Module 1: Measurement of various process parameters

Measurement of temperature

It is measurement of hotness or coldness of body relative to standard scale & is related with reference to its power of communicating heat to surroundings.

When body is heated or cooled, various primary effects can result, & one of these effects can be employed for measurement purposes

i) Change in physical or chemical state

ii) Change in physical dimensions

iii) Variation in electrical properties

Applications:

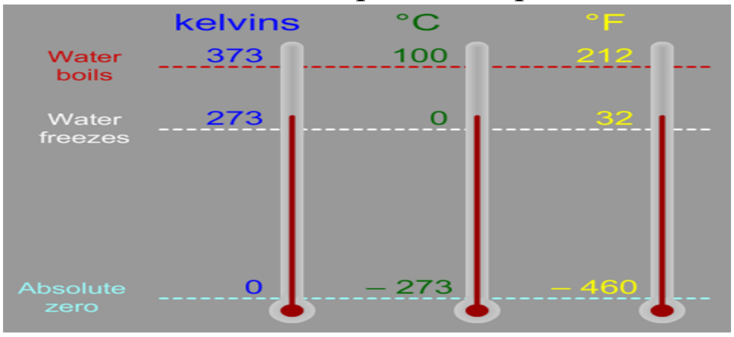
Process controls industry has developed large number of sensors & devices to handle demand Industrial environment

Most mechanical engineers: water temperature of engine or load device or temperature of weld in laser welding application

Temperature scale

There are three temperature scales in use today, Fahrenheit, Celsius & Kelvin.

These scales are based on number of increments between freezing point & boiling point of water at standard atmospheric temperature.



Measurement of temperature 1. Thermocouple 2. Thermistor 3. Thermometer 4. RTD

Thermocouple: Device which is used for measurement of temperature variations

Active transducers: generate electric current or voltage directly in response to stimulation.

<u>Principle:</u>

1. Thermocouple is composed of atleast two metals joined together to form two junctions.
2. Common materials include Cu/constantan (Type T), Fe/constantan (Type J), & chromel / alumel (Type K). 3. Hot junction/measuring junction- unknown body.
4. Cold/reference junction- known temperature

<u>Seebeck effect-</u>

This effect states that when two different or unlike metals are joined together at two junctions, electromotive force(emf) is generated at two junctions.

The amount of emf generated is different for different combinations of metals.

<u>Peltier effect-</u>

When two dissimilar metals are joined together to form two junctions, emf is generated within circuit due to different temperatures of two junctions of circuit.

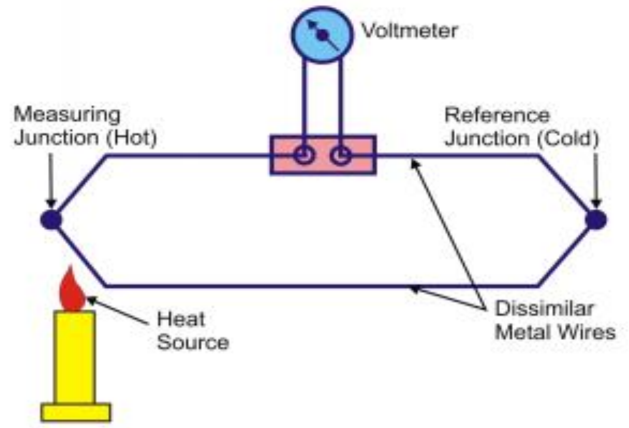
Working

Thermocouple measures voltage generated between two junctions.

In thermocouple, emf set up is measured by sending current through moving coil instrument, deflection being directly proportional to emf.

The reference junction is usually at 0 °C.

Thermocouples- upto 1400 °C.



emf produced in thermocouple is given by

$$E = a(\Delta\theta) + b(\Delta\theta)^2$$

$\Delta\theta$ = Difference in temp^r bet^n two junctions (°C)

a, b = constants (Sensitivities of materials)

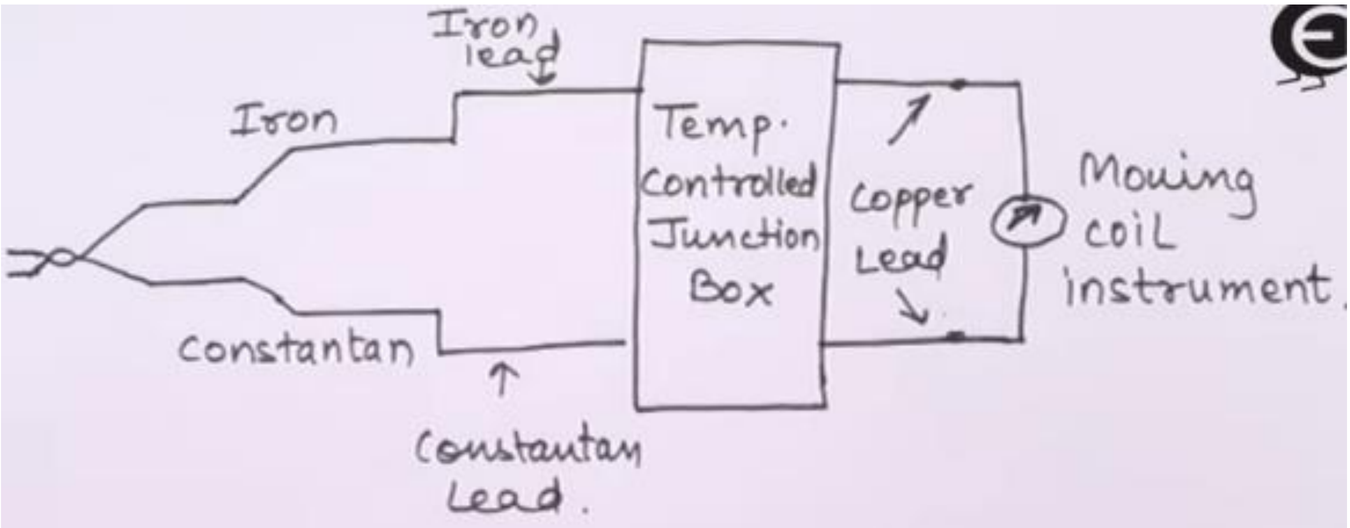
Combination of metals used for thermocouple should always produce linear rise in emf.

$$E = a(\Delta\theta)$$

b=negligible

$$\boldsymbol{\Delta\theta = \frac{E}{a}}$$

Choice of metals used for thermocouple: Temperature range Atmosphere



Advantages

1. It is rugged in construction
2. Covers wide temperature range
3. Using extension leads & compensating cables, long transmission distances for temperature measurement possible. This is most suitable for temperature measurement of industrial furnaces.
4. Comparatively cheaper in cost
5. Calibration can be easily checked
6. Offers good reproducibility
7. High speed of response

Limitations

1. Lower accuracy
2. Should be protected against contamination(stray magnetic,electric fields)to ensure long life
3. Placed at remote locations from measuring devices
4. In many applications, amplification of signal is required.

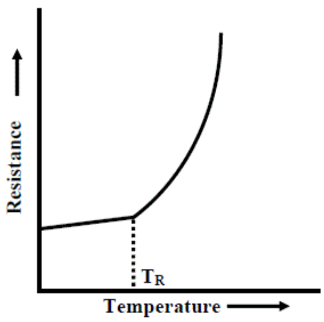
Thermistors

A thermistor is type of resistor with resistance varying according to its temperature. resistance is measured by passing small, measured direct current through it & measuring voltage drop produced. There are basically two broad types

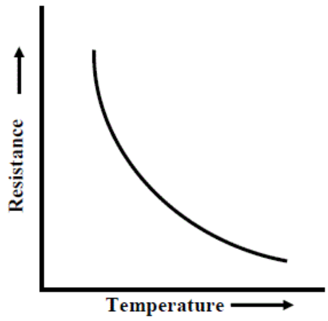
NTC-Negative Temperature Coefficient: used mostly in temperature sensing

PTC-Positive Temperature Coefficient: used mostly in electric current control.

