20% at 10^{-3} and 10^{-9} mbar ±100% at 10^{-10} mbar	

Bridgeman Pressure Gauge

When a wire is subjected to pressure from all sides its electrical resistance changes. This principle can be utilized to obtain a primary type resistive pressure sensor and is called as a Bridgeman pressure sensor. The distortion produced in the crystal lattice due to the external pressure causes the change in resistance. In most common metal wires, the resistance decreases with increase in pressure, while for antimony, bismuth, lithium, and manganin, it increases. In cesium, it initially decreases for small values of pressure changes and reaches a minimum, beyond which it increases with increase in pressure. But these metals cannot be used for practical purposes in a bridgeman gauge. The gauge must be used at a constant temperature, and has a range from 0 to 1000 MPa, but usable only at high pressure, as, at low values of pressure the change in resistance value is very small because of the small value of the pressure co-efficient of resistance.

The constructional features of bridgeman gauge has improves since it was first proposed. The basic construction is shown in the figure below. It has a bone ring shape with an insulated manganin wire having a pressure co-efficient of resistance of 23×10^{-7} cm^2/kg so that the total resistance of the wire is 100 ohm. The winding is generally bifilar for avoiding inductive effect. Carbon can also be used for pressure measurement in the form of granules or discs. With pressure, its resistance also changes, but non-linearly and is not suitable for a linear scale measurement. The carbon resistance pressure gauge diagram is shown below.

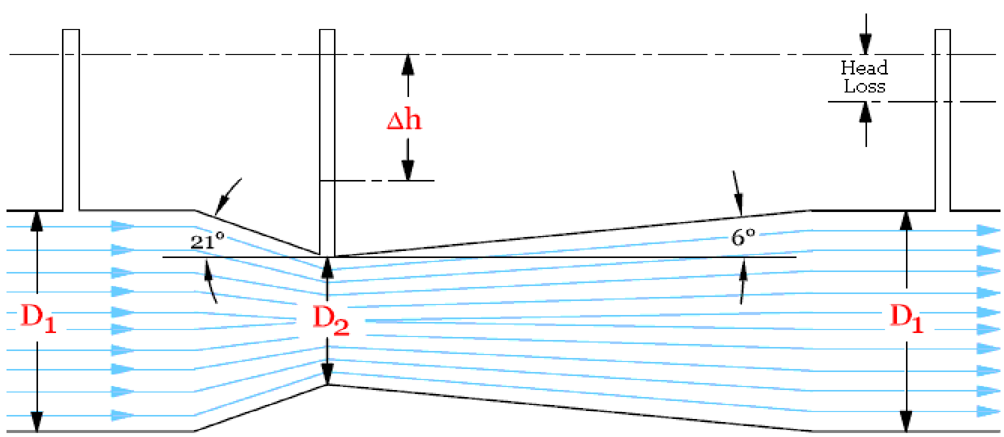


Venturi Meters

The principle of this flow measurement device was first documented by J.B. Venturi in 1797 in Italy. The principle under which these devices operate is that some pressure head is converted velocity head when the cross-sectional area of flow decreases (Bernoulli equation).

Thus, the head differential can be measured between the upstream section and the throat section to give an estimation of flow velocity, and this can be multiplied by flow area to arrive at a discharge value. The converging section is usually about 21°, and the diverging section is usually from 5° to 7°.

Venturi Flow Meter



A FORM OF THE CALIBRATION EQUATION IS:

$$Q = C A_2 \frac{\sqrt{2g \Delta h (sg - 1)}}{\sqrt{1 - \beta^4}}$$

Where **C** is a dimensionless coefficient from approximately 0.935 (small throat velocity and diameter) to 0.988 (large throat velocity and diameter); **B** is the ratio of D_2 / D_1; D_1 & D_2 are the inside diameters at the upstream and throat sections, respectively; A_2 is the area of the throat section; **ΔH** is the head differential; and "**SG**" is the specific gravity of the manometer liquid.

The discharge coefficient, **C**, is a constant value for given venturi dimensions. Note that if $D_2 = D_1$, then **B** = 1, and **Q** is undefined; if $D_2 > D_1$, you get the square root of a negative number (but neither condition applies to a venturi). The coefficient, **C** must be adjuste to accommodate variations in water temperature. The value of **B** is usually between 0.25 and 0.50, but may be as high as 0.75.

Straightening vanes may be required upstream of the venturi to prevent swirling flow, which can significantly affect the calibration. It is generally recommended that there should be a distance of at least 10xD_1 of straight pipe upstream of the venturi.

The head loss across a venturi meter is usually between 10% and 20% of **ΔH**. This percentage decreases for larger venturis and as the flow rate increases. Venturi discharge measurement error is often within ±0.5% to ±1% of the true flow rate value.

Venturi meters have been made out of steel, iron, concrete, wood, plastic, brass, bronze, and other materials and many commercial venturi meters have patented features.

Orifice plate flow meter

How does a orifice plate work?

Published April 17, 2019

The orifice plate flow meter is commonly used in clean liquid, gas, and steam services. It is available for all pipe sizes but it is very cost-effective for measuring flows in larger ones (over 6" diameter). The orifice plate is also approved by many organizations for custody transfer of liquids and gases.

The orifice plate calculations used nowadays still differ from one another, although various organizations are working to adopt an universally accepted orifice flow equation. Orifice plate sizing programs usually allow the user to select the flow equation desired.

The orifice plate meter can be made of any material, although stainless steel is the most common. The thickness of the plate used (1/8-1/2") is a function of the line size, the process temperature, the pressure, and the differential pressure. The traditional orifice flow meter is a thin circular plate (with a tab for handling and for data), inserted into the pipeline between the two flanges of an orifice union. This method of installation is cost - effective, but it calls for a process shutdown whenever the plate is removed for maintenance or inspection. In contrast, an orifice fitting allows the orifice to be removed from the process without depressurizing the line and shutting down flow. In such fittings, the universal orifice plate, a circular plate with no tab, isused.

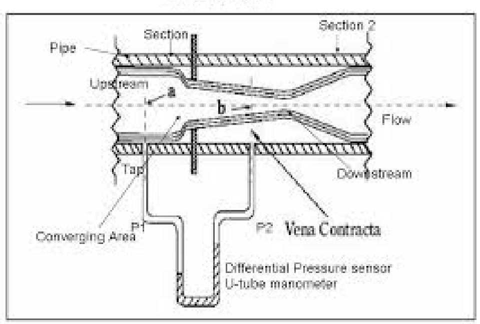
The concentric orifice plate flow meter has a sharp (square-edged) concentric bore that provides an almost pure line contact between the plate and the fluid, with negligible friction drag at the boundary. The beta (or diameter) ratios of concentric orifice plates range from 0.25 to 0.75. The maximum velocity and minimum static pressure occurs at some 0.35 to 0.85 pipe diameters downstream from the orifice plate. That point is called the vena contracta. Measuring the differential pressure at a location close to the orifice plate minimizes the effect of pipe roughness, since friction has an effect on the fluid and the pipe wall.

