Analog Devices

Temperature Devices – RTD, Thermocouple

Pressure/Flow/Level Transducers.

Weighing Scales

Encoders

Current to Pneumatic Converters

Analog Devices

Transducer obtains information in the form of one or more physical quantities and converts this into an electrical output signal.

Transducers consist of two principle parts,

A primary measuring element referred to as a sensor

Transmitter unit responsible for producing an electrical output that has some relationship to the physical measurement.

Analog Devices – Precision

Precision is the accuracy with which repeated measurements of the same variable can be made under identical conditions.

In process control, precision is more important than accuracy.

It is usually preferable to measure a variable precisely than it is to have a high degree of absolute accuracy.

Analog Devices – Precision

The amount of change in the output signal from a transducers element to a specified change in the input variable being measured.

OR

The smallest change in the measured variable which will produce a change in the output signal from the sensing element.

Analog Devices

Resolution is defined as the smallest change of input that results in a significant change in transducer output.

Repeatability is the closeness of agreement between a value of consecutive measurements of the output for the same value of input under identical operating conditions

Rangeability This is the region between stated upper and lower range-values of which the quantity is measured. It is also referred as **Range**.

Span is the ALGEBRAIC difference between the upper and lower range values. It should not confused with Range or Rangeability.

Temperature Measurement

Temperature Sensors

Temperature is the most common PV measured in process control.

Most common transducer are,

Thermocouple

Resistance Temperature Detector (RTD)

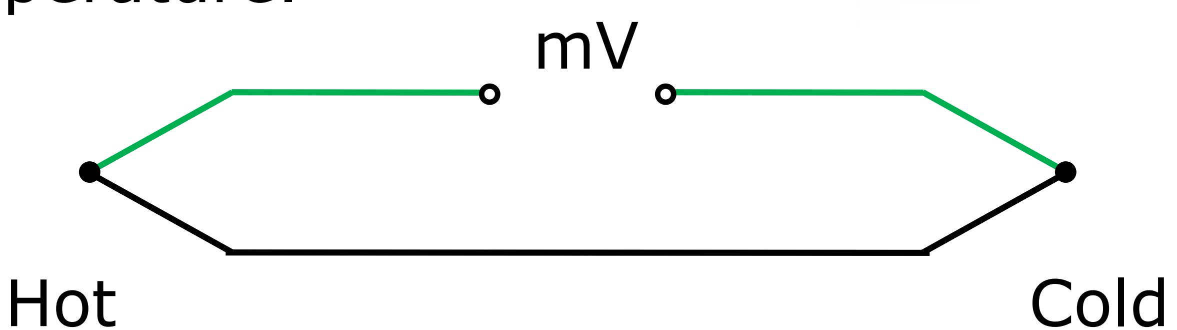
Thermistors

Radiation Pyrometers

Thermocouple

Principal two dissimilar metals always have a contact potential between them, and this contact potential changes as the temperature at contact point changes

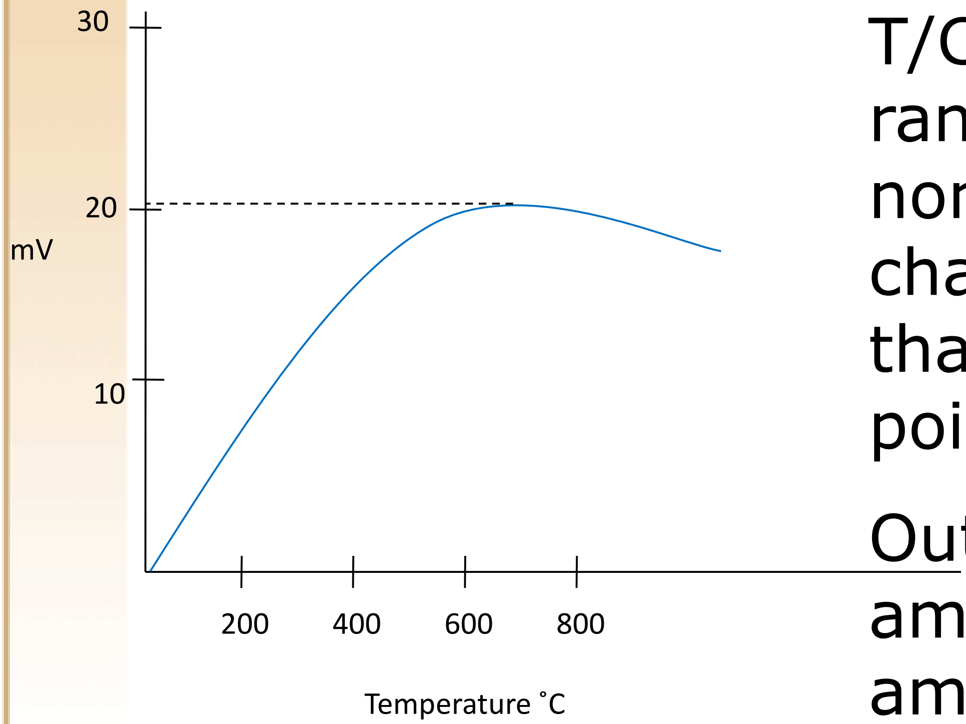
To measure the contact potential two contact points or junctions are required at different temperature.