PTC thermistor

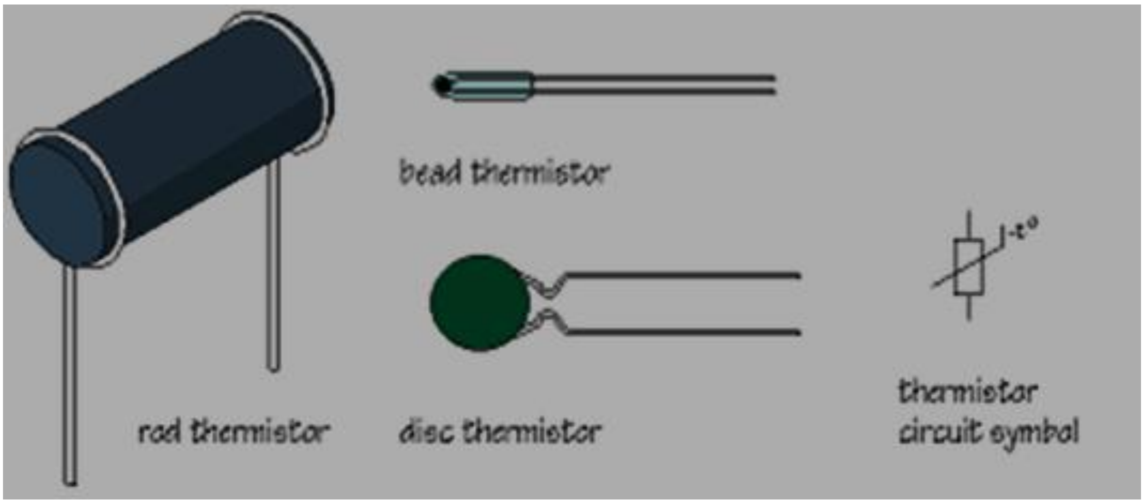


NTC thermistor



Construction

1. Thermistors are fabricated from semiconductor materials which include oxides of copper, manganese, nickel, cobalt
2. These oxides are blended in suitable proportion & compressed into desired shapes from powders & heat treated to recrystallize them, resulting in dense ceramic body with required R – T characteristics.



Advantages:

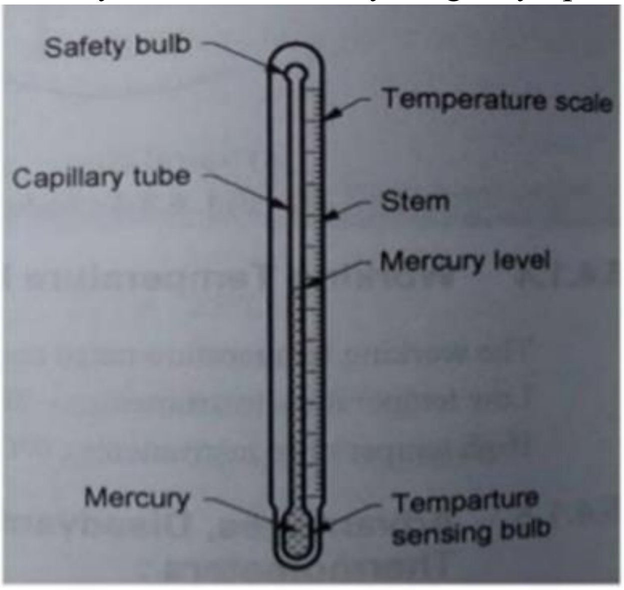
1. They are simple & easy owing to their small sizes.
2. Their cost is low.
3. They are highly sensitive.
4. They can be adapted to various electrical read outs. With help of computers thermistors can be easily used for accurate temperature measurement.

Disadvantages:

1. The temperature vs resistance curve of thermistors are highly nonlinear.
2. It is not rugged & requires delicate handling which limits its application.
3. They are susceptible to self-heating errors.
4. Their range is limited to few hundred degree Celsius.
5. Thermistors use semiconductors which are prone to permanent de-calibration (drifting out of their specified nature)

Liquid in glass thermometer

Volume of mercury changes slightly with temperature; small change in volume drives narrow mercury column relatively long way up tube.



Construction

1. A bulb which acts as container for functioning liquid(Mercury, Alcohol, Pentene, Toluene) where it can easily expand or contract in capacity.
2. A stem, "a glass tube containing tiny capillary connected to bulb & enlarged at bottom into bulb that is partially filled with working liquid".
3. A temperature scale which is basically preset or imprinted on stem for displaying temperature readings.
4. Point of reference i.e. calibration point which is most commonly ice point.
5. A working liquid which is generally either mercury or alcohol.
6. An inert gas, mainly argon or nitrogen which is filled inside thermometer above mercury to trim down its volatilization.

Advantages

1. They are comparatively cheaper than other temperature measurement devices.
2. They do not necessitate power supply or batteries for charging.
3. They can be frequently applied in areas where there is problem of electricity.
4. They provide very good repeatability & their calibration remains unaffected.

Limitations

1. They are considered inapt for applications involving extremely high or low temp^r.
2. They can't be applied in regions where highly accurate results are desirable.
3. As compared to electrical thermometers, they are very weak & delicate. Therefore, they must be handled with extra care because they are likely to break.
4. Besides, they can't provide digital & automated results. Hence, their use is limited to areas where only manual reading is adequate, for example, household thermometer.
5. Temp^r readings should be noted immediately after removal because glass thermometer can be affected by environmental temp^r, heat produced by hand holding it, cleaning, etc. This temp^r should be recorded because glass thermometer does not offer recall of measured temp^r.
6. Reading temp^r via liquid-in-glass thermometers call for brilliant eyesight.
7. Liquid element contained in glass thermometer may be perilous or risky to health owing to their potential chemical spills.
8. These thermometers display temp^r either in Celsius or Fahrenheit scales. Thus, temp^r conversion would be needed if temp^r reading is wanted in some other scale

Resistance temperature detectors(RTD)

Principle- resistance of conductor changes when temperature is changed.
The variation of resistance R with temperature T can be represented by

$$\mathbf{R = R_{ref}\,[1 + \alpha(T - T_{ref})]}$$

Where,

$\mathbf{R}$ = Conductor resistance at temperature "T"

$\mathbf{R_{ref}}$ = Conductor resistance at reference temperature T_{ref} , usually 20°C, but sometimes 0°C.

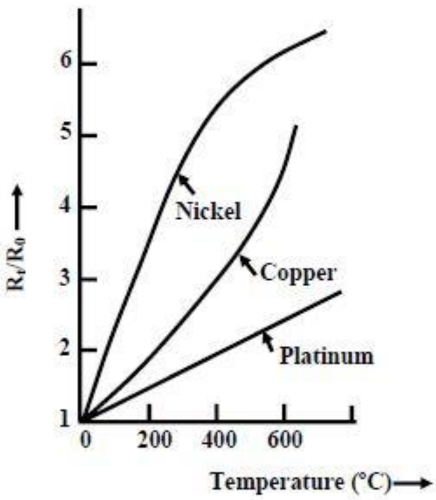
$\boldsymbol{\alpha}$ = Temperature coefficient of resistance for conductor material.

$\mathbf{T}$ = Conductor temperature in degrees Celcius.

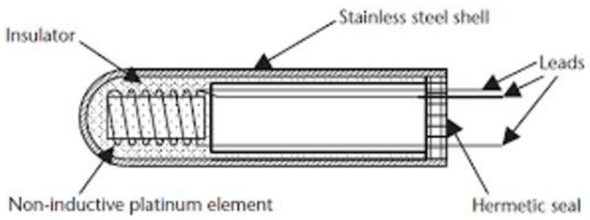
$\mathbf{T_{ref}}$ = Conductor temperature in degrees Celcius.

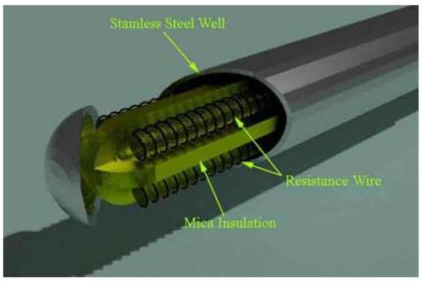
In RTD devices; Cu, Ni & Platinum are widely used metals. These metals are having different resistance variations with respective to temperature variations. Platinum has temperature range of 650°C, & then Cu & Ni have 120°C & 300°C.
Positive temperature coefficient
Platinum

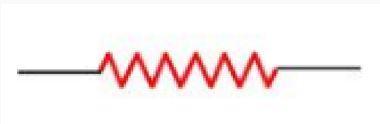
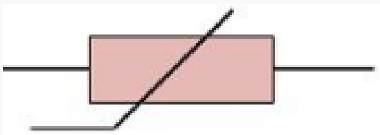
1. Withstand high temperature
2. Excellent stability
3. Less susceptible to contamination
4. 100 Ohm at 0°C with resistance temperature coefficient of 0.00385/°C



The construction is typically such that wire is wound on form (in coil) on notched mica cross frame to achieve small size, improving thermal conductivity to decrease response time & high rate of heat transfer is obtained.
Mica is placed in between steel sheath & resistance wire for better electrical insulation.
In industrial RTD’s, coil is protected by stainless steel sheath or protective tube.