Flange taps are predominantly used in the United States and are located 1 inch from the orifice plate's surfaces (Figure 2-3). They are not recommended for use on pipelines under 2 inches in diameter. Corner taps are predominant in Europe for all sizes of pipe, and are used in the United States for pipes under 2 inches (Figure 2-3). With corner taps, the relatively small clearances represent a potential maintenance problem. Vena contracta taps (which are close to the radius taps, Figure 2-4) are located one pipe diameter upstream from the plate, and downstream at the point of vena contracta. This location varies (with beta ratio and Reynolds number) from 0.35D to 0.8D.

The vena contracta taps provide the maximum pressure differential, but also the most noise. Additionally, if the plate is changed, it may require a change in the tap location. Also, in small pipes, the vena contracta might lie under a flange. Therefore, vena contracta taps normally are used only in pipe sizes exceeding six inches.

Radius taps are similar to vena contracta taps, except the downstream tap is fixed at 0.5D from the orifice plate (Figure 2-3). Pipe taps are located 2.5 pipe diameters upstream and 8 diameters downstream from the orifice (Figure 2-3). They detect the smallest pressure difference and, because of the tap distance from the orifice, the effects of pipe roughness, dimensional inconsistencies, and, therefore, measurement errors are the greatest.

Orifice Flow Meter



What are the best applications for a orifice plate flow meter?

The concentric orifice plate is recommended for clean liquids, gases, and steam flows when Reynolds numbers range from 20,000 to 107 in pipes under six inches. Because the basic orifice flow equations assume that flow velocities are well below sonic, a different theoretical and computational approach is required if sonic velocities are expected.

A rotameter consists of a tapered tube, typically made of glass with a 'float' (a shaped weight, made either of anodized aluminum or a ceramic), inside that is pushed up by the drag force of the flow and pulled down by gravity. The drag force for a given fluid and float cross section is a function of flow speed squared only, see drag equation.[3]

A higher volumetric flow rate through a given area increases flow speed and drag force, so the float will be pushed upwards. However, as the inside of the rotameter is cone shaped (widens), the area around the float through which the medium flows increases, the flow speed and drag force decrease until there is mechanical equilibrium with the float's weight.

Floats are made in many different shapes, with spheres and ellipsoids being the most common. The float may be diagonally grooved and partially colored so that it rotates axially as the fluid passes. This shows if the float is stuck since it will only rotate if it is free. Readings are usually taken at the top of the widest part of the float; the center for an ellipsoid, or the top for a cylinder. Some manufacturers use a different standard.[3]

The "float" must not float in the fluid: it has to have a higher density than the fluid, otherwise it will float to the top even if there is no flow.

The mechanical nature of the measuring principle provides a flow measurement device that does not require any electrical power. If the tube is made of metal, the float position is transferred to an external indicator via a magnetic coupling. This capability has considerably expanded the range of applications for the variable area flowmeter, since the measurement can observed remotely from the process or used for automatic control.

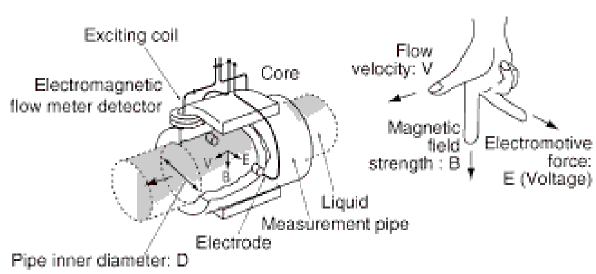
Advantages

- A rotameter requires no external power or fuel, it uses only the inherent properties of the fluid, along with gravity, to measure flow rate. [3]
- A rotameter is also a relatively simple device that can be mass manufactured out of cheap materials, allowing for its widespread use.
- Since the area of the flow passage increases as the float moves up the tube, the scale is approximately linear.[2]
- Clear glass is used which is highly resistant to thermal shock and chemical action.

Disadvantages:

- Due to its reliance on the ability of the fluid or gas to displace the float, graduations on a given rotameter will only be accurate for a given substance at a given temperature. The main property of importance is the density of the fluid; however, viscosity may also be significant. Floats are ideally designed to be insensitive to viscosity; however, this is seldom verifiable from manufacturers' specifications. Either separate rotameters for different densities and viscosities may be used, or multiple scales on the same rotameter can be used.[1]
- Because operation of a rotameter depends on the force of gravity for operation, a rotameter must be oriented vertically. Significant error can result if the orientation deviates significantly from the vertical.
- Due to the direct flow indication the resolution is relatively poor compared to other measurement principles. Readout uncertainty gets worse near the bottom of the scale. Oscillations of the float and parallax may further increase the uncertainty of the measurement.[1]
- Since the float must be read through the flowing medium, some fluids may obscure the reading. A transducer may be required for electronically measuring the position of the float.
- Rotameters are not easily adapted for reading by machine; although magnetic floats that drive a follower outside the tube are available.[1]
- Rotameters are not generally manufactured in sizes greater than 6 inches/150 mm, but bypass designs are sometimes used on very large pipes.

A **magnetic flow meter** (**mag meter**, **electromagnetic flow meter**) is a transducer that measures fluid flow by the voltage induced across the liquid by its flow through a magnetic field. A magnetic field is applied to the metering tube, which results in a potential difference proportional to the flow velocity perpendicular to the flux lines. The physical principle at work is electromagnetic induction. The magnetic flow meter requires a conducting fluid, for example, water that contains ions, and an electrical insulating pipe surface, for example, a rubber-lined steel tube.

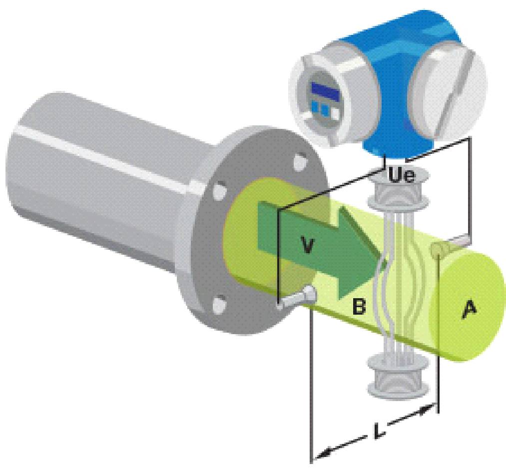


If the magnetic field direction were constant, electrochemical and other effects at the electrodes would make the potential difference difficult to distinguish from the fluid flow induced potential difference. To mitigate this in modern magnetic flowmeters, the magnetic field is constantly reversed, cancelling out the electrochemical potential difference, which does not change direction with the magnetic field. This however prevents the use of permanent magnets for magnetic flowmeters.