T/C principle can be explained by Seebeck and Peltier Effect.

Thermocouple

Following figure shows the characteristic of T/C.



T/C is useful over a limited range of temperature due to non-linear shape of characteristic and reversal that takes after turnover point.

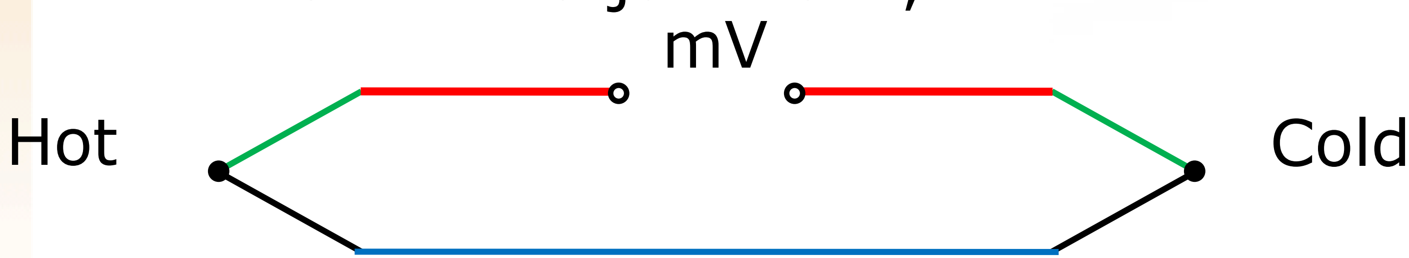
Output of T/C has very low amplitude (in mVs) so DC amplification is required.

Basic Advantage of T/C is the size of element.

Thermocouple

A T/C measurement is always differential measurement, Measuring temperature difference between **reference junction** (Cold junction) and **measuring junction** (Hot Junction).

If connecting cable between Hot Junction and Cold junction are not of the same material as T/C they will create extra junctions,



These junctions can induce voltages depending upon temperature at the junctions.

Thermocouple

Secondly, Reference junction temperature should be constant and ideally should be 0 °C for accurate measurement, but it is never.

Compensation is required to overcome these change in ref. junction temperature, which can be done by **"Cold Junction Compensation"**

Usual method of compensation is to provide a coil or thermistor at reference junction to measure temperature of reference junction.

Output of thermistor is given to the transmitter circuit of thermocouple, which will correct for above effect.

Thermocouple

Metal Composition		*Temperature Span*	*Seebeck Coefficient*
K	*Chromel vv Alumel*	-190 to +1371 $^{\circ}C$	40 $\mu V/^{\circ}C$
J	*Iron vv Constantan*	-190 to +760 $^{\circ}C$	50 $\mu V/^{\circ}C$
T	*Copper vv Constantan*	-190 to +760 $^{\circ}C$	50 $\mu V/^{\circ}C$
E	*Chromel vv Constantan*	-190 to +1472 $^{\circ}C$	60 $\mu V/^{\circ}C$
S	*Platinum vv 10% Rhodium/Platinum*	0 to +1760 $^{\circ}C$	10 $\mu V/^{\circ}C$
R	*Platinum vv 13% Rhodium/Platinum*	0 to +1670 $^{\circ}C$	11 $\mu V/^{\circ}C$

Resistance Temperature Detector

Pure Metal and certain alloys changes its resistance as per change in surrounding temperature.