Basis For Comparison	RTD (Resistance Temperature Detector)	Thermistor
Definition	The device use for measuring the change in temperature is known as the RTD or Resistance Temperature Detector.	It is a thermal resistor whose resistance changes with the temperature.
Symbol		
Material	Metals (platinum, nickel, copper, etc.)	Semiconductor
Accuracy	Less accurate.	Their accuracy is high. It can detect even small changes in temperature because of negative temperature coefficient.
Response Time	Slow	Fast
Temperature Range	-230°C to 660°C	-60°C to 15°C
Characteristic Graph	Linear	Non-linear

Sensitivity	Low	High
Size	Large	Small
Cost	Cheap	Expensive
Resistivity	High	Low
Hysteresis Effect	Low	High
Applications	In industries for measuring large temperature.	For measuring the temperature of home appliances.

Measurement of pressure

Most pressure sensors used in process control result in transduction of pressure information into physical displacement.

Measurement of pressure requires techniques for producing displacement & means for converting such displacement into proportional electrical signal.

Diaphragms

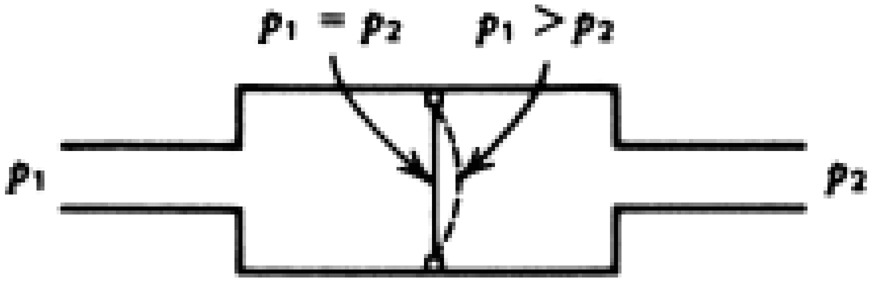
Bellows

Bourdon Tube

Diaphragm

One common element used to convert pressure information into physical displacement is diaphragm (thin, flexible piece of metal)

If pressure p1 exists on one side of diaphragm & p2 on other, then net force is exerted given by



$$F = (p_2 - p_1)A$$

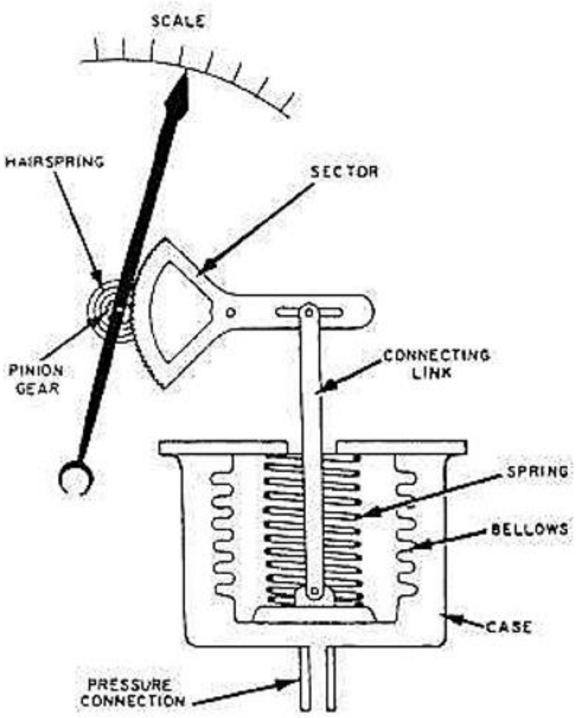
where A = diaphragm area in m^2

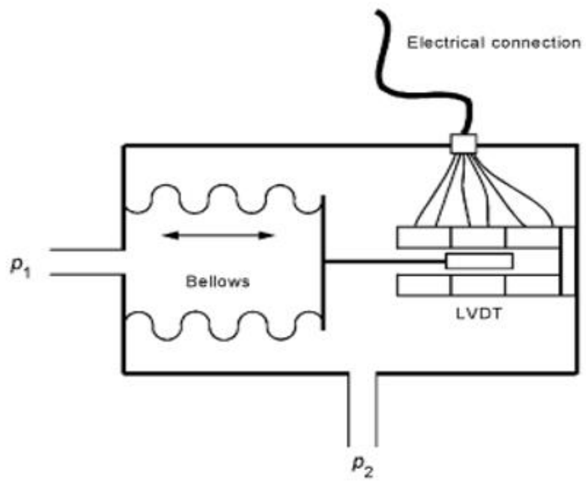
p_1, p_2 = pressure in N/m^2

A diaphragm is like spring & therefore extends or contracts until **Hooke's law(F=-kx)** force is developed that balances pressure difference force.
Notice that since force is greater on p1 side of diaphragm, it has deflected toward p2 side. extent of this deflection (i.e., **diaphragm displacement) is measure of pressure difference.**
Methods to detect diaphragm deflection

1. Mechanically coupled indicating needle
2. LVDT(Linear Variable Differential Transducer)
3. Strain Gauge
4. Other velocity or displacement sensors

Bellows

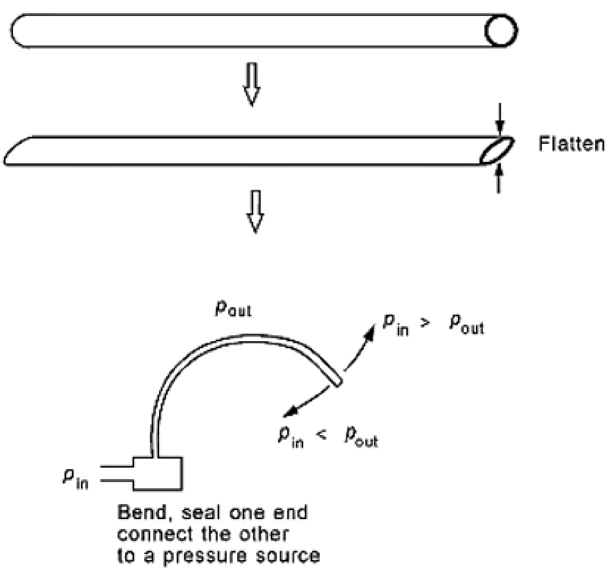


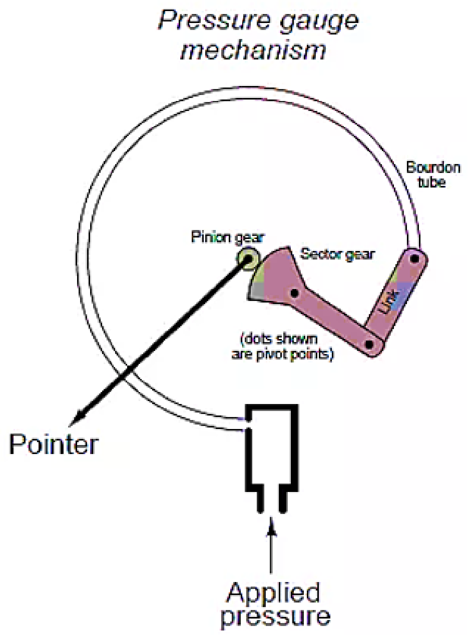


1. The accordion-shaped sides of bellows are made from thin metal(stainless steel, brass,bronze etc.). When there is pressure difference, net force will exist on flat, front surface of bellows.
2. The bellows assembly will then collapse like accordion if p2 is greater than p1 or expand if p2 is less than p1.
3. We have displacement which is proportional to pressure difference. This conversion of pressure to displacement is very nearly linear. t. Here LVDT is used to convert displacement to voltage amplitude.

Bourdon Tube

1. A hard metal tube, usually type of bronze or brass, is flattened, & one end is closed off. tube is then bent into curve or arc, sometimes even spiral.
2. The open end is attached to header by which pressure can be introduced to inside of tube. When this is done, tube will deflect when inside applied pressure is different from outside pressure.

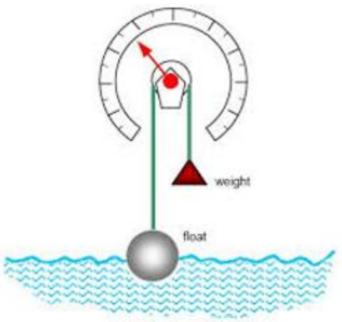


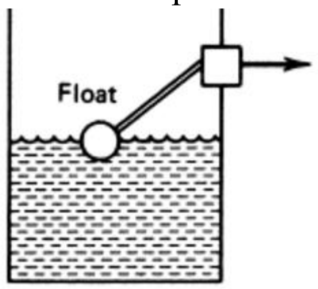


The tube will tend to straighten out if inside pressure is higher than outside pressure & to curve more if pressure inside is less than that outside.
Most of common, round pressure gauges with meter pointer that rotates in proportion to pressure are based on this sensor. In this case, deflection is transformed into pointer rotation by system of gears.
Of course, for control applications, we are interested in converting deflection into electrical signal. This is accomplished by various types of displacement sensors to measure deflection of Bourdon tube.
Measurement of level: 1. Mechanical type 2. Electrical type 3. Ultrasonic type

Mechanical Type- Float

One of most common techniques for level measurement, particularly for liquids, is float that is allowed to ride up & down with level changes. This float is connected by linkages to secondary displacement measuring system such as potentiometric device or LVDT core.