Electromagnetic Flow Meters, simply known as mag flow meter is a **volumetric flow meter** which is ideally used for waste water applications and other applications that experience low pressure drop and with appropriate liquid conductivity required.

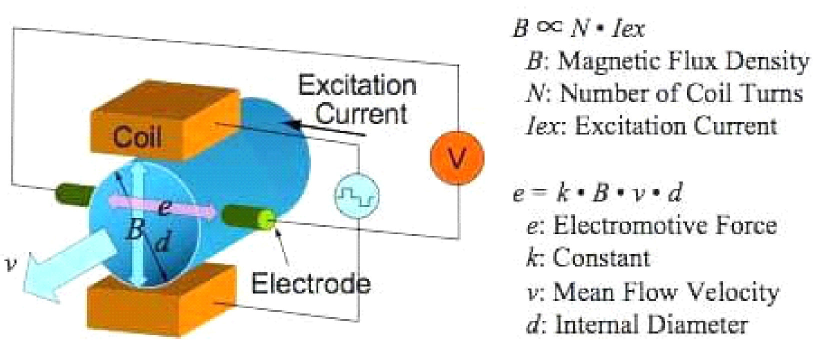
The device doesn't have any moving parts and cannot work with hydrocarbons and distilled water. Mag flow meters are also easy to maintain.

Electromagnetic Flow Meters



Principle of Magnetic Flow Meter Based on Faraday's Law

Magnetic flow meters works based on Faraday's Law of Electromagnetic Induction. According to this principle, when a conductive medium passes through a magnetic field B, a voltage E is generated which is proportional to the velocity v of the medium, the density of the magnetic field and the length of the conductor.



In a magnetic flow meter, a current is applied to wire coils mounted within or outside the meter body to generate a magnetic field. The liquid flowing through the pipe acts as the conductor and this induces a voltage which is proportional to the average flow velocity.

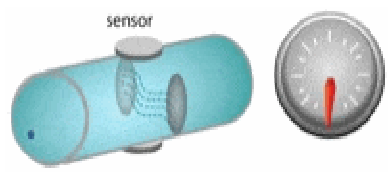
This voltage is detected by sensing electrodes mounted in the **Magflow meter** body and sent to a transmitter which calculates the volumetric flow rate based on the pipe dimensions.

Mathematically, we can state Faraday's law as

E is proportional to V x B x L

[E is the voltage generated in a conductor, V is the velocity of the conductor, B is the magnetic field strength and L is the length of the conductor].

It is very important that the liquid flow that is to be measured using the magnetic flow meter must be electrically conductive. The Faraday's Law indicates that the signal voltage (E) is dependent on the average liquid velocity (V), the length of the conductor (D) and the magnetic field strength (B). The magnetic field will thus be established in the cross-section of the tube.



Basically when the conductive liquid flows through the magnetic field, voltage is induced. To measure this generated voltage (which is proportional to the velocity of the flowing liquid), two stainless steel electrodes are used which are mounted opposite each other.

The two electrodes which are placed inside the flow meter are then connected to an advanced electronic circuit that has the ability to process the signal. The processed signal is fed into the microprocessor that calculates the volumetric flow of the liquid.

Electromagnetic Flow Meters Formula:

Electromagnetic flow meters use Faraday's law of electromagnetic induction for making a flow measurement. Faraday's law states that, whenever a conductor of length 'l' moves with a velocity 'v' perpendicular to a magnetic field 'B', an emf 'e' is induced in a mutually perpendicular direction which is given by

$e = Blv$ ...(eq1)

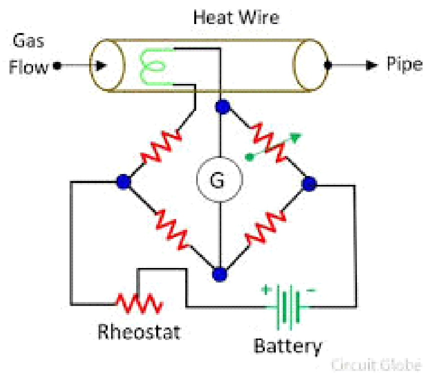
where

Hot Wire Anemometer

Definition: The Hot Wire Anemometer is a device used for measuring the velocity and direction of the fluid. This can be done by measuring the heat loss of the wire which is placed in the fluid stream. The wire is heated by electrical current.

The hot wire when placed in the stream of the fluid, in that case, the heat is transferred from wire to fluid, and hence the temperature of wire reduces. The resistance of wire measures the flow rate of the fluid.

The hot wire anemometer is used as a research tool in fluid mechanics. It works on the principle of transfer of heat from high temperature to low temperature.



Construction of Hot Wire Anemometer

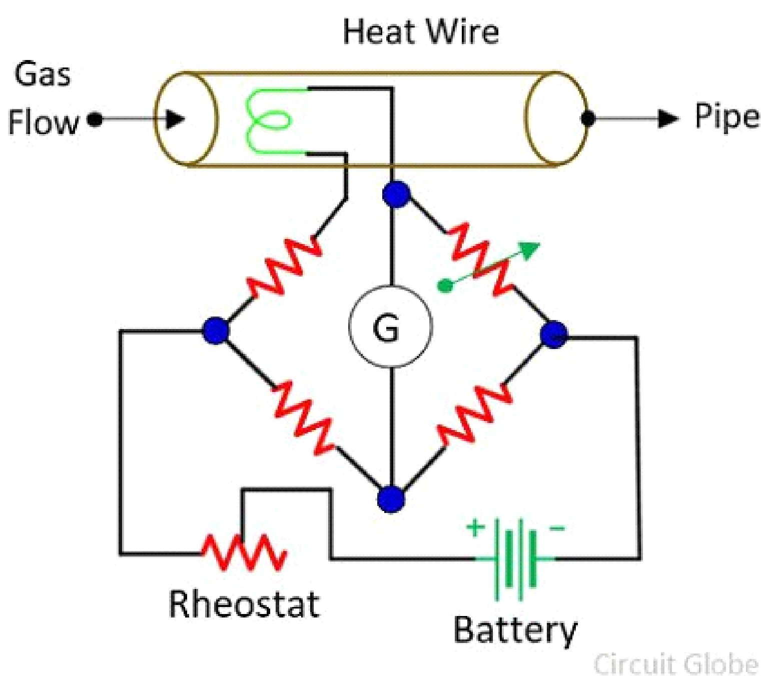
The hot wire anemometer consists two main parts.

- Conducting wire
- Wheat stone bridge.

The conducting wire is housed inside the ceramic body. The wires are taking out from the ceramic body and connecting to the Wheatstone bridge. The wheat stone bridge measures the variation of resistance.

Constant Current Method

In the constant current method, the anemometer is placed in the stream of the fluid whose flow rate needs to be measured. The current of constant magnitude is passed through the wire. The Wheatstone bridge is also kept on the constant voltage.