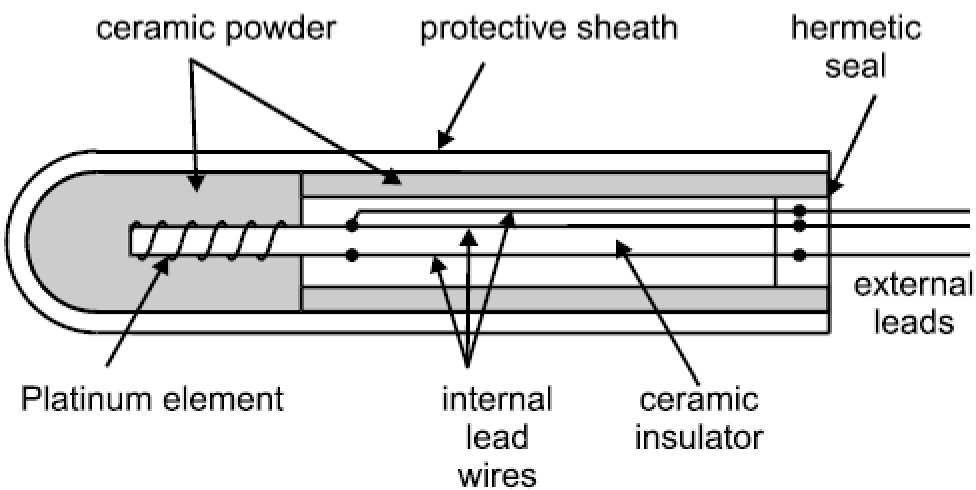
Resistance of such metals increases as temperature increase and decreases as temperature decrease.

Metals used in RTD should have,

- Linear temperature-resistance characteristic
- High coefficient of resistance.
- Ability to withstand repeated temperature cycles.
- Capable of being drawn into fine wire

Resistance Temperature Detector

Commonly used metals are **Platinum**, **Copper** and **Nickel**

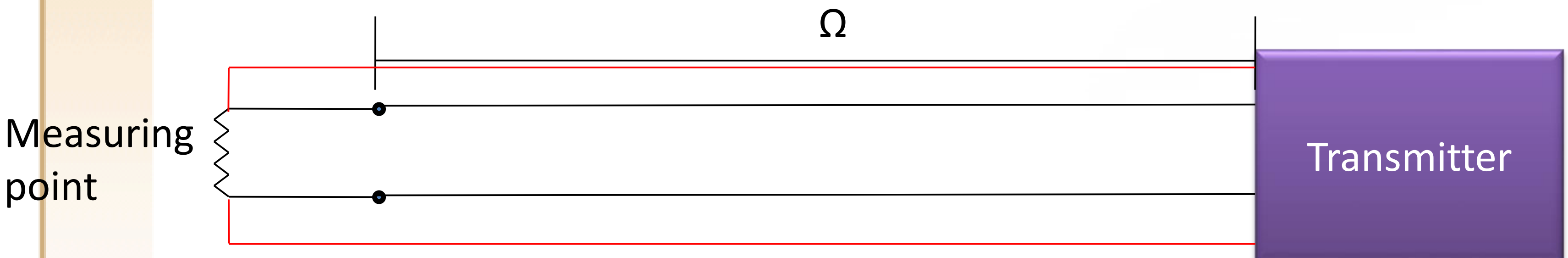


RTD elements are usually long, spring-like wires surrounded by an insulator and enclosed in a sheath of metal.

Resistance Temperature Detector

RTDs located in field are connected to transmitter thru long cables, resistance of these cables adds up to the total resistance of circuit.

This will generate an error in the reading and requires to be compensated.



To compensate this error extra wire is connected from measuring point to transmitter.

For perfect compensation both leads must have compensation.

Thermistors

Thermistors are form of temperature sensitive resistors constructed from metal oxide

Thermistors have Negative Temperature Coefficient (NTC), i.e. as temperature rises resistance decreases.

Thermistors normally available for temperature ranges of 150-200 ˚C.

These elements are the most sensitive and fastest temperature measuring devices.

However cost is very high compared to very small temperature range.

Radiation Pyrometers.

Radiation pyrometers are non contact type instruments best suited for temperature measurement.

Radiation pyrometers operate by measuring the total amount of energy radiated by a hot body.

Target when heated emits energy in a particular wavelength which is proportional to the temperature of target.