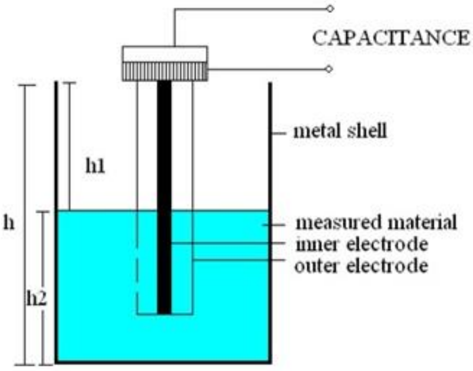


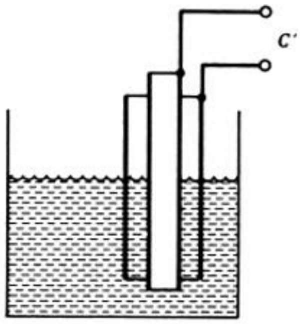


a) Level measurement by a float and linkage

Electrical type- Capacitive

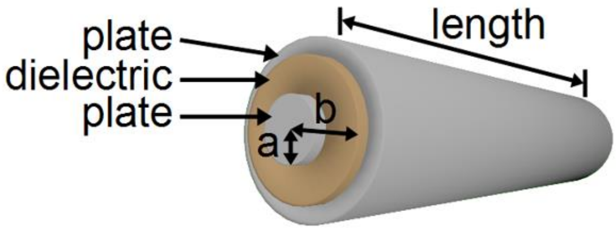
Two concentric cylinders are contained in liquid tank. level of liquid partially occupies space between cylinders, with air in remaining part. This device acts like two capacitors in parallel, one with dielectric constant of air & other with that of liquid. Thus, variation of liquid level causes variation of electrical capacity measured between cylinders.

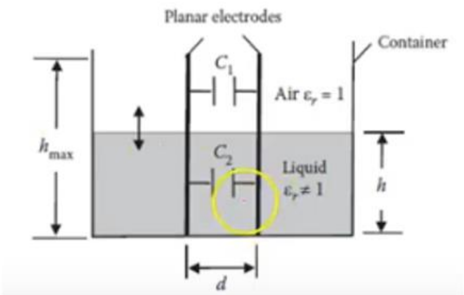


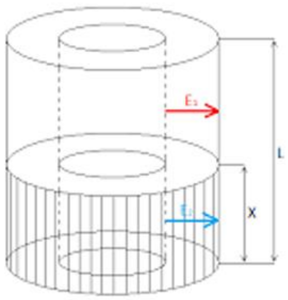


b) Level measurement by a concentric cylindrical capacitor

$$C = \frac{2\pi\epsilon L}{\ln(\frac{b}{a})}$$

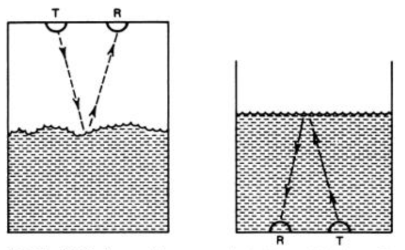






Ultrasonic type

Figure shows external & internal techniques. Obviously, external technique is better suited to solid-material level measurement. In both cases, measurement depends on length of time taken for reflections of ultrasonic pulse from surface of material.



a) Solid or liquid, above surface measurement

b) Liquid material, below surface material

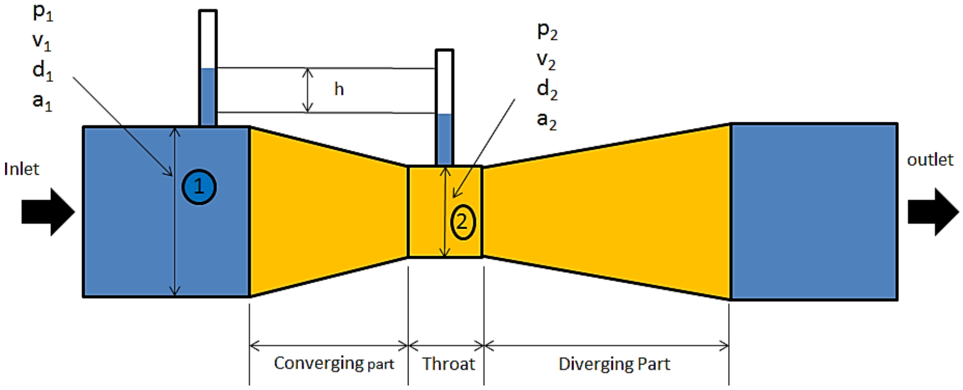
FIGURE 11
Ultrasonic level measurement needs no physical contact with the material, just a transmitter, *T*, and receiver, *R*.

Measurement of Flow: Venturi meter, Orifice meter, Rotameter, Vortex Tube, Pitot Tube

Venturi meter

<u>Construction</u>

Short converging part: It is tapered portion whose radius decreases as we move forward.
Throat: It is middle portion of venturi. Here velocity of fluid increases & pressure decreases. It possesses least cross section area.
Diverging part: In this portion fluid diverges.



<u>Bernoulli's equation</u>

1. Bernoulli's principle states that increase in speed of fluid occurs simultaneously with decrease in pressure or decrease in fluid's potential energy.
2. Bernoulli's principle can be derived from principle of conservation of energy . This states that, in steady flow, sum of all forms of energy in fluid along streamline is same at all points on that streamline. This requires that sum of kinetic energy , potential energy, & internal energy remains constant.
3. Thus increase in speed of fluid – implying increase in its kinetic energy (dynamic pressure) – occurs with simultaneous decrease in (the sum of) its potential energy (including static pressure) & internal energy.
4. According to Venturi effect, fluid's pressure decreases as its velocity increases.

$$p + \frac{1}{2}\rho V^2 + \rho g h = constant$$

where p is the pressure, ρ is the density, V is the velocity, h is elevation, and g is the gravitational acceleration

$$p_1 - p_2 = \frac{1}{2}\rho(V_2^2 - V_1^2)$$

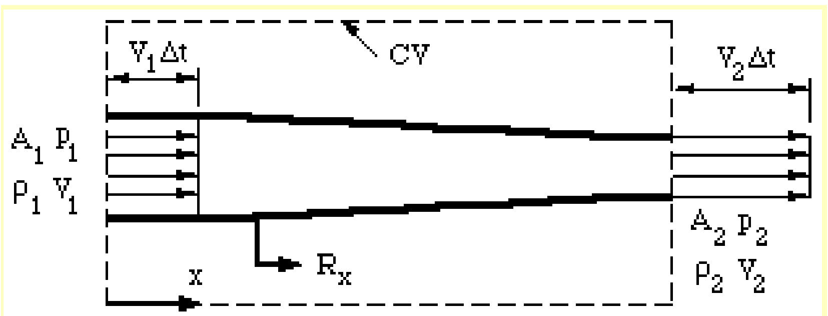
and $$A_1V_1 = A_2V_2$$

Therefore,

$$A_2 < A_1, \quad V_2 > V_1$$

$$V_2 > V_1, \quad p_2 < p_1$$

decreasing area = increasing velocity
increasing velocity = decreasing pressure



Working

1. As water enters at inlet section i.e. in converging part it converges & reaches to throat.
2. The throat has uniform cross section area & least cross section area in venturi meter. As water enters in throat its velocity gets increases & due to increase in velocity pressure drops to minimum.
3. Now there is pressure difference of fluid at two sections. At section 1(i.e. at inlet) pressure of fluid is maximum & velocity is minimum. & at section 2 (at throat) velocity of fluid is maximum & pressure is minimum.
4. The pressure difference at two section can be seen in manometer attached at both section.
5. This pressure difference is used to calculate rate flow of fluid flowing through pipe.