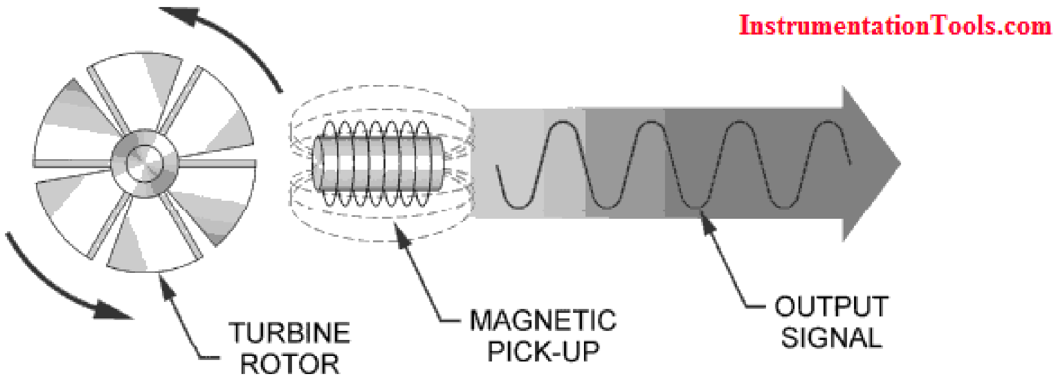
When the wire is kept in the stream of liquid, in that case, the heat is transferred from the wire to the fluid. The heat is directly proportional to the resistance of the wire. If heat reduces, that means the resistance of wire also reduces. The Wheatstone bridge measures the variation in resistance which is equal to the flow rate of the liquid.

Turbine Flow Meter is a volumetric measuring turbine type. The flowing fluid engages the rotor causing it to rotate at an angular velocity proportional to the fluid flow rate.

The angular velocity of the rotor results in the generation of an electrical signal (AC sine wave type) in the pickup. The summation of the pulsing electrical signal is related directly to total flow.

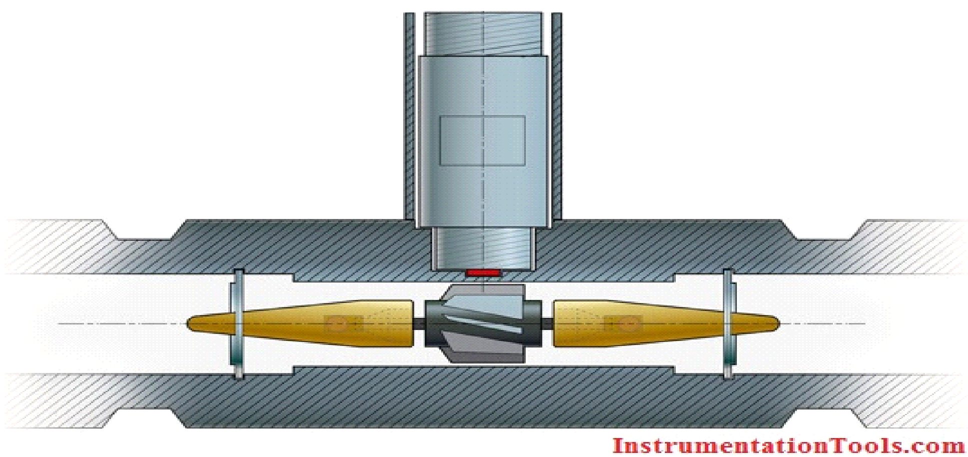
The frequency of the signal relates directly to flow rate. The vaned rotor is the only moving part of the flow meter.

Turbine Flow Meter



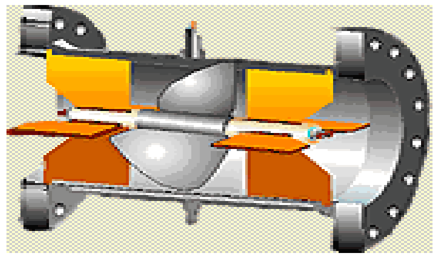
The Turbine flow meter (axial turbine) was invented by **Reinhard Woltman** and is an accurate and reliable flow meter for liquids and gases. It consists of a flow tube with end connections and a magnetic multi bladed free spinning rotor (impeller) mounted inside; in line with the flow. The rotor is supported by a shaft that rests on internally mounted supports.

The Supports in Process Automatics Turbine Flow Meters are designed to also act as flow straighteners, stabilizing the flow and minimizing negative effects of turbulence. The Supports also house the unique open bearings; allowing for the measured media to lubricate the bushes – prolonging the flow meters life span. The Supports are fastened by locking rings (circlips) on each end.



The rotor sits on a shaft ,which in turn is suspended in the flow by the two supports. As the media flows, a force is applied on the rotor wings. The angle and shape of the wings transform the horizontal force to a perpendicular force, creating rotation. Therefore, the rotation of the rotor is proportional to the applied force of the flow.

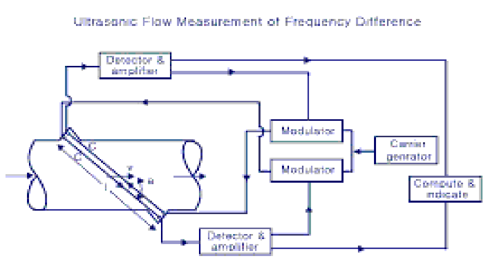
Because of this, the rotor will immediately rotate as soon as the media induces a forward force. As the rotor cannot turn thru the media on its own, it will stop as soon as the media stops. This ensures an extremely fast response time, making the Turbine Flow Meter ideal for batching applications.



A pick-up sensor is mounted above the rotor. When the magnetic blades pass by the pickup sensor, a signal is generated for each passing blade. This provides a pulsed signal proportional to the speed of the rotor and represents pulses per volumetric unit.; and as such the flow rate too.

What is an Ultrasonic Flow Meter?

Definition: An ultrasonic flow meter can be defined as, a meter that is used to measure liquid velocity with ultrasound to analyze the volume of liquid flow. This is a volumetric flow meter that needs bubble or minute particles within the liquid flow. These meters are suitable in the applications of wastewater but they will not work with drinking/distill water. So this type of flow meter is ideal for the applications wherever chemical compatibility, low maintenance, and low-pressure drop are required.



ultrasonic-flow-meter

These meters will affect the audio properties of the liquid and also impact through viscosity, density, temperature, etc. Like mechanical flow meters, these meters do not include moving parts. The price of these meters will change greatly so frequently it can be used and maintained at a low cost.

Ultrasonic Flow Meter Working Principle

An ultrasonic flow meter construction can be done by using upstream and downstream transducers, sensor pipe and reflector. The working principle of ultrasonic flow meter is, it uses sound waves to resolve the velocity of a liquid within a pipe. There are two conditions in the pipe like no flow and flowing. In the first condition, the frequencies of ultrasonic waves are transmitted into a pipe & its indications from the fluid are similar. In the second condition, the reflected wave's frequency is dissimilar because of the Doppler Effect.

ultrasonic-flow-meter-construction

Whenever the liquid flows in the pipe quickly, then the frequency shift can be increased linearly. The transmitter processes the signals from the wave & its reflections determine the flow rate. Transit time meters transmit & receive ultrasonic waves in both the directions within the pipe. At no-flow condition, the time taken to flow in between upstream & downstream in between the transducers is the same.

