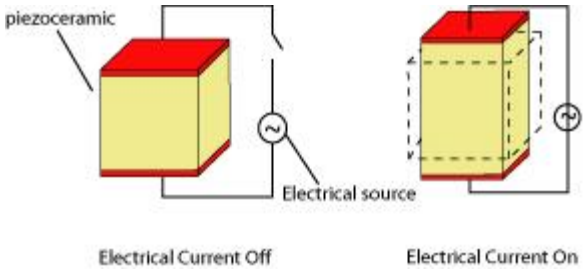
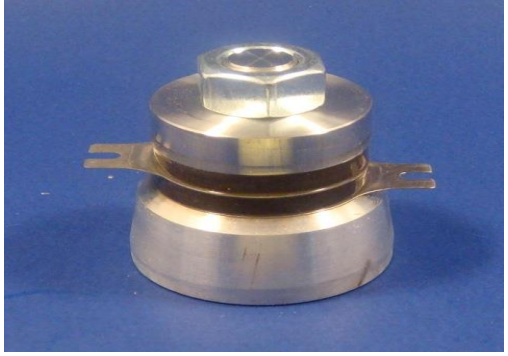


The active element is the heart of the transducer as it converts the electrical energy to acoustic energy, and vice versa. The active element is basically a piece of polarized material (i.e. some parts of the molecule are positively charged, while other parts of the molecule are negatively charged) with electrodes attached to two of its opposite faces. When an electric field is applied across the material, the polarized molecules will align themselves with the electric field, resulting in induced dipoles within the molecular or crystal structure of the material. This alignment of molecules will cause the material to change dimensions. In addition, a permanently-polarized material such as quartz (SiO_2) or barium titanate ($BaTiO_3$) will produce an electric field when the material changes dimensions as a result of an imposed mechanical force. This phenomenon is known as the piezoelectric effect.



Piezoelectric transducers are a type of electroacoustic transducer that convert theelectrical charges produced by some forms of solid materials into energy. Theword "piezoelectric" literally means electricity caused by pressure. An early application of piezo transducer technology occurred during World War I with the use of sonar, which used echoes to detect the presence of enemy ships.

Typically used in cleaning systems, the expansion and contraction causes the ultrasonic diaphragm, which serves as the pressure-sensing element of the transducer, to vibrate, introducing ultrasonic activity into the cleaning tank in the process. The piezoelectric ultrasound transducer also offers the advantages of high electroacoustic efficiency while minimizing heat generation.

- When a piezoelectric material is subjected to stress or force, it generates an electrical potential or voltage proportional to the magnitude of the force. This makes this type of transducer ideal as a converter of mechanical energy or force into electric potential
- The high sensitivity of piezoelectric transducers makes them useful in microphones, where they convert sound pressure into electric voltage, in precision balances, in accelerometers and motion detectors, and as generators and detectors of ultrasound.
- They are also used in non-destructive testing, in the generation of high voltages, and in many other applications requiring the precise sensing of motion or force.
- The piezoelectric effect also works in reverse, in that a voltage applied to a piezoelectric material will cause that material to bend, stretch, or otherwise deform. This deformation is usually very slight and proportional to the voltage applied, and so the reverse effect offers a method of precision movement on the micro scale.
- A transducer may, therefore, be used as an actuator for the exact adjustment of fine optical instruments, lasers, and atomic force microscopes.

- The voltage generated by piezoelectric transducers can be quite high, often in the thousands of volts, but is brief, occurring only when the material is initially deformed. This makes them useful in electronic cigarette lighters and push-button igniters for gas ranges and grills.
- In these applications, pushing a button activates a small, spring-loaded hammer, which strikes a piezoelectric material and generates a voltage sufficient to cause an electric arc to jump between the exposed electrodes of the igniter.
- Originally thought to be a property only of specific types of crystals like quartz and topaz, advances in materials science have resulted in the creation of polymers and ceramics that also show piezoelectric properties. In fact, the most common piezoelectric material currently in use is the man-made ceramic lead zirconate titanate, known as PZT. This material has the ability to provide twice the voltage of quartz under a given force.
- These transducers are simple, reliable, and very robust, and so find wide use in industry, medicine, and aero-space work. They're unaffected by external electromagnetic fields, and so can be used in applications where electronic sensors would fail. They are stable over a broad range of temperatures, but may be effected by long use as high temperatures.

Photovoltaic

- **Photovoltaics** (**PV**) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect.
- A photovoltaic effect is the affect when electromagnetic radiationfalls on a thin film of one solid deposited on the surface of a dissimilar solid producing a diffence in potential between the two material
- Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material.
- Materials presently used for photovoltaics include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide.