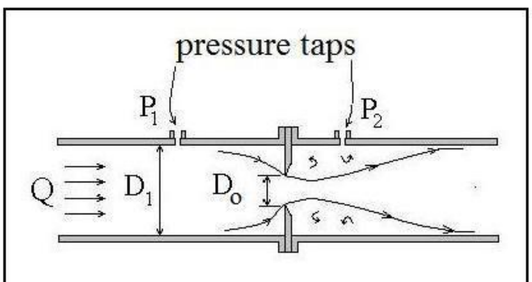
Orifice Meter

An Orifice Meter is basically type of flow meter used to measure rate of flow of Liquid or Gas, especially Steam, using Differential Pressure Measurement principle.
As name implies, it consists of Orifice Plate which is basic element of instrument. When this Orifice Plate is placed in line, differential pressure is developed across Orifice Plate. This pressure drop is linear & is in direct proportion to flow-rate of liquid or gas.

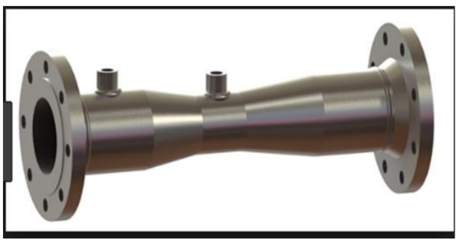
Construction:

Inlet Section
A linearly extending section of same diameter as inlet pipe for end connection for incoming flow connection. Here we measure inlet pressure of fluid / steam / gas.
Orifice Plate
An Orifice Plate is inserted in between Inlet & Outlet Sections to create pressure drop & thus measure flow. The Orifice plates in Orifice meter, in general, are made up of stainless steel of varying grades.
Outlet Section
A linearly extending section similar to Inlet section. Here also diameter is same as that of outlet pipe for end connection for outgoing flow. Here we measure Pressure of media at this discharge. As shown in adjacent diagram, gasket is used to seal space between Orifice Plate & Flange surface, prevent leakage.

Sections 1 & 2 of Orifice meter, are provided with opening for attaching differential pressure sensor (u-tube manometer, differential pressure indicator).



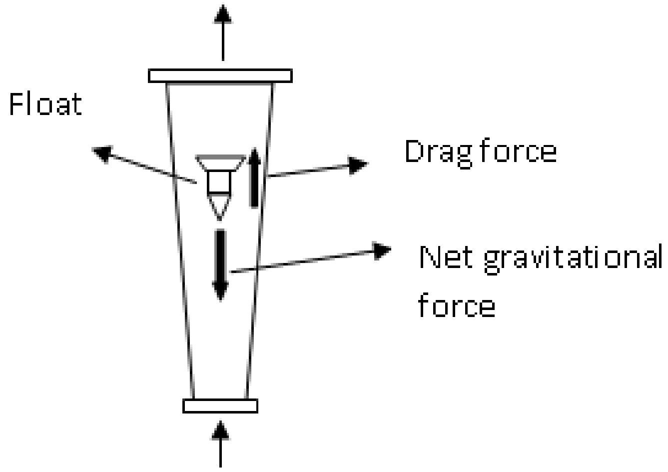
Orifice Meter Parameters



Operation

1. The fluid flows inside Inlet section of Orifice meter having pressure P1.
2. As fluid proceeds further into Converging section, its pressure reduces gradually & it finally reaches value of P2 at end of Converging section & enter Cylindrical section.
3. The differential pressure sensor connected between Inlet & and Cylindrical Throat section of Orifice meter displays difference in pressure (P1-P2). This difference in pressure is in direct proportion to flow rate of liquid flowing through Orifice meter.
4. Further fluid passed through Diverging recovery cone section & velocity reduces thereby it regains its pressures. Designing lesser angle of Diverging recovery section, helps more in regaining kinetic energy of liquid.

Rotameter



A rotameter is made up of tapered tube & float inside it. glass tapered tube has scale on surface or scale is placed adjacent to it, according to purpose.
Tapered tube: Tapered tube is placed vertically in flow channel with conical shape inside. quantity measured is defined by height of float going up. Glass tubes are used for both liquid & gas measurement. Metallic tubes are used where process fluid with high $temp^r$ & pressure.
Float: Stainless steal floats are commonly used, there are different types of metals from lead to aluminium used as floats. float material, shapes are also varied according to applications considering density.

Spherical shape floats are used for small flows.

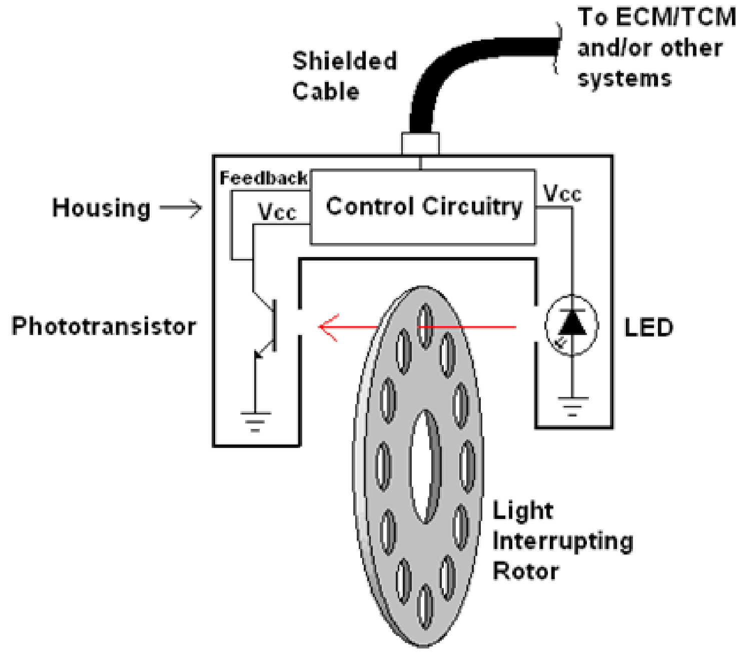
Fluid enters from bottom of tapered tube, then some of fluid strikes directly into float bottom & others pass aside float. Now float experience two forces in opposite direction, darg force upward & gravitational force downward.

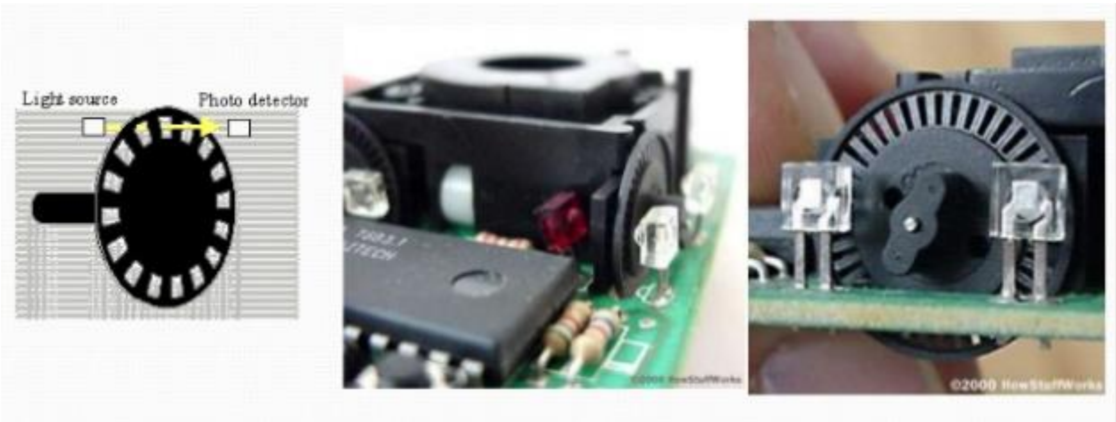
Fluid flow moves float upward against gravity.At some point, flowing area reaches point where pressure-induced force on floating body exactly matches weight of float. float will find equilibrium when area around float generates enough drag equal to weight - buoyancy.

As float weight & gravity are constant, distance float displaced upward is proportional to flow velocity of fluid passing through tapered tube.