Under these two flowing conditions, the wave at upstream will flow with less speed than the downstream wave. As the liquid flows faster, the distinction between the up & downstream times raises. The times of the upstream & downstream processed by the transmitter to decide the flow rate.

Types of Ultrasonic Flow Meter

Ultrasonic flow meters available in the market are radar, Doppler velocity, ultrasonic clamp-on, and ultrasonic level.

- Doppler velocity type meters use reproduced ultrasonic noise to calculate the liquid's velocity.
- Radar type meter employs microwave technology for transmitting small pulses to reflect off a flowing surface back to the sensor for deciding velocity.
- Ultrasonic clamp-on type meter is ideal for applications wherever accessing the pipe is difficult otherwise not possible.
- Ultrasonic level type meter is ideal for determining the fluid level in both open & closed channels.

Advantages of Ultrasonic Flow Meter

The advantages are

- It does not block the path of liquid flow.
- The o/p of this meter is different for density, viscosity & temperature of the liquid.
- The flow of liquid is bidirectional
- The dynamic response of this meter is good.
- The output of this meter is in analog form
- Conservation of energy
- It is appropriate for huge quality flow measurement
- It is handy to fit and maintain
- Versatility is good
- There is no contact to liquid
- There is no leakage risk
- There are no moving parts, pressure loss
- High accuracy

Disadvantages of Ultrasonic Flow Meter

The disadvantages are

- It is expensive as compared with other mechanical flow meters.
- Design of this meter is complex
- Auditory parts of this meter are expensive.
- These meters are complicated as compared with other meters, thus it requires specialists for maintaining and repairing these meters
- It cannot measure cement or concrete pipes one they rusted.
- It doesn't work once the pipe contains holes or bubbles in it
- Can't measure cement/concrete pipe or pipe with such material lining

Applications

The applications of ultrasonic flow meters include the following.

- These meters are used in wastewater and dirty liquid applications
- These meters are used wherever chemical compatibility, less maintenance, and low-pressure drop are required.
- These meters are used to measure the velocity of a liquid through ultrasound to analyze volume flow.
- These meters measure the disparity between the transit time of ultrasonic pulses which transmits with the direction of liquid flow
- The applications of these meters range from process to custody flow
- This is one kind of device for volumetric flow measurement for liquids as well as gases.
- These are excellent alternatives for both vortex & electromagnetic flowmeters.

Unit 4:

Level Measurement Definition

Level measurement is a single dimension from a reference point. As shown tank level is measured, either by Inage method or Outage method. Each Manufacturer has a different Instruction Set.

Level Measurement Principle

Level devices operate under three main different principles:

- The position (height) of the liquid surface
- The pressure head
- The weight of the material

There are two methods used to measure the level of a liquid:

- Direct Methods
- Indirect or inferential Methods
- Direct Methods ( ) Visual Methods)

The direct method measures the height above a zeropoint by any of the following methods point by any of the following methods. Direct methods for level measurement are mainly used where level changes are small and slow such as;
Sump tanks and Bulk storage tanks.
Direct methods are simple and reliable. There are four types of direct level measurement devices:
1.Dip-sticks & Dip-Rods
2.Weighted gauge tape
3.Sight Gauges, and
4.Floats.

Sight Gauges

There are various types of sight gauges, the two most
common types being used are:
1.Sight glass; flat tubular and reflex Sight glass; flat, tubular and reflex
2.Magnetic sight gauges.

The flat glass

The flat glass type, is used for non pressurized vessels.
It is a glass window or windows that forms part of the vessel.
A typical application is in hot oil tanks, where excessive foam
contaminated oil may be easily detected.

Tubular Sight Glasses

Light is refracted from the vapor portion of the column and is shown generally generally as white color. Light is absorbed absorbed by the liquid portion in the column and is shown generally as a dark color.

They are used mainly for non-corrosive, non-toxic inert at moderate temperatures and pressures.

Magnetic type Sight gauges

The magnetic level gauge, consisting of a magnetic float that travels travels up and down on the inside of a long, non-magnetic magnetic (usually stainless steel) pipe. The pipe is connected to flanged nozzles nozzles on the side of the tank. The pipe column is provided provided
with a visual indicator, consisting of triangular wafer elements

These elements flip over (from green to red, or any other color) when the magnet in the float reaches their level. Alarm switches and transmitter options are available with similar magnetic coupling schemes.

Operational considerations for Sight Glasses

Sight glasses are usually installed with shutoff valves and a drain valve for the purpose of maintenance, repair and replacement.

o An important safety feature of these external sight glasses is the inclusion of ball check valves within the isolation valves.

The purpose of these check valves is to prevent the escape dangerous fluids if the glass breaks.
Therefore it is important that the isolation valves are left fully open when the sight glass
is in use, otherwise the operation of the check valves may be inhibited.

o Sight gauges must be accessible and located within visual range.

They are not suitable for dark liquids Dirty liquids will prevent They are not suitable for dark liquids. Dirty liquids will prevent the viewing of the liquid level.

Floats

Floats give a direct readout of liquid level when they are connected to an indicating instrument through a mechanical linkage.

A simple example of this is the weighted tape tank gauge, the position of the weighted anchor against a gauge board gives an indication of the liquid level in the tank.

The scale of the gauge board is in reverse order i e the zero The scale of the gauge board is in reverse order, i.e. the zero level indication is at the top and the maximum level indication is at the bottom of the gauge board.

Indirect (inferential) Methods

The indirect or inferential method of measurement uses the changing position of the
liquid surface to determine level with reference to a datum line.

It can be used for low & high levels where the
use of the direct method instruments is
impractical.

1.Hydro static Pressure Methods
2.Displacement devices
3.Capacitance Level Instrumentation
4.Radiation-Based Level Gauges

Hydrostatic Pressure Methods

A vertical column of fluid exerts a pressure due to the column's weight. The relationship between column height and fluid pressure at the bottom of the column is constant for any particular fluid (density) regardless of vessel width or shape.

This principle makes it possible to infer the height of liquid in a vessel by measuring the pressure generated at the bottom:

The level of liquid inside a tank can be determined from the pressure reading if the weight density of the liquid is constant.

Level measurement involving the principles of hydrostatics have taken numerous forms, including:

1.The diaphragm-box system
2. differential-pressure t meters
3.The air-bubble tube or purge system

- ***created***

Sight Glasses and Gage Glasses

The sight glass is an important method for visually determining level. The sight glass is a transparent tube of glass or plastic mounted outside the vessel and connected to the vessel with pipes. The liquid level in the sight glass matches the level of liquid in the process tank.