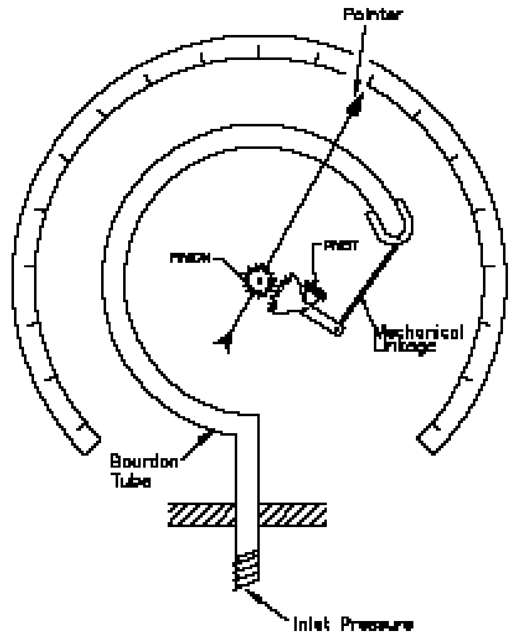
This energy is in the range of Infrared wavelength and are detected by infrared sensitive materials.

Typical range of Pyrometers are 0 ~ 4000 °C

Pressure Measurement

Bourdon Type Pressure Sensor

The bourdon tube consists of a thin-walled tube that is flattened diametrically on opposite sides



The tube is bent lengthwise into an arc of a circle of 270 to 300 degrees.

Pressure applied to the inside of the tube causes distention of the flat sections and tends to restore its original round cross-section.

The tube is permanently fastened at one end, the tip of the tube traces a curve that is the result of the change in angular position with respect to the center.

Pressure Sensors

Pressure is defined as force per unit area, and may be expressed in units of newtons per square meter, millimeters of mercury, atmospheres, bars

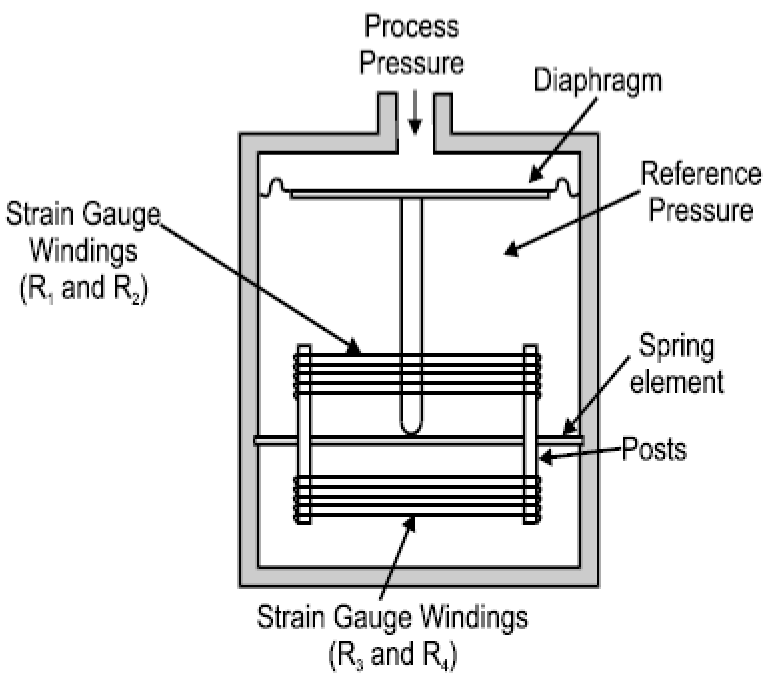
If measured against a vacuum, the measured pressure is called absolute pressure.

Against local ambient pressure it is gauge pressure.

If the reference pressure is user supplied, differential pressure is measured.

Strain Gauge Pressure Sensor

In process control applications, one of the most common ways to measure pressure is using a strain gauge sensor.



Typically, four strain gauges are bonded to a metal or plastic flexible diaphragm and connected into a Wheatstone bridge circuit

Change in Pressure causes displacement of Diaphragm.

Displacement of Diaphragm causes change in electrical signals proportional to Pressure.

Strain Gauge Pressure Sensor

This circuit is suited to both static and dynamic Pressure measurements.

Strain gauge elements can detect absolute gauge, and differential spans from 30 in. H2O to upwards of 200,000 psig.