- Photovoltaics are best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons.

- The photovoltaic effect refers to photons of light exciting electrons into a higher state of energy, allowing them to act as charge carriers for an electric current.

- The term photovoltaic denotes the unbiased operating mode of a photodiode in which current through the device is entirely due to the transduced light energy.

- Virtually all photovoltaic devices are some type of photodiode

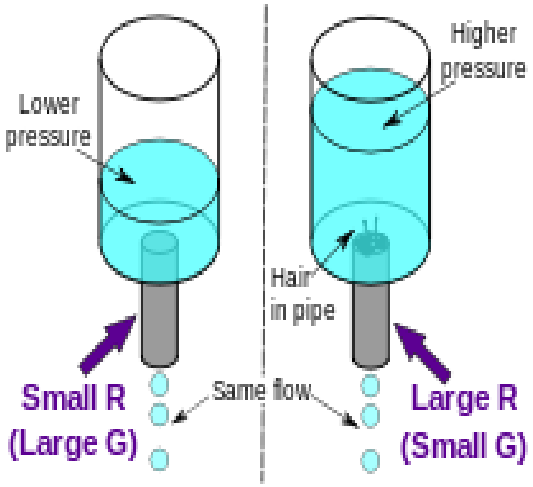
- Solar panels used to power homes and businesses are typically made from solar cells combined into modules that hold about 40 cells.

- A typical home will use about 10 to 20 solar panels to power the home.

- The panels are mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun, allowing them to capture the most sunlight.

- Many solar panels combined together to create one system is called a solar array.

- For large electric utility or industrial applications, hundreds of solar arrays are interconnected to form a large utility-scale PV system.



RESISTANCE

- The hydraulic analogy compares electric current flowing through circuits to water flowing through pipes.
- When a pipe (left) is filled with hair (right), it takes a larger pressure to achieve the same flow of water.
- Pushing electric current through a large resistance is like pushing water through a pipe clogged with hair
- It requires a larger push (electromotive force) to drive the same flow (electric current).

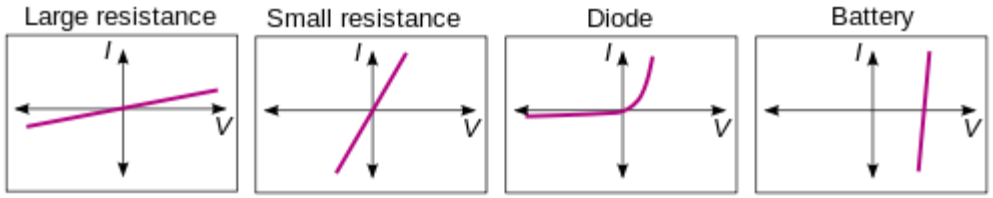
In the hydraulic analogy current flowing through a wire (or resistor) is like water flowing through a pipe, and the voltage drop across the wire is like the pressure drop which pushes water through the pipe. Conductance is proportional to how much flow occurs for a given pressure, and resistance is proportional to how much pressure is required to achieve a given flow

- The voltage *drop* (i.e., difference in voltage between one side of the resistor and the other), not the voltage itself, provides the driving force pushing current through a resistor.
- In hydraulics, it is similar: The pressure *difference* between two sides of a pipe, not the pressure itself, determines the flow through it.
- there may be a large water pressure above the pipe, which tries to push water down through the pipe. But there may be an equally large water pressure below the pipe, which tries to push water back up through the pipe. If these pressures are equal, no water will flow.
- The resistance and conductance of a wire, resistor, or other element is primarily determined by two factors: geometry (shape) and materials.
- In the same way, a long, thin copper wire has higher resistance (lower conductance) than a short, thick copper wire.

- Geometry is important because it is more difficult to push water through a long, narrow pipe than a wide, short pipe.
- Materials are important as well.
- A pipe filled with hair restricts the flow of water more than a clean pipe of the same shape and size. In a similar way, electrons can flow freely and easily through a copper wire, but cannot as easily flow through a steel wire of the same shape and size, and they essentially cannot flow at all through an insulator like rubber, regardless of its shape.

- The difference between, copper, steel, and rubber is related to their microscopic structure and electron configuration, and is quantified by a property called resistivity.

Those substances through which electricity can flow are called conductors. A piece of conducting material of a particular resistance meant for use in a circuit is called a resistor. Conductors are made of high-conductivity materials such as metals, in particular copper and aluminium. Resistors, on the other hand, are made of a wide variety of materials depending on factors such as the desired resistance, amount of energy that it needs to dissipate, precision, and costs.