Measurement of speed Optical sensor Tachometer

Optical Sensor



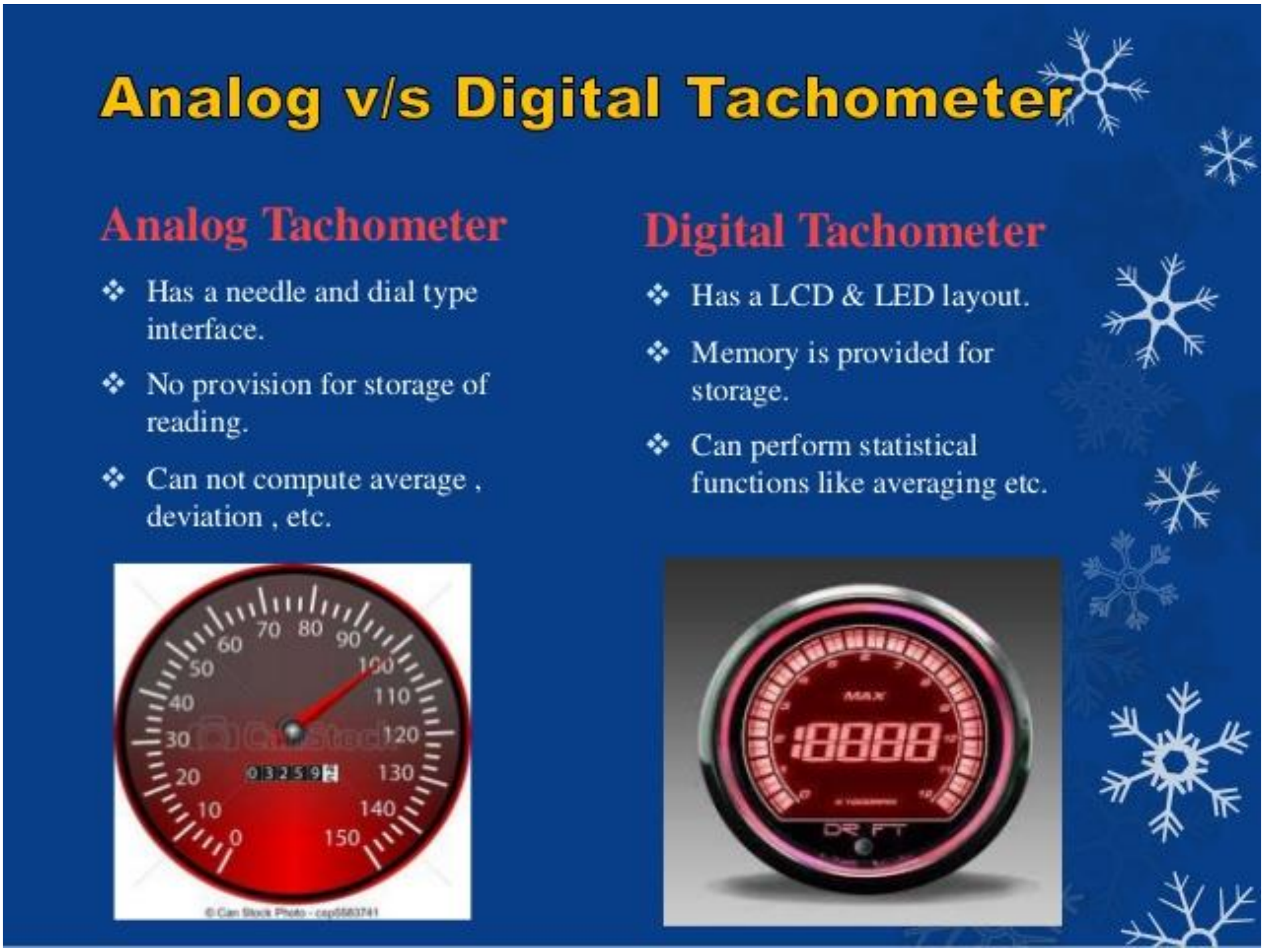


Working

1. An opaque disc with perforations or transparent windows at regular intervals is mounted on shaft whose speed is to be measured.
2. A LED source is aligned on one side of disc in such way that its light can pass through transparent windows of disc. As disc rotates light will alternately pass through transparent windows & be blocked by opaque sections.
3. On rotation of disc, holes & opaque portions of disc come alternately in between light source & light sensor. When hole comes in between two, light passes through holes & falls on light sensor, with result that output pulse is generated. But when opaque portion of disc comes in between, light from source is blocked & hence there is no pulse output. Thus whenever hole comes in line with light source & sensor, pulse is generated. These pulses are counted/measured through electronic counter.
4. A photo detector fixed on other side of disc detects variation of light & output of detector after signal conditioning, which is square wave whose frequency is decided by speed & number of holes(transparent windows) on disc.

Tachometer

1. The word tachometer is derived from two Greek words: tachos means “speed” & metron means “to measure”.
2. A tachometer is sensor device for measuring rotation speed of object such as engine shaft in car . It indicates number of revolutions per minute(RPM) performed by object. Types of tachometer commonly available:-
3. Analog Tachometer :- Comprises needle & dial type interface.
4. Digital Tachometer :- Comprises LCD or LED readout & memory.
5. Contact/Non-Contact tachometer :- Sensor is in directly contact with rotating shaft in case of contact type.
6. Time/Frequency measuring tachometer :-Time measuring device calculates speed by measuring time b/w incoming pulses whereas frequency measuring devices measures frequency of incoming pulses.



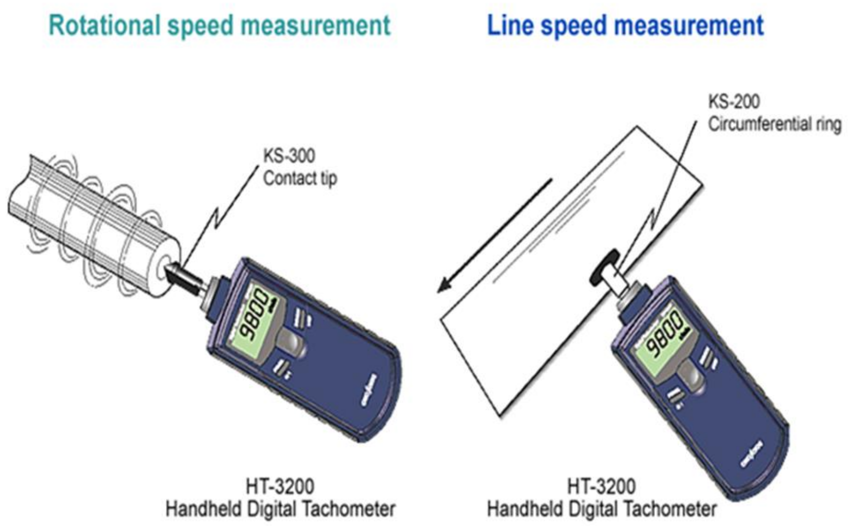
Contact Type

- The tachometer has to be in physical contact with the rotating shaft
- Preferred where the tachometer is generally fixed to the machine
- Generally, optical encoder / magnetic sensor is attached to shaft of tachometer

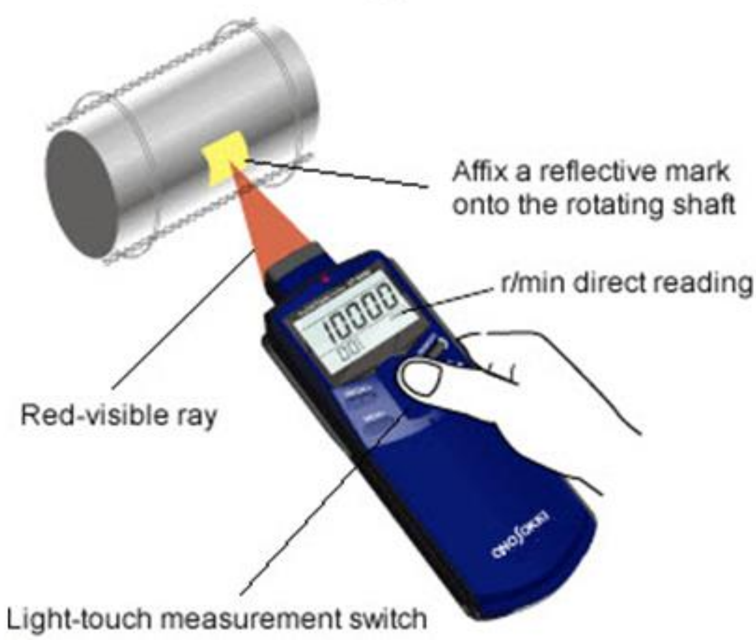
Non Contact Type

- The tachometer does not need to be in physical contact with the rotating shaft
- Preferred where the tachometer needs to be mobile
- Generally, laser is used or an optical disk id attached to rotating shaft and read by a IR beam or laser