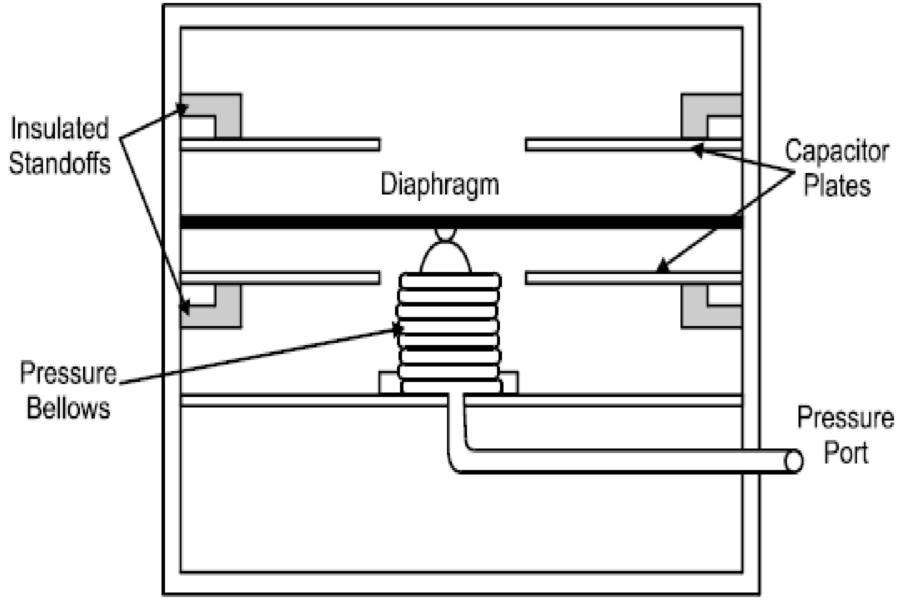
Strain gauge elements can detect absolute gauge, and differential spans from 30 in. H2O to upwards of 200,000 psig.

Their inaccuracy is around 0.2% and 0.5% of Span.

Capacitance Pressure Sensor

Capacitive pressure measurement involves sensing the change in capacitance that results from the movement of a diaphragm.

The sensor is energized electrically with a high frequency oscillator.



As the diaphragm is deflected due to pressure changes, the relative capacitance is measured by a bridge circuit.

Capacitance Pressure Sensor

Capacitive pressure measurement is also quite common for determining the level in a tank or vessel.

Highly accurate with accuracy – 0.01% ~ 0.2%

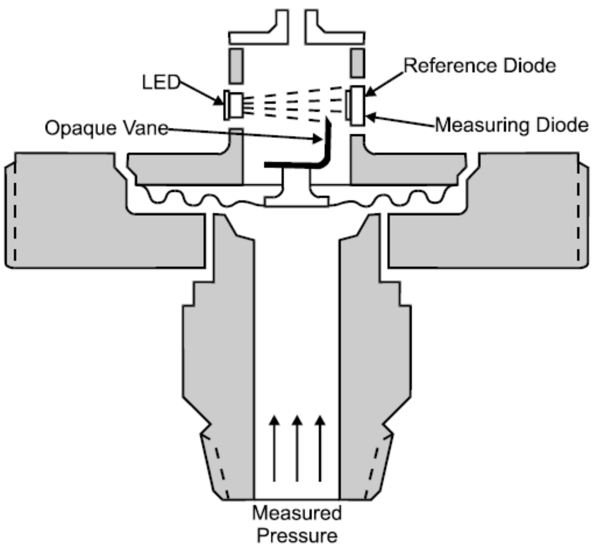
Pressure ranges from 0.01 PSI 5000 PSI.

Capacitance Sensors are sensitive to Temperature and Vibration.

Optical Pressure Sensors

Optical sensors can be used to measure the movement of a diaphragm due to pressure.

An opaque vane is mounted onto a diaphragm and moves in front of an infrared light beam.



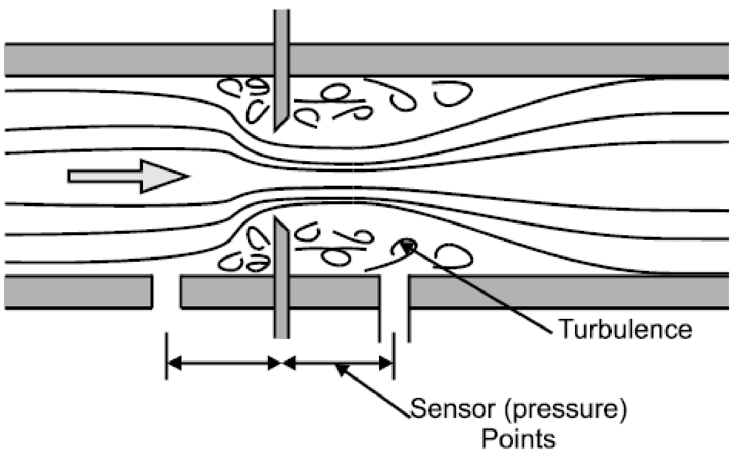
The received light on the measuring diode indicates the position of the diaphragm.