The current-voltage characteristics of four devices: Two resistors, a diode, and a battery. The horizontal axis is voltage drop, the vertical axis is current. Ohm's law is satisfied when the graph is a straight line through the origin. Therefore, the two resistors are "ohmic", but the diode and battery are not.

PHOTO-CONDUCTIVITY

- **Photoconductivity** is an optical and electrical phenomenon in which a material becomes more electrically conductive due to the absorption of electromagnetic radiation such as visible light, ultraviolet light, infrared light, or gamma radiation.
- When light is absorbed by a material such as a semiconductor, the number of free electrons and electron holes increases and raises its electrical conductivity.
- To cause excitation, the light that strikes the semiconductor must have enough energy to raise electrons across the band gap, or to excite the impurities within the band gap.
- When a bias voltage and a load resistor are used in series with the semiconductor, a voltage drop across the load resistors can be measured when the change in electrical conductivity of the material varies the current flowing through the circuit.
- Classic examples of photoconductive materials include the conductive polymer polyvinylcarbazole used extensively in photocopying (xerography); lead sulfide, used in infrared detection applications, such as the U.S. Sidewinder and Russian Atoll heat-seeking missiles; and selenium, employed in early television and xerography.

- **photoconductivity,** the increase in the electrical conductivity of certain materials when they are exposed to light of sufficient energy. Photoconductivity serves as a tool to understand the internal processes in these materials, and it is also widely used to detect the presence of light and measure its intensity in light-sensitive devices.

- Certain crystalline semiconductors, such as silicon, germanium, lead sulfide, and cadmium sulfide, and the related semimetal selenium, are strongly photoconductive.

- Normally, semiconductors are relatively poor electrical conductors because they have only a small number of electrons that are free to move under a voltage.

- Most of the electrons are bound to their atomic lattice in the set of energy states called the valence band. But if external energy is provided, some electrons are raised to the conduction band, where they can move and carry current.

- **Photoconductivity** ensues when the material is bombarded with photons of sufficient energy to raise electrons across the band gap, a forbidden region between the valence and conduction bands. In cadmium sulfide this energy is 2.42 electron volts (eV), corresponding to a photon of wavelength 512 nanometres (1 nm = 10^{-9} metre), which is visible green light. In lead sulfide the gap energy is 0.41 eV, making this material sensitive to infrared light.

- Because the current ceases when the light is removed, photoconductive materials form the basis of light-controlled electrical switches. These materials are also used to detect infrared radiation in military applications such as guiding missiles to heat-producing targets. Photoconductivity has broad commercial application in the process of photocopying, or xerography, which originally used selenium but now relies on photoconductive polymers.

APPLICATION

- When a photoconductive material is connected as part of a circuit, it functions as a resistor whose resistance depends on the light intensity.

- In this context the material is called a photoresistor (also called light-dependent resistor or photoconductor).

- The most common application of photoresistors is as photodetectors, i.e. devices that measure light intensity.

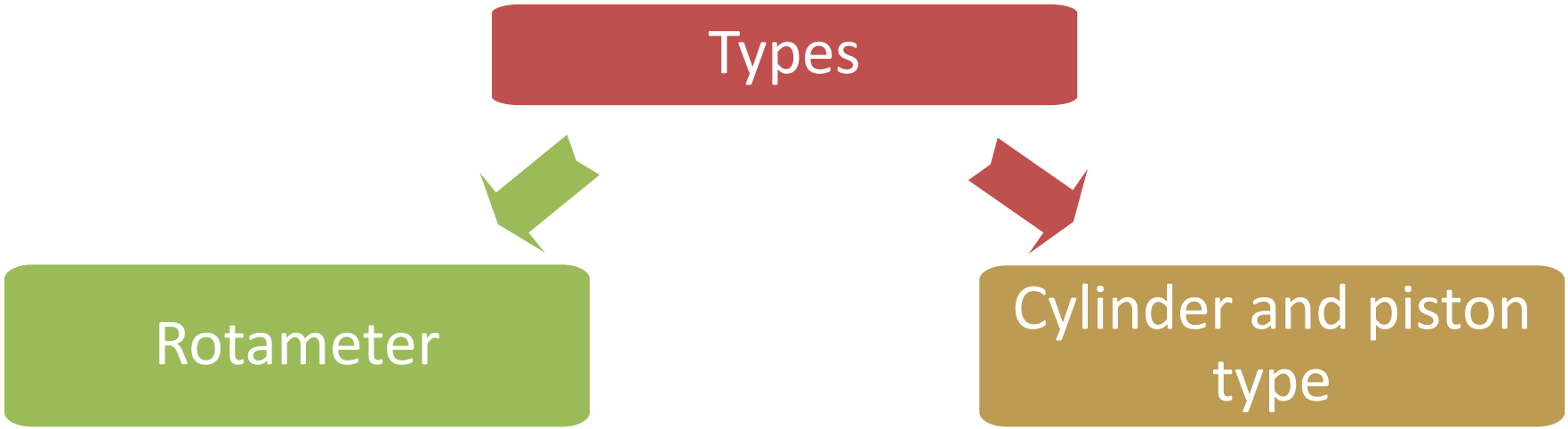
- Photoresistors are not the only type of photodetector—other types include CCDs, photodiodes and phototransistors—but they are among the most common photodetectors.