In process systems that contain a liquid under high pressure a reflex sight glass is used. This device is armored, to permit it to tolerate higher temperatures and higher pressures. Gage glasses are typically glass covered ports in a vessel that make it possible to observe the level of the substance in the vessel. Many gage glasses will have a scale mounted on the tank that allows the level to be read.

- **Float Devices**

These devices operate by float movement with a change in level. This movement is then used to convey a level measurement. An object of lower density than the process liquid is placed in the vessel, causing it to float on the surface. The float rises and falls with the level, and its position is sensed outside the vessel to indicate level measurement.

- **Magnetic-Type Float Devices**

  Floats can also be used with magnets to detect and indicate level. This type of measurement system uses the attraction between two magnets to follow the level of a process liquid.

  Variable displacement sensors.

  When a body is immersed or partly immersed in a liquid, it loses weight equal to the liquid weight displaced. Variable displacement level devices utilize this principle by measuring the weight of the immersed displacer.

- **Archimedes' Principle**

  Archimedes' Principle states that a body immersed in a liquid will be buoyed up by a force equal to the weight of the liquid it displaces. This upward pressure acting on the area of the displacer creates the force called buoyancy.

- **Principles of Variable Displacement**

  The float displaces its own weight in the liquid in which it floats. It will sink into the liquid until a volume of liquid is displaced that is equal in weight to that of the float. When the specific gravity of the liquid and the cross-sectional area of the float remain constant, the float rises and falls with the level. So, the float will assume a constant relative position with the level and its position is a direct indication of level. The amount of liquid displaced by variable displacers depends on how deeply the device is submerged in the liquid. With variable displacement devices, the amount of displacement varies with the level of the liquid.

  The span of the displacer is the distance that the displacer will respond to the forces of buoyancy. Buoyant force depends on the amount of liquid displaced and the density of the liquid. It is important to note the relationship of specific gravity to the change in weight of the displacer as the level changes. Displacers used in liquids with lower specific gravity will not change weight as dramatically as those used in liquids with higher specific gravity. This is why displacer level measuring systems are not used in applications where they could be immersed in liquids of varying specific gravities.

- **Liquid-Liquid Interface Measurement**

  An advantage of variable displacers is that they are capable of detecting liquid-liquid interfaces as well as liquid-gas interfaces. When a displacer is used to determine the level of an interface between two liquids, it is always completely submerged.

- **Variable Displacement Level Measuring Devices**

  A displacer must be connected to a measuring mechanism which, when sensing the changes in buoyant force, converts this force into an indication of level. A displacer body can be suspended directly in a tank, or installed in a float chamber on the outside of the vessel. Torque tube displacer level instrument is suspended from an arm that is attached to a torque tube or torque rod. A knife-edge bearing supports the movable end of the torque tube. This type of bearing provides an almost frictionless pivot point. The torque tube must be sufficient strength to support the full weight of the displacer in the absence of buoyancy, or when the level is at minimum. It is a solid or hollow tube that transfers displacer motion to an electronic instrument or a pneumatic instrument that will produce a signal proportional to the changes in the weight of the displacer. Spring balance displacers are devices similar to torque tube displacers. In these devices, the torsional spring of the torque tube is replaced by a conventional range spring. The motion of the displacer is transferred to the indicator by means of magnetic coupling.

- **Applications**

Variable displacement level devices are most often used for local level indication or control. Because displacers are immersed in process fluids, their material of construction must be compatible with the process. Displacers are also extremely sensitive to changes in the density of process liquids. Provisions must be made to measure and compensate for such changes in density when variable displacers are used.

Pressure sensors.

Since level can be determined by pressure, or head, many pressure measuring devices are used for indicating level.

- **Hydrostatic Pressure**

A liquid at rest in a vessel exerts a pressure on the walls of the vessel. At any given point the pressure on the wall of the vessel is proportional to the vertical distance between that point and the surface of the liquid, and varies with the height of the liquid. The relationship between the weight produced by the vertical height of a column of water and the pressure exerted on the supporting surfaces of the vessel can be used to determine level. The relationship between pressure and level makes it possible to convert hydrostatic measurements directly to level in feet or inches. In the following equations, "WC" stands for water column and is usually omitted from equations as understood in discussions of hydrostatic pressure.

1 lb./in.2 = 2.31 feet water

= 27.7 inches water (WC)

1 psi = 2.31 feet

= 27.7 inches

- **Open-Tank Head Level Measurement**

If level is to be determined and indicated by measuring pressure, the specific gravity of the liquid must be known. The specific gravity of water is 1.00. If the liquid has a lower specific gravity, the pressure exerted by the column of liquid will be less than that exerted by a column of water of the same height. For liquids with a specific gravity greater than 1.00, the pressure exerted by the column of liquid will be greater. To compensate for the difference in specific gravity, the following equation is used:

$h = (p (2.31 \text{ ft.})) / G$

where:

h = height in feet

p = pressure

G = specific gravity

- **Diaphragm Box**

The diaphragm box is submerged in the process liquid and connected to a pressure gage by a gage line. The hydrostatic head produced by the level of the liquid in the tank exerts pressure on the bottom of the diaphragm causing it to flex upward. This action compresses the gas in the box and the gage line. The pressure is applied to a gage or other pressure element that is part of an indicator assembly calibrated to indicate liquid level units.

- **Air-Trap Sensors**

As the liquid level rises, the hydrostatic head forces liquid up into an air trap sensor, or inverted bell. As the level of the liquid rises, it compresses the air trapped in the bell and the gage line until an equilibrium between the air pressure and the pressure exerted by the hydrostatic head is reached.

- **Air Bubble or Surge Tube**

Known by various names, including an air bubble, a surge tube, an air purge and a dip tube, this type of system uses a continuous air supply that is connected to a tube that extends into the tank to a point that represents the minimum level line. An air regulator controls the air flow. It increases air flow to the tube until all liquid is forced from the tube. At this pressure and flow rate, the air begins to bubble out of the bottom of the tube. This indicates that the air pressure forcing the liquid out of the tube is equal to the hydrostatic head produced by the height of the process liquid being forced into the tube. The air pressure acting against the hydrostatic head provides the pressure indication to the gage.

This is most useful for applications such as underground tanks and water wells. However, as with other hydrostatic pressure systems, the major limitation of these systems is that they are generally limited to open-tank applications.

- **Closed-Tank Applications**

In open tanks, measurements are referenced to atmospheric pressure. At atmospheric pressure, the pressure on the surface of the liquid is equal to the pressure on the reference side of the pressure element in the measuring instrument. When atmospheric pressure changes, the change is equal on both the surface of the liquid and the reference side of the measuring element. To compensate for the effects on level measurement caused by such pressure variations in closed-tank applications, a differential pressure (d/p) cell is often used to measure and indicate level. The d/p cell only responds to differences in pressure applied to two measuring taps. One pressure tap is the measuring point on the tank, which is usually below the minimum level point for the liquid. The other tap is usually located near the top of the tank. The tap in the liquid region of the tank is referred to as the high-side; the other tap, located above the level of the liquid, is referred to as the low-side. System pressure is sensed by both the high and low sides. In addition to system pressure, the high side also senses the pressure exerted by the height of the liquid. Since both sides are exposed to the same system pressure, the effects of system pressure are canceled and the differential pressure cell only indicates liquid level.