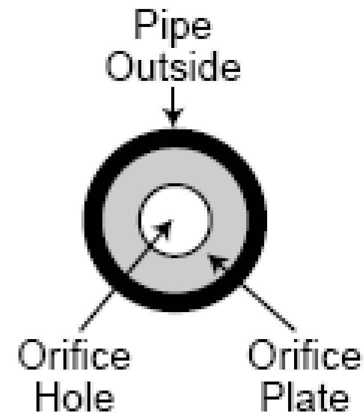
By using a reference diode, the temperature effects are cancelled as they affect the sensing and reference diodes in the same way.

Flow Measurement

Orifice Plate Flow Sensor

When Obstructed energy of flow system reduces. This is the basic principle used in Orifice Plate.





A standard orifice plate is simply a smooth disc with a round, sharp-edged opening in center.

A differential pressure is created across the orifice which has Square root relation with flow

Orifice Plate Flow Sensor

They are simple in construction and are available in large size and opening ratio.

Suitable for most gases and liquids.

Major disadvantage of orifice plate is that it creates a

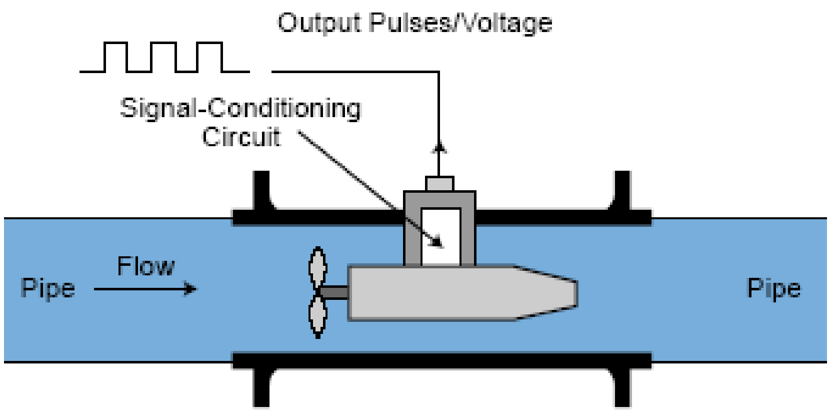
Low accuracy affected by density, pressure and viscosity.

They are subject to erosion, which will eventually cause inaccuracies in the measured differential pressure.

Turbine Flow Meter

Turbine meters have rotor-mounted blades that rotate when a fluid pushes against them.

The rotational speed of the turbine is proportional to the velocity of the fluid.



Magnetic pick-up or inductive proximity switch detects the rotor blades as they turn.

As each blade tip on the rotor passes the coil it changes the flux and produces a pulse.

The rate of pulses indicates the flow rate through the pipe.

Turbine Flow Meter

Turbine meters require a good laminar flow.

High accuracy, repeatability and rangeability for a defined viscosity and measuring range.

They have larger pressure and temperature reanges.

10 pipe diameters of straight line upstream, and no less than 5 pipe diameters downstream from the meter are required.

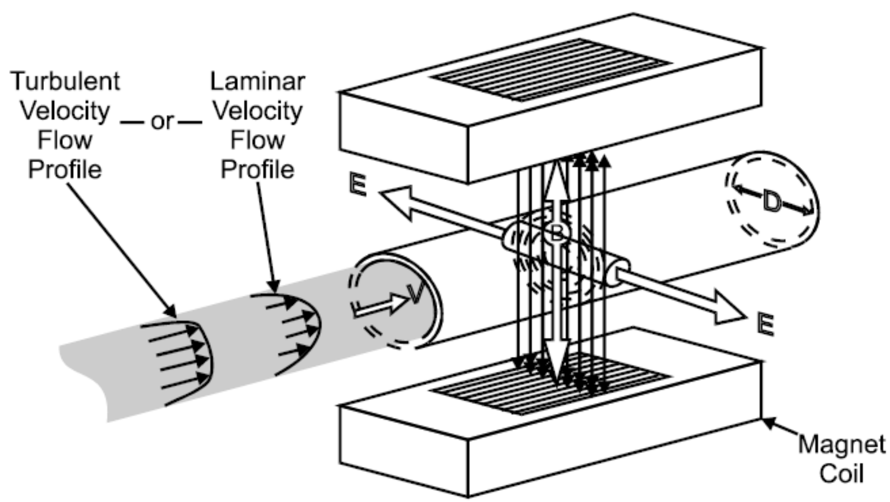
They are suitable for clean liquid and gases also they are not suitable for highly viscous liquids.