Contact type tachometer

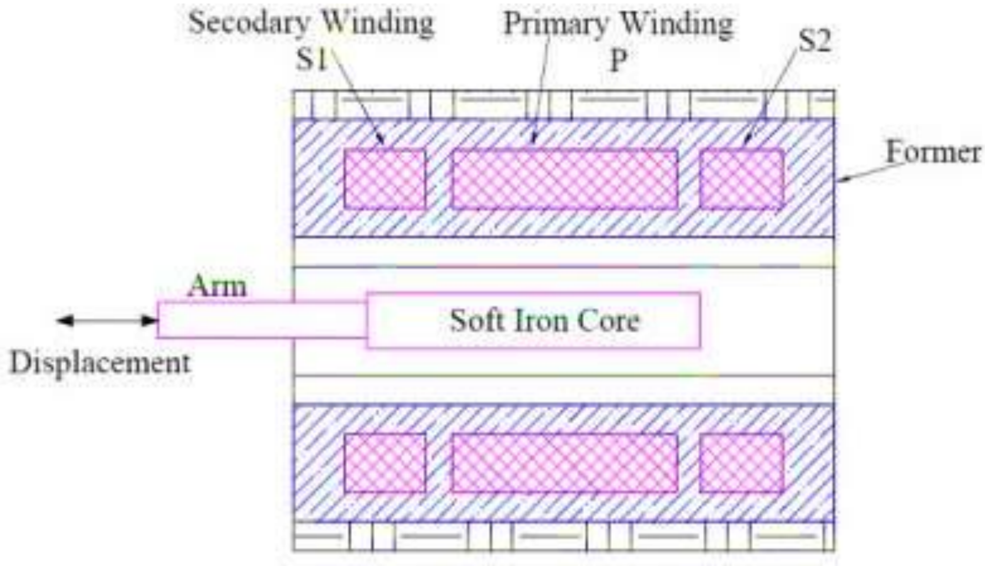


Non contact type tachometer



Measurement of displacement

LVDT-Linear Variable Differential Transformer, LVDT is most used inductive transducer for translating linear motion into electrical signal. This transducer converts mechanical displacement proportionally into electrical signal.

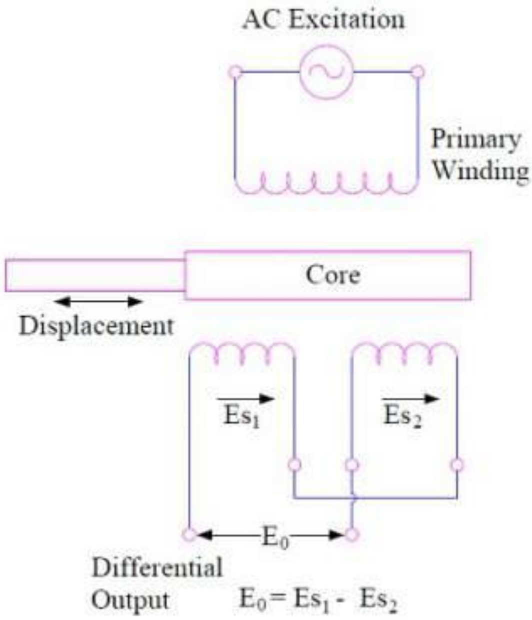


Construction

LVDT is transformer consisting of one primary winding P & two secondary winding S_1 & S_2 mounted on cylindrical former. two secondary winding have equal number of turns & placed identically on either side of primary winding as shown in figure.

A movable soft iron core is placed inside former. movable core is made of nickel iron with hydrogen annealed. Hydrogen annealing is done to eliminate harmonics, residual voltage of core & thus provides high sensitivity. movable core also is laminated in order to reduce eddy current loss. assembly of laminated core is placed in cylindrical steel housing & end lids are provided for electromagnetic & electrostatic shielding. displacement to be measured is attached to this movable soft iron core.

Working Principle of LVDT:



Since primary winding of Linear Variable Differential Transformer (LVDT) is supplied with AC supply, it produces alternating magnetic flux in core which in turn link with secondary winding S_1 & S_2 to produce emf due to transformer action.

Let us assume that emf produced in secondary winding S_1 is E_{s1} & that in S_2 is E_{s2}. magnitude of E_{s1} & E_{s2} will depend upon magnitude of rate of change of flux (dØ / dt) as per Faraday's Law.

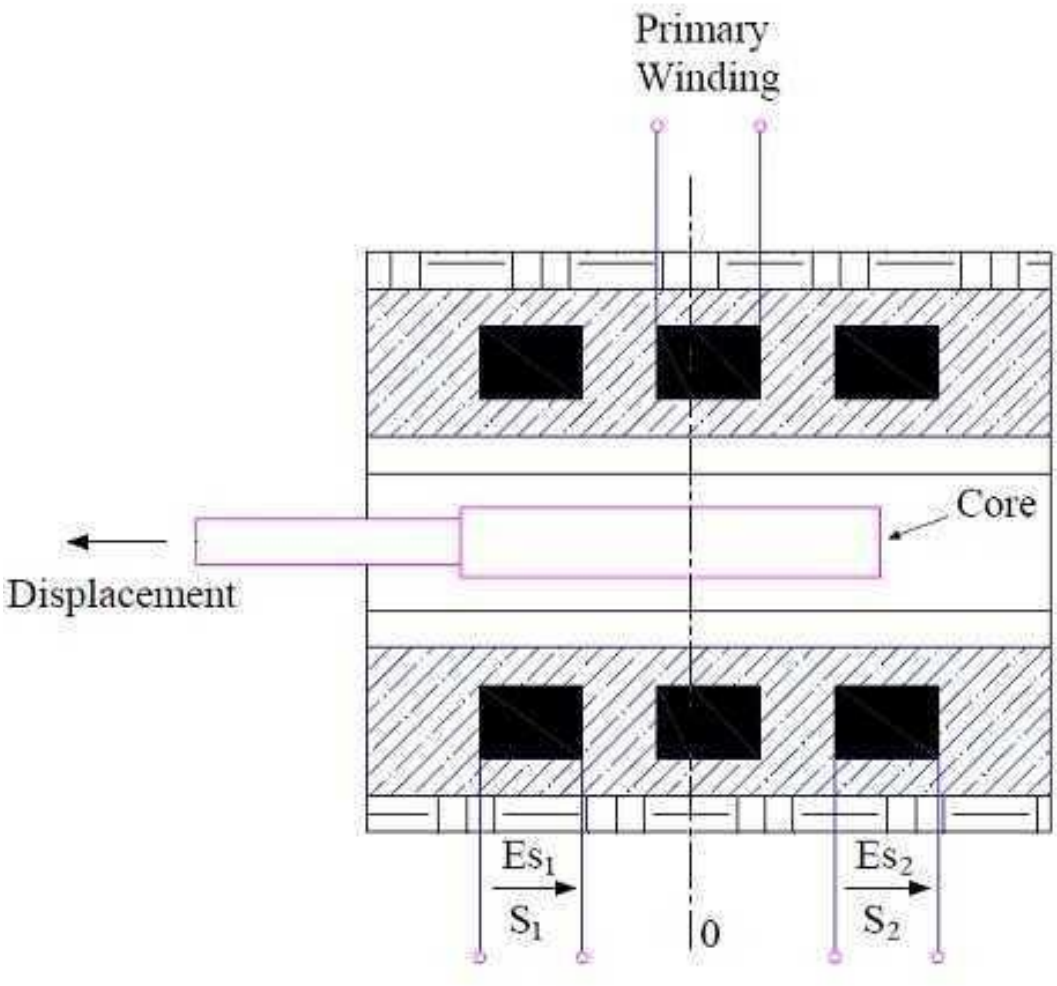
To get single output voltage from Linear Variable Differential Transformer (LVDT), both secondary winding are connected in series but in phase opposition as shown in figure. Due to this connection, net output voltage E_0 of LVDT is given as below.

$E_0 = E_{s1} – E_{s2}$

Since secondary windings of LVDT are identical & placed symmetrically on either side of core, therefore under normal position flux linkage of both secondary winding S_1 & S_2 will be same. This means $E_{s1} = E_{s2}$ & hence net output voltage E_0 of LVDT = 0. This position of soft iron core is called NULL position. Thus NULL position of Linear Variable Differential Transformer is normal position of movable core where net output voltage is zero.

Now, as core can either be moved toward right or left to null position. Let us now consider such movement of core under two cases.

Working of LVDT:



Case-1: Core is moved left to NULL position
When core of LVDT is moved to left of NULL position '0' as shown in figure, flux linkage of secondary winding S_1 will become more than that of winding S_2. This means emf induced in winding S_1 will be more than S_2. Hence $E_{s1} > E_{s2}$ & net output voltage

$E_0 = (E_{s1} - E_{s2})$ = Positive.

Case-2: Core is moved right to NULL position
When core of LVDT is moved toward right of NULL position '0', emf induced in secondary winding S_2 will be more than that of S_1. This means $E_{s2} > E_{s1}$ & hence net output voltage $E_0 = (E_{s1} - E_{s2})$ = negative.

From above two cases, we can have following conclusions:
1) direction of movement of physical quantity can be identified by output voltage of LVDT. If output voltage E_0 is positive, this means physical quantity is moving toward left.
2) If output voltage E_0 is negative, this will mean that physical quantity is moving in right direction from NULL position.
3) amount / magnitude of displacement is proportional to magnitude of output voltage. more output voltage, more will be displacement.

Application
LVDT is used in those applications where displacement ranging from fraction of mm to few cm is to be measured. As primary transducer, it converts mechanical displacement into electrical signal.
Acting as secondary transducer, it is used for measurement of force, pressure, weight etc.

Force

- Force is defined as an influence that causes an object to change its rate or direction of movement or rotation.
- A force can accelerate objects by pulling or pushing them.
- The relationship between force, mass, and acceleration was defined by Isaac Newton in his second law of motion, which states that an object's force is the product of its mass and acceleration.

Force = Mass x Acceleration
$N = kg \times m/s^2$

Force Measurement Method

1) Balancing the unknown force against known gravitational force due to standard mass. Scales and balances works based on this principle.
2) Applying unknown force to an elastic member (spring, Beam, Cantilever, etc.) and measuring the resulting deflection on calibrated force scale or the deflection may be measured by using a secondary transducers. i.e. Elastic force meter, providing ring.
3) Translating the force to a fluid pressure and then measuring the resultant pressure. Hydraulic and Pneumatic load cells works on this principle.
4) Applying force to known mass and then measuring the resulting acceleration.
5) Balancing force against a magnetic force which is developed by interaction of a magnet and current in coil.

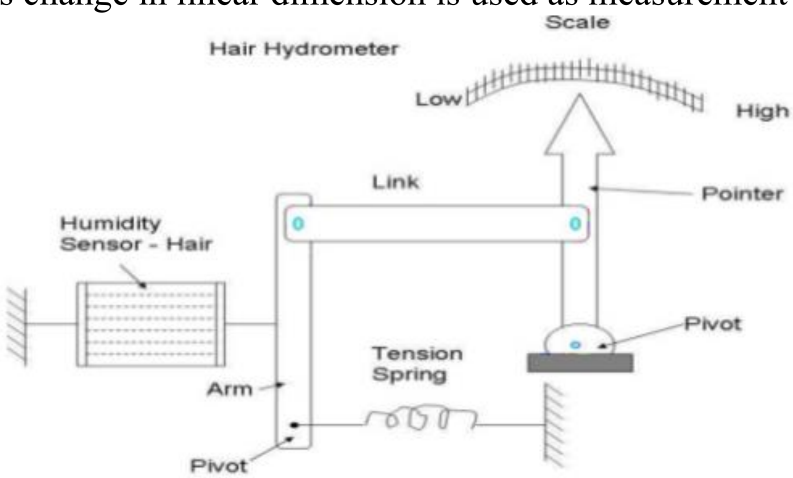
Measurement of humidity

Humidity measurement finds wide applications in different process industries. Moisture in atmosphere must be controlled below certain level in many manufacturing processes. e.g. textiles, papers,cereals must be dried to standard storage conditions in order to prevent quality detoriation. Humidity measurement can be done with help of hygrometer, psychrometer, dew point measurement, capacitance method, IR technique(satellites), humidistat etc.

Hygrometer

Due to humidity, several materials experience change in physical, chemical & electrical properties. This property is used in transducer that are designed & calibrated to read relative humidity directly.

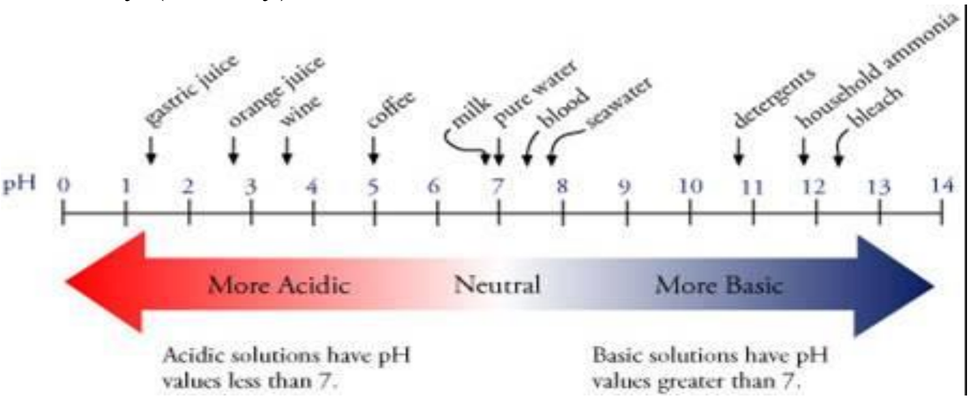
Certain hygroscopic materials such as human hair, animal membranes, wood, paper, etc., undergo changes in linear dimensions when they absorb moisture from their surrounding air. This change in linear dimension is used as measurement of humidity present in air.

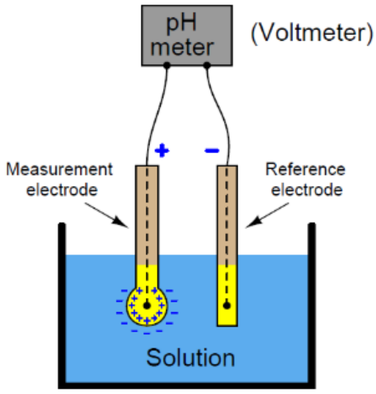


Human hair has a property that its length increases when it is wet and its length decreases when it goes dry .

Measurement of pH

pH is measure of hydrogen ion concentration in solution. It describes degree of acidity or alkalinity (basicity) of solution.





The pH value of solution is measured using pH electrode. It consists essentially of pair of electrodes, measurement & reference electrode, both submerged in solution of unknown pH. These two electrodes essentially form two half cells. Although potential developed in reference cell is constant, potential of measurement cell depends on the concentration of hydrogen ions in solution.

Applications of pH measurement:

For diagnosis of various disorders in human body

Pharmaceutical

Agriculture

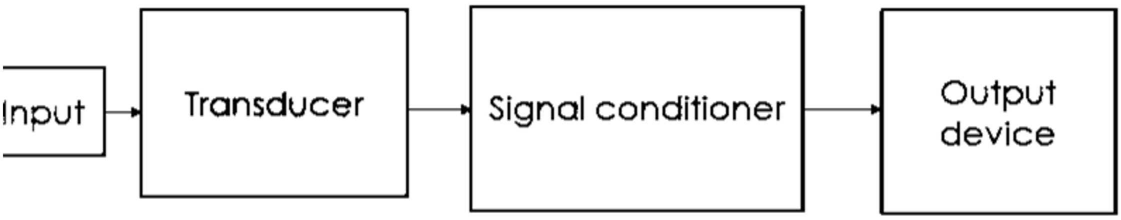
Corrosion prevention

Dyeing

Printing

Signal Conditioning

used to process output signal from sensors of measurement system to be suitable for next stage of operation



Block diagram of instrumentation system.

The function of signal conditioning circuits include following items:

1. Signal amplification (Op-amp)
   Increase level of input signal, Improve sensitivity & resolution of measurement.
2. Filtering (Op-amp)
   Reject useless noise within certain frequency range, Prevent signal aliasing & distortion.
3. Interfacing with µP (ADC)
4. Protection (Zener & photo isolation)
5. Linearization, Current: voltage change circuits, resistance change circuits (Wheatstone bridge), error compensation
6. Attenuation: Contrary to amplification.

Estimation of errors & calibration
Measurement error is defined as difference between true or actual value & measured value. Error may arise from different source & are usually classified into following types. These types are Gross Errors, Systematic Errors, Random Errors

Gross Error
The gross error occurs because of human mistakes. Such type of error is very common in measurement. complete elimination of such type of error is not possible. Some of gross error easily detected by experimenter but some of them are difficult to find.
Careful reading & recording of data can reduce gross errors to great extent.

Systematic Errors
The systematic errors are mainly classified into three categories.
1. Instrumental Errors
2. Environmental Errors
3. Observational Errors

Random Errors
The error whose cause is not clearly known & they affect readings in random way are known as random errors.

Calibration
The accuracy of all measuring devices degrade over time. This is typically caused by normal wear & tear. However, changes in accuracy can also be caused by electric or mechanical shock or hazardous manufacturing environment.
In order to ensure that instrument reading will give actual value within reasonable accuracy, calibration is required at frequent intervals.

Benefits of Calibration
1. It fulfills requirements of traceability to national / international standards like ISO 9000, ISO 14000 etc.
2. As proof that instrument is working.
3. Confidence in using instruments.
4. Traceability to national measurement standard.
5. Interchangeability.
6. Reduced rejection, failure rate thus higher return.
7. Improved product & service quality leading to satisfied customers.
8. Power saving.
9. Cost Saving.
10. Safety.