- Some photodetector applications in which photoresistors are often used include camera light meters, street lights, clock radios, and infrared detectors.

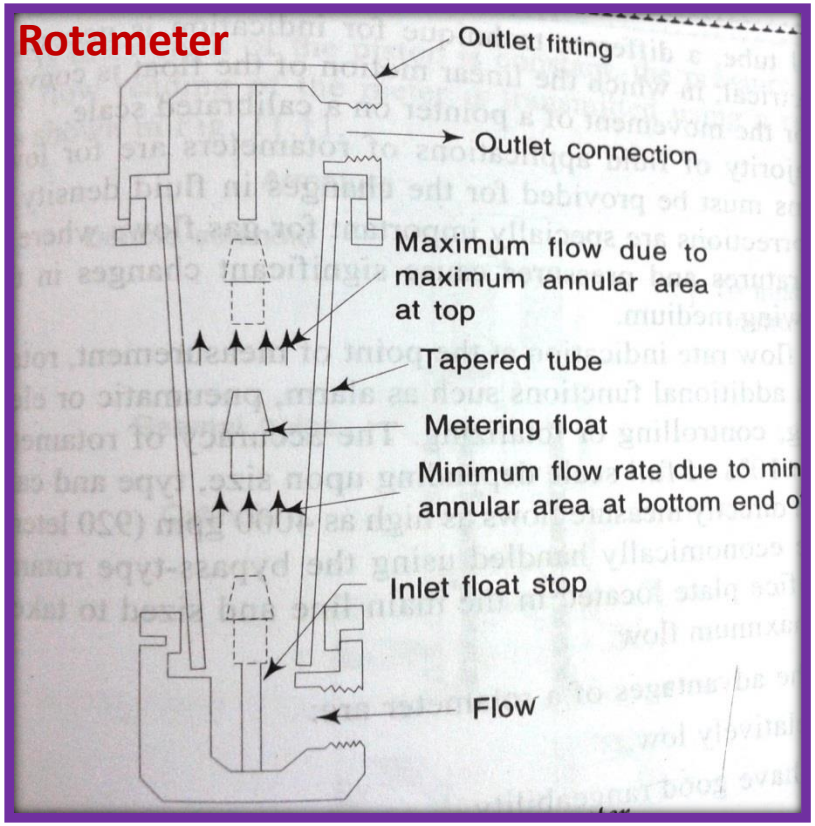
Variable flow meters

- The size of restriction is adjusted by an amount necessary to keep the pressure differential constant when the flow rate changes

- Amount of adjustment required is proportional to the flow rate



Rotameter



- When fluid enters the metering tube , the float moves up and the flow area of annular orifice increases .
- The pressure differential across the annular orifice is proportional to the square of its flow area and to the square of flow rate
- The float is pushed upward until the lifting force produced by pressure differential across its upper and lower surface is equal to the weight of the float
- If the flow rate rises , the pressure differential and hence the lifting force increases temporarily and float then rises
- The area of the annular orifice to which the float moves, changes in proportion to the flow rate
- Any decrease in flow rate causes the float drop to lower

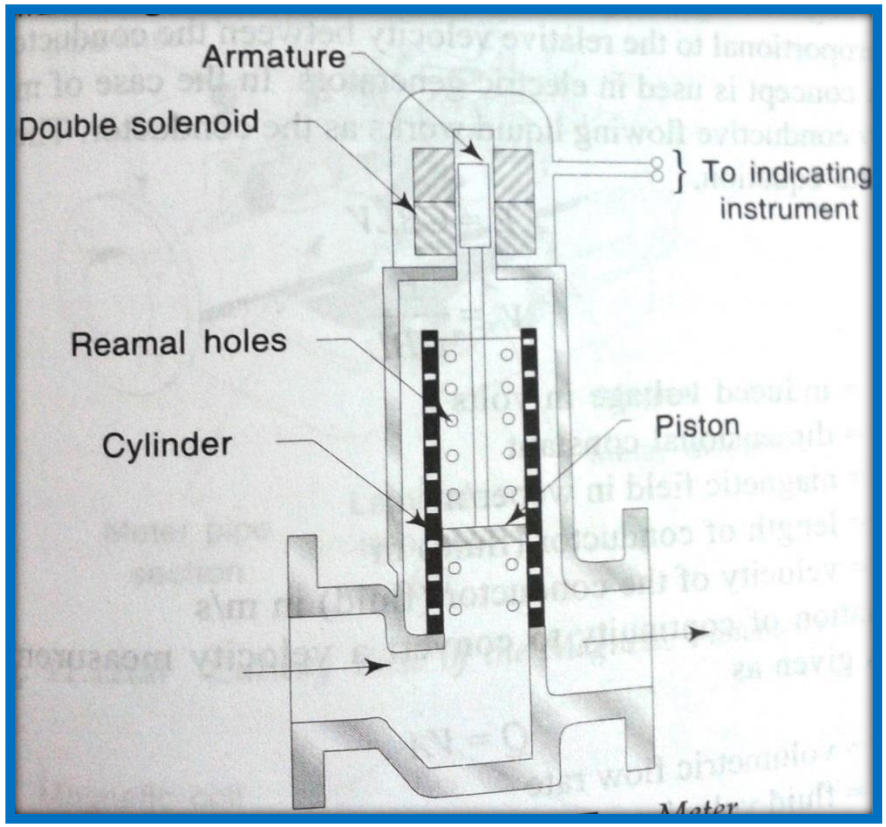
Advantages :

- Cost is relative low
- Good for metering small flows
- Handles wide variety of corrosives

Disadvantages:

- Glass tube type is subjected to breakage
- Must be mounted vertically
- Not good in pulsating services

Cylinder and piston type



- When fluid enters the cylinder , the piston exerts a constant downward force and the difference in pressure between the two side s of the piston in particular position.
- As the down stream flow is increased, the pressure on the load side of the piston is reduced.
- The increased differential pressure then forces the piston up, thereby increasing the area of the opening through which the flow can flow until the pressure differential is again balanced.
- Linear movement of the piston in the cylinder is sensed by the LVDT which converts linear motion into voltage signal

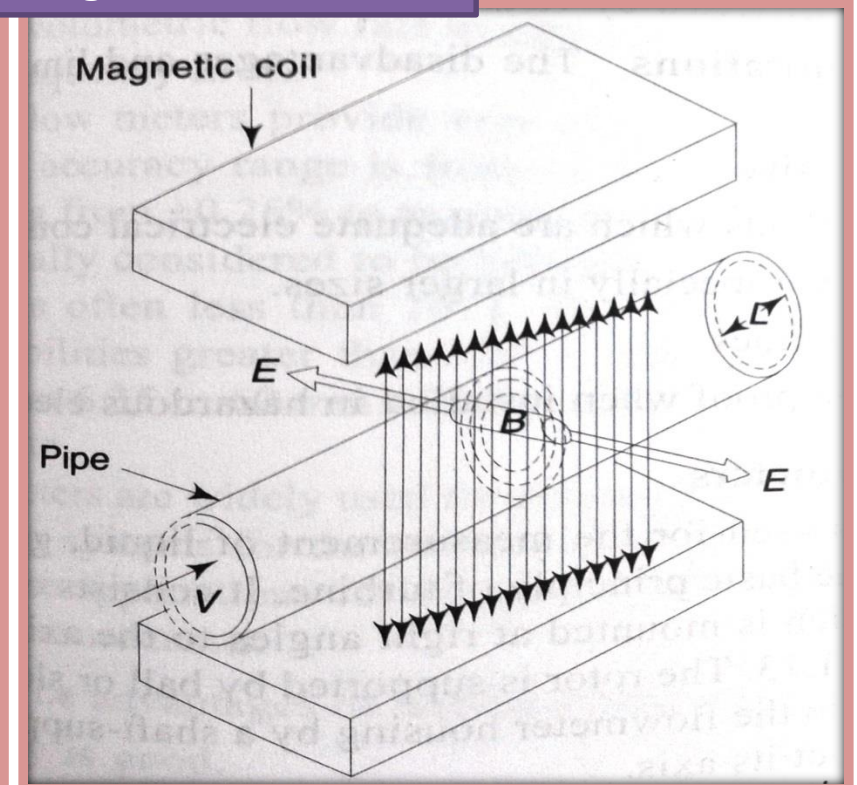
Advantages:

- **Good for high viscosity fluids**
- **High accuracy**
- **The range of such instruments can have wide variations**
- **Measure very low flow rate, say 0.08cc/min**

Disadvantages:

- Cost is relatively high
- Limited size range about 25 to 100mm

Magnetic flow meter



- These meters utilize the **principle of faraday's law of electromagnetic induction for making of a flow measurement**
- It states that whenever a conductor moves through a magnetic field of given field strength, a voltage is induced in the conductor which is proportional to the velocity between the conductor and magnetic field

$$V = (E/CBL)$$

E= induced voltage in volts

C= dimensional constant

B= magnetic field in weber/m^2

L= Length of conductor (fluid) m

V= velocity of the conductor (fluid) in m/s

- As the liquid passes through the pipe section , it also passes through the magnetic field setup by the magnet coil ,
- thus inducing voltage in the liquid which is detected by the pair of electrodes mounted in the pipe wall.
- **The amplitude of the induced voltage is proportional to the velocity of the flowing liquid**

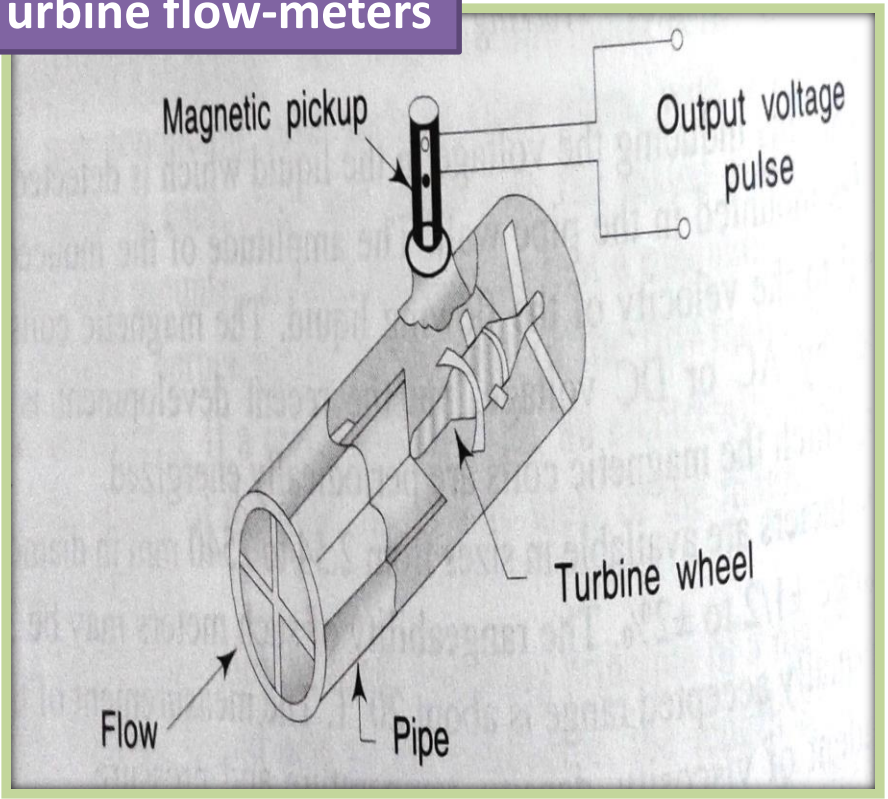
Advantages:

- It can handle slurries and greasy materials
- It can handle corrosive fluids available in large pipe sizes and capacities
- Measurements are unaffected by viscosity, density, temperature and pressure

Disadvantages:

- It is relatively expensive
- It works only with fluids which are the adequate electrical conductors
- It must be full at all times

Turbine flow-meters



Advantages :

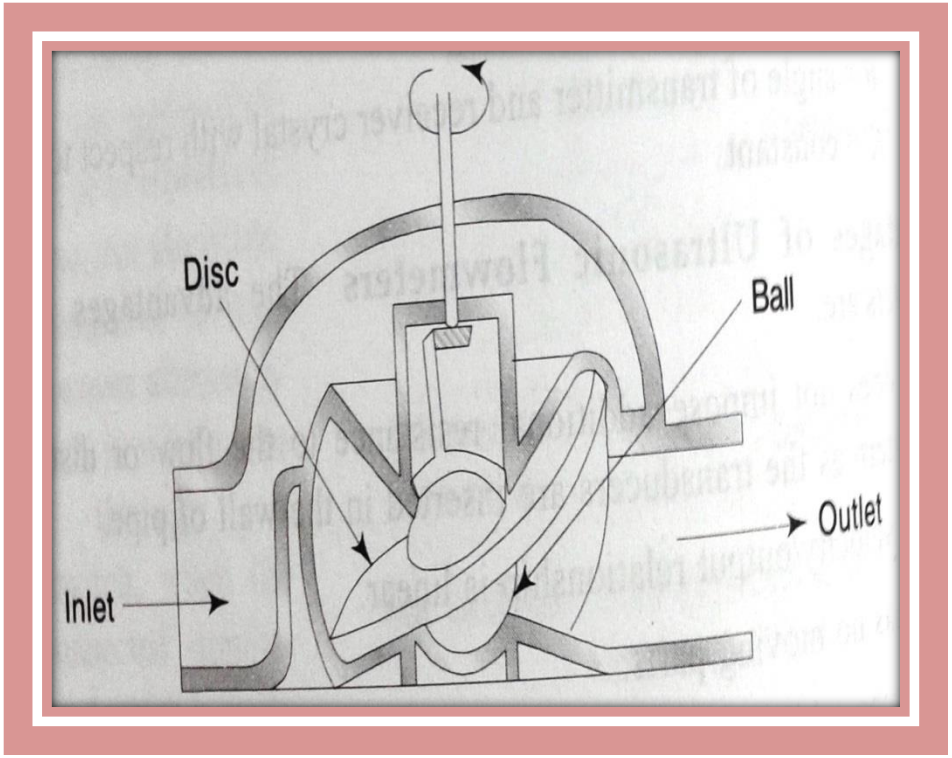
- Its accuracy is good
- It provides excellent repeatability and rangeability
- It allows fairly low pressure drop
- It is to install and maintain

Disadvantages:

- Its cost is high
- Its use is limited for slurry applications
- It faces problems caused by non-lubricating fluids

- **It works on the basic principle of turbine**
- The flowing fluid impinges on the turbine blades, imparting a force to the blade surface which causes the rotation of the rotor
- The speed of the rotor is directly proportional to the fluid velocity and hence then to volumetric flow rate when it is at a steady rotational speed
- The speed of the rotation is monitored in most of the meters by a magnetic –pickup coil which is fitted to the outside of the meter housing
- The magnetic –pickup coil consists of a permanent magnet with coil winding which is mounted in close proximity to the rotor but internal to the fluid channel

Positive displacement : Nutating Disc Meters



- These device is work on the principle that as the liquid flow through the meter, it separates the flow of liquid into separate known volumetric increments which are counted and totaled
- The sum of the increments give the measurement of the total volume of liquid passed through the meter
- As the liquid flows through the meter pressure drops from inlet to outlet causes a wobbling or nutating motion to the disc
- For Each nutating of disc a specific volume of liquid equal to the metering chamber minus the volume of the disc assembly, passes through the meter
- The movements of the disc is transmitted by the gear train to the totalizing register

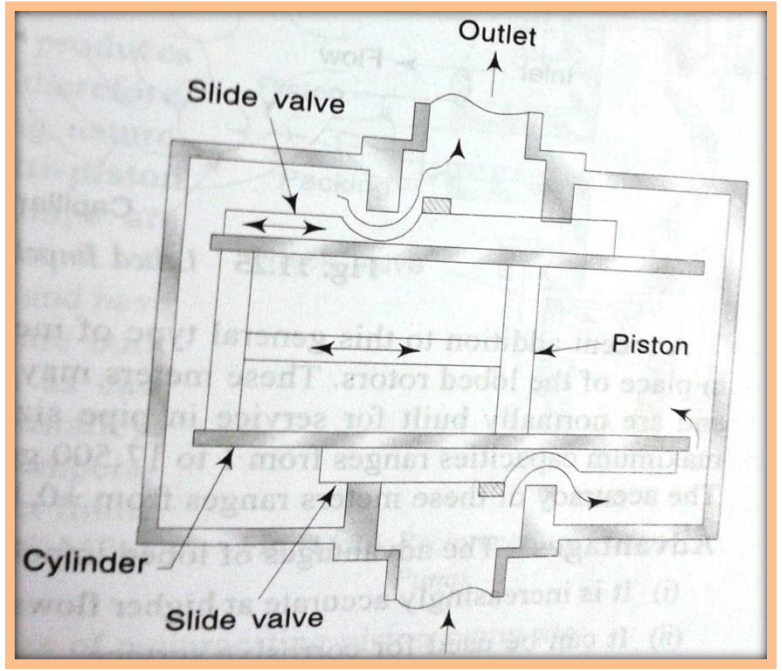
Advantages:

- Its cost is relatively low
- It is applicable to automatic liquid batching system
- It can make use of moderate pressure loss

Disadvantages:

- **It is limited as to pipe size and capacity**
- **It has fair accuracy**

Reciprocating Piston Meters



- The fluid to be measured enters through the inlet forcing the piston to the left until the cylinder is full and piston is in its extreme left position
- At this point an external leakage causes both slide valves to moves and thus the liquid enters the left cylinder forcing the piston to extreme right position
- When the cylinder becomes full, the slide valves again move and the cycle is repeated.

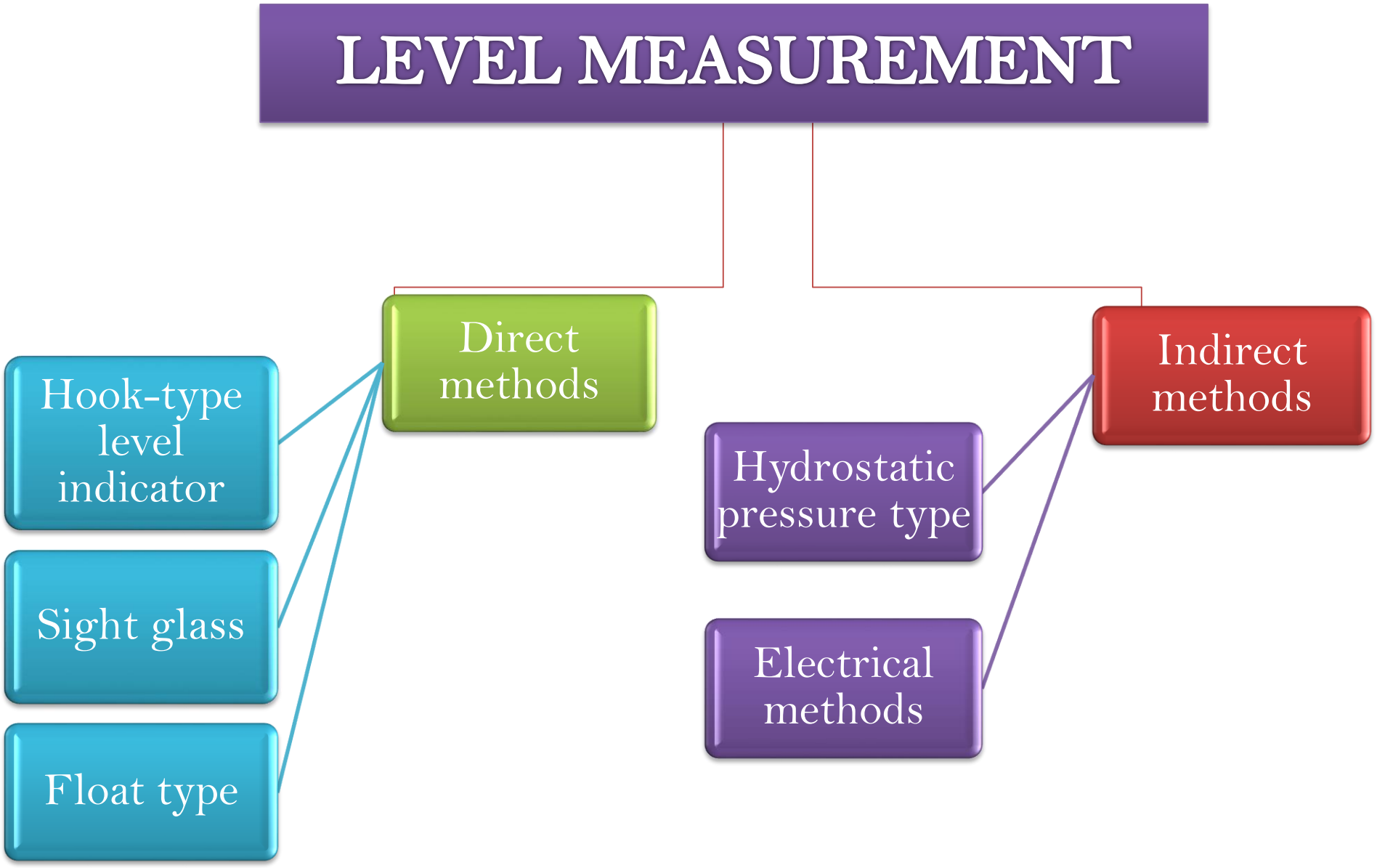
Advantages:

- Its accuracy is high
- Construction material are not limited in reciprocating piston meters

Disadvantages:

- Their cost is relatively high
- They are subjected to leakage
- Problems are created by dirty fluids
- Require high maintenance cost

LEVEL MEASUREMENT



LEVEL TYPE MEASUREMENT