They are are commonly used for custody transfer applications of clean liquids and gases.

Magnetic Flow Meter

This device is used to make flow measurements on a conductive liquid.

A charged particle moving through the magnetic field produces a voltage proportional to the velocity of the particle.



A conductive liquid consisting of charged particles will then produce a voltage proportional to the volumetric flow rate.

They have no obstructions or restrictions to flow

Magnetic Flow Meter

Most industrial liquids can be measured by magnetic flow meters, these include acids, bases, water, and aqueous solutions.

Magnetic flow meters are very accurate and have a linear relationship between the output and flow-rate.

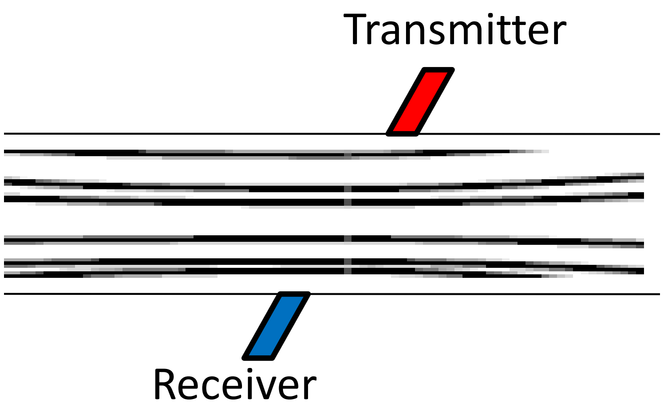
Magmeters are not greatly affected by the profile of the flow, and are not affected by viscosity or the consistency of the liquid.

For correct operation of the magmeter, the pipeline must be full.

They are expensive and limited to conductive fluids only

Ultrasonic Flow Measurement

Ultrasonic Flow Meter has a ultrasonic pulse transmitter and a receiver mounted diagonally on the pipe.



The transit-time is measured from when the transmitter sends the pulse to when the receiver detects the pulse.

The transit-time of a pulse is proportional to velocity of liquid passing thru the pipe.

Transit-time ultrasonic flow measurement is suited for clean fluids.

Ultrasonic Flow Measurement

The Doppler effect device relies on objects with varying density in the flow stream to return the ultrasonic energy.

A beam of ultrasonic energy is transmitted diagonally through the pipe.

Portions of this ultrasonic energy are reflected back from particles in the stream of varying density.

Since the objects are moving, the reflected ultrasonic energy will has a different frequency.

The amount of difference between the original and returned signals is proportional to the flow velocity.

Ultrasonic Flow Measurement

Suitable for large diameter pipes, No obstructions, no pressure loss

Fast response, Installed on existing installations, Not affected by fluid properties

Accuracy is dependant on flow profile. Turbulence or even the swirling of the process fluid can affect the ultrasonic signals

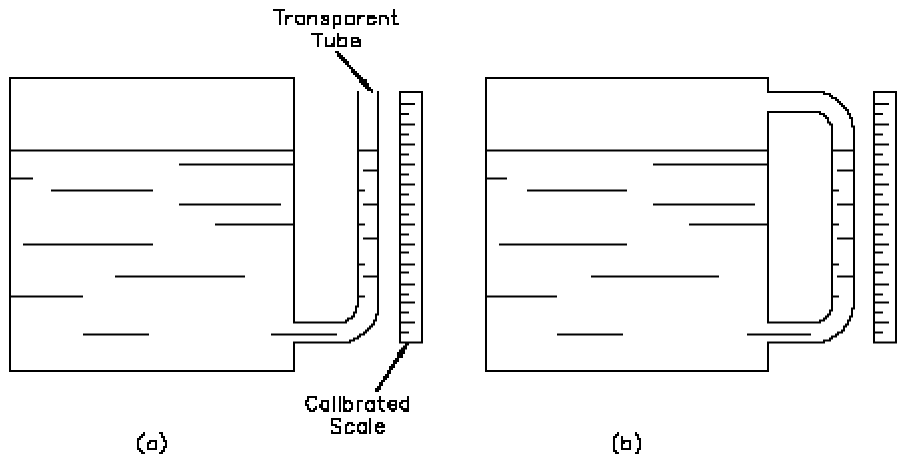
Accuracy is dependant on flow profile. Turbulence or even the swirling of the process fluid can affect the ultrasonic signals

Ultrasonic devices are dependent on the flow profile, and are also affected by temperature and density changes.