An instrument can be calibrated to compensate for the additional static pressure created by the condensed liquid. This compensation or adjustment is called zero elevation. Other means are also available to eliminate inaccuracies due to wet leg problems. For instance, in what is referred to as a wet-leg installation, the low pressure leg is deliberately filled with liquid. Another method involves the use of a device called a pressure repeater or one-to-one relay. The repeater is installed at the top of the tank and linked by pipe to an air relay. The pressure in the tank actuates the air relay, which is connected to an air supply. When the pressure in the tank increases, the relay increases the air pressure on the low-pressure leg. The relay regulates the air pressure so that it is equal to that of the tank pressure. When the pressure in the tank decreases, the relay vents air from the low pressure leg to maintain the equilibrium. Zero suppression, is the correction adjustment required to compensate for error caused by the mounting position of the instrument with respect to the level measurement reference.Electrical sensors.

- **Capacitance**

A capacitor consists of two plates separated from each other by an insulating material called a dielectric. In applications involving capacitance measuring devices, one side of the process container acts as one plate and an immersion electrode is used as the other. The dielectric is either air or the material in the vessel. The dielectric varies with the level in the vessel. This variation produces a change in capacitance that is proportional to level. Thus, level values are inferred from the measurement of changes in capacitance, which result from changes in the level.

Capacitance type level measurement devices offer many advantages. Simple in design, they contain no moving parts and require minimal maintenance. The availability of corrosive resistant probes is also an advantage. Measurement is subject to error caused by temperature changes affecting the dielectric constant of the material. If the probes should become coated with a conductive material, errors in measurement may occur.

- **Conductivity**

A material's ability to conduct electric current can also be used to detect level. This method is typically used for point measurement of liquid interfaces of relatively high conductivity. Conductivity applications are usually limited to alarm devices and on/off control systems. A common arrangement is two electrodes positioned at the top in a tank. One extends to a minimum level and the other is positioned so that its lower edge is at the maximum level. The tank is grounded and functions as the common, or third electrode. Usually, a stilling well is provided to ensure that the interface is not disturbed and to prevent false measurement.

There are limitations to the conductivity method. The first is process substance must be conductive. Second, only point detection measurements can be obtained. The possibility of sparking also makes this method prohibitive for explosive or flammable process substances.

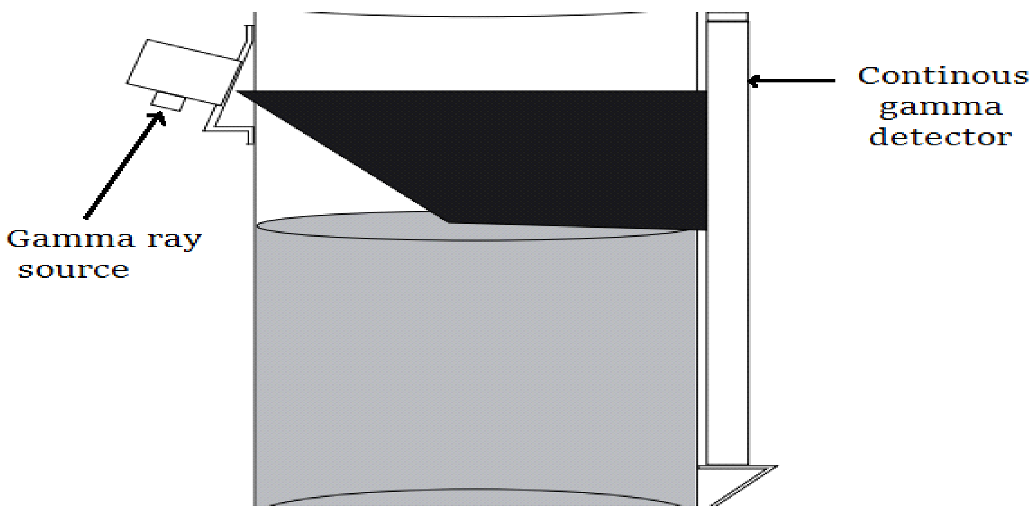
Advantages include low cost and simple design, as well as the fact that there are no moving parts in contact with the process material. These advantages make this type of system an effective method of detecting and indicating level for many water-based materials.

- **Resistance**

Resistance type level detectors use the electrical relationship between resistance and current flow to accurately measure level. The most common design uses a probe consisting of two conductive strips. One strip has a gold-plated steel base; the other is an elongated wire resistor. The strips are connected at the bottom to form a complete electrical circuit. The upper ends of the strips are connected to a low voltage power supply. The probe is enclosed in a flexible plastic sheath which isolates the strips from the process material. As the level of the process material rises, the hydrostatic pressure forces the resistance strips together up to the interface. This action shorts the circuit below the interface level, and total resistance is reduced proportionately. Resistance sensing devices can be used for liquid-gas interfaces and for slurries or solids. As with the other electrical level sensors discussed, resistance-type level detectors require relatively little maintenance.

Radiation level measurement techniques

Posted on : February 19, 2018 **By** Sivaranjith



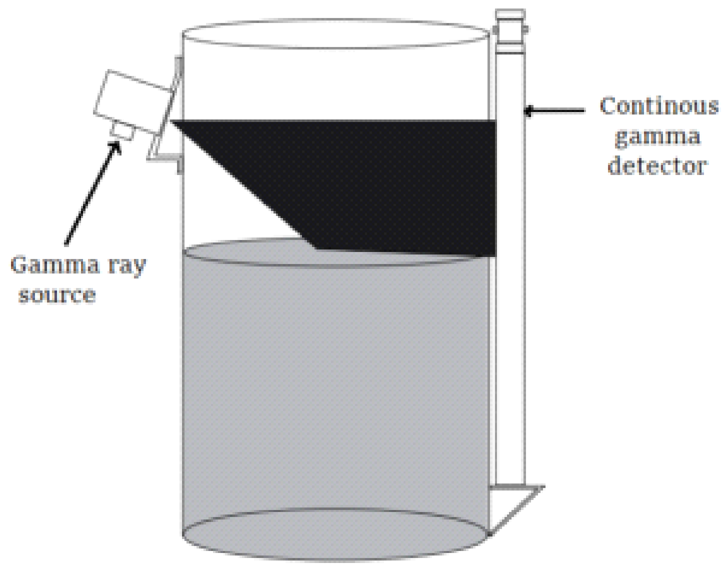
Instrumentation Level Measurement

The radiation/nuclear level measurement technique is used to measure the level of fluid or solid in a closed tank using Gamma rays. Gamma radiation sources are chosen for use in level detecting equipment because gamma rays have great penetrating power and cannot be deflected.

Principle:

Level measurement with radiation works on the principle of passing gamma radiation through the material to be measured. As the radiation passes through this material, the level can be determined by the amount of attenuation. The wave attenuates when it passes through materials.

Working and Construction:



The Gamma-ray is emitted from a source to the tank and propagates through the tank. There is a continuous strip detector that detects all the Gamma rays pass across the tank. If the continuous strip detects rays equal to the length and it is in maximum absorption, the tank is empty. As the level rises the absorption level decreases.

Different components of Radiation meter:

The source:

The main component of this type of measuring device is the radioactive source. The two common types of radioactive sources are Caesium 137 (Cs 137) and Cobalt 60 (Co 60). The activity of the radioactive substance decreases with time. The time taken for the activity of such a substance to halve is termed its half-life. Cobalt 60 has a half-life of 5.3 years while Caesium 137, on the other hand, has a half-life of 32 years.

There are strip source and point source:

The stripped source is more accurate as it radiates a long, narrow, uniform beam in the direction of the detector. As the level changes, the detector is covered and protected from the source and the corresponding response changes. The response is uniform and linear over the entire span, producing a linear signal that corresponds with changes in level.

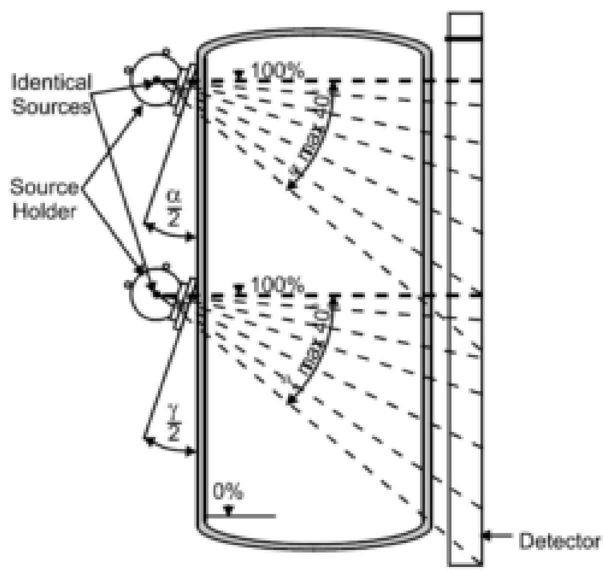
The point source works in a similar way to the strip source system, in that the strip detector measures the radiation from the source. The radiation sensed by the detector is still attenuated with level, however, the point source system produces a non-linear response with level change.

The Strip Detector:

The detector for continuous measurement is a type of scintillation counter and photomultiplier. This type of sensing has the advantage of the high sensitivity of the scintillation crystals (compared to Geiger counters) coupled with the safety and economy of a point source.

The rod scintillation counter is a rod of optically pure perspex within which scintillation crystals are uniformly distributed. In the presence of gamma radiation, the scintillation crystals emit flashes of light which are then detected by a photomultiplier at the base of the rod and converted into electrical pulses.

To improve linearity and accuracy, we use multiple point sources:



Advantages:

- Suitable for a variety of products
- Mounted without obstruction
- Can be mounted external to the vessel

Disadvantages:

- Must always be mounted on the side of the vessel
- Special safety measures are required for the use of gamma radiation
- May also involve licensing requirements
- Expensive

Ultrasonic level detectors use the principle of reflection of an acoustic wave from liquid to vapour phase and vapors to liquid phase.

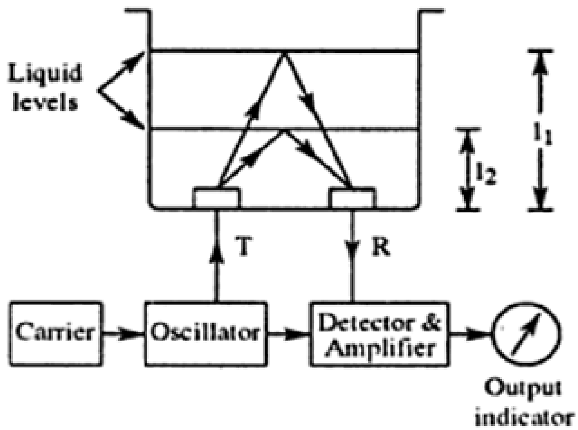


fig: A

Ultrasonic level measurement work as similar to the working of sonar. An ultrasonic sound sends by the transmitter reflects back touching the water level to the receiver or Echo.

The Ultrasonic level detector measures the level on the basis of:

- Time required by the echo signal to reach the receiver.
- Change of phase of the wave during the time.

Considering the liquid used in a storage tank, there are two ways to fix the level detector in the tank within the tank at the top of the tank. Fig A level detector is shown as in the bottom of the tank, which is said to be liquid phase level measurement.

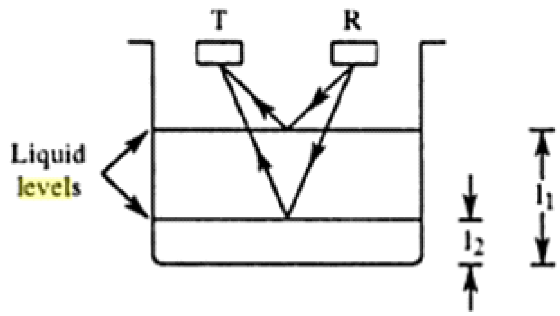


fig: B

Fig B shows a vapor phase measurement setup.

The liquid phase method is used in storage tanks of oil and chemical and for aircraft or marine equipment tanks. The vapors phase method is used in mines, oil-well etc…

Piezoelectric crystals are used to produce ultrasonic sound

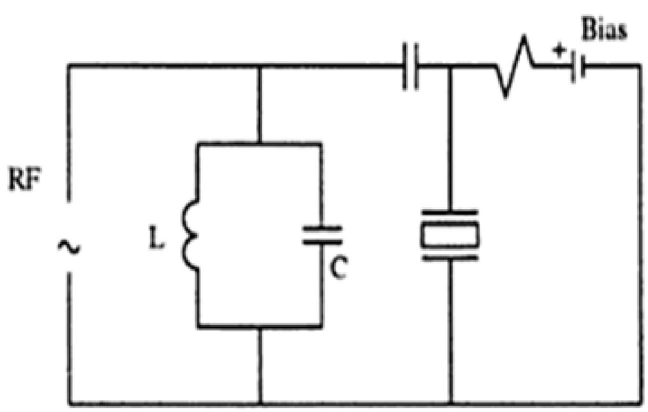


fig: C

The above-shown L-C piezoelectric circuit is used as the oscillator circuit to produce the ultrasonic wave with frequency ranging from 30-300kHz. LC circuit is used to avoid spurious crystal oscillation.