Level Measurement

Gauge Glass Measurement

A very simple means by which liquid level is measured in a vessel is by the gauge glass method

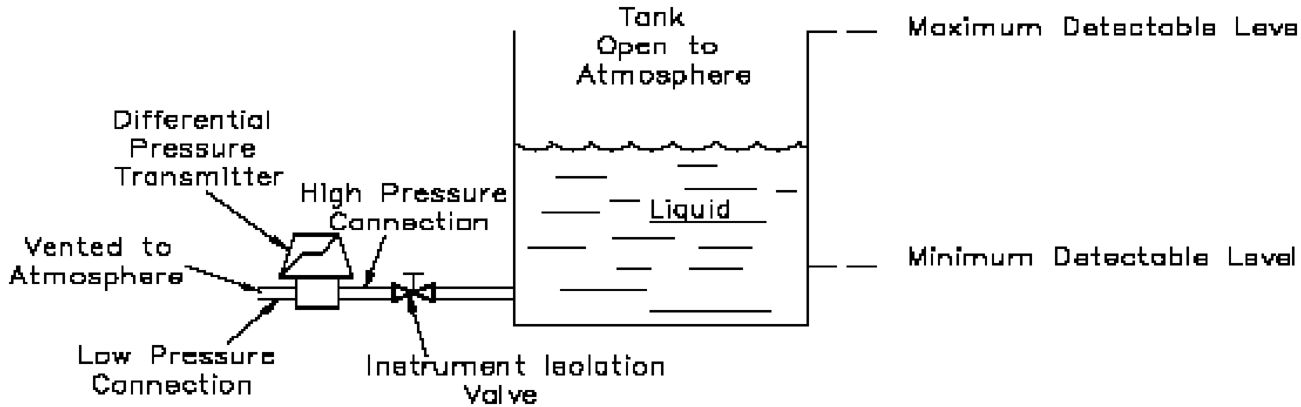


In the gauge glass method, a transparent tube is attached to the bottom and top of the tank that is monitored.

The height of the liquid in the tube will be equal to the height of Liquid in the tank.

Differential Pressure Measurement

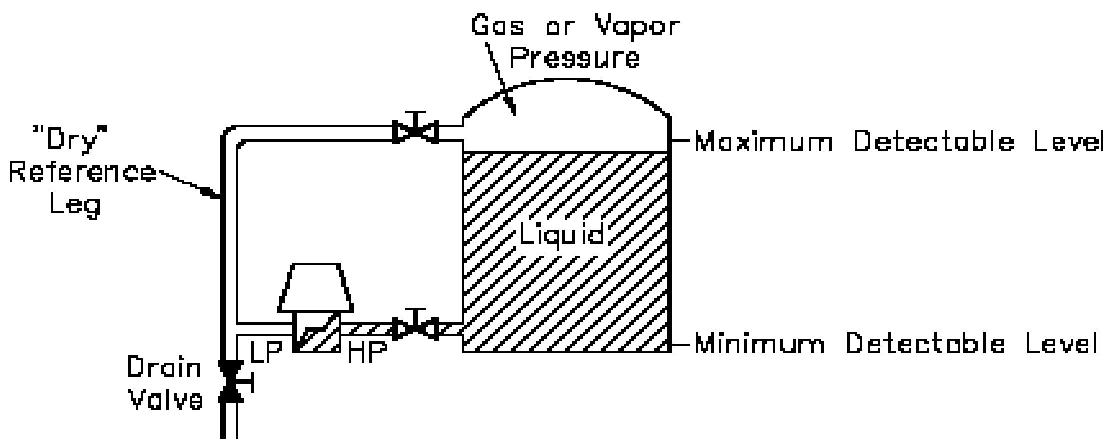
The differential pressure (DP) detector method of liquid level measurement uses a DP detector connected to the bottom of the tank being monitored.



Pressure Measured is proportional to the amount or level of liquid in the tank.

Differential Pressure Measurement

If tank is open to atmosphere only the High pressure port is connected to bottom of tank and low pressure port is vented to atmosphere.



However, if tank is not open to atmosphere then High pressure port is connected to bottom of tank and low pressure port is connected to the top of tank.

Ultrasonic Level Measurement

Ultrasonic transmitter and receiver are installed at the top of silo or tank.

Transmitter transmits a ultrasonic pulse which is reflected from the surface.

Time taken by pulse to return back will depend upon level of liquid or solid in the silo.

Ultrasonic measurement systems are not sensitive to pressure variations.

Variations in temperature will affect the sound velocity

Mounting of Ultrasonic Transmitter should be perfect for better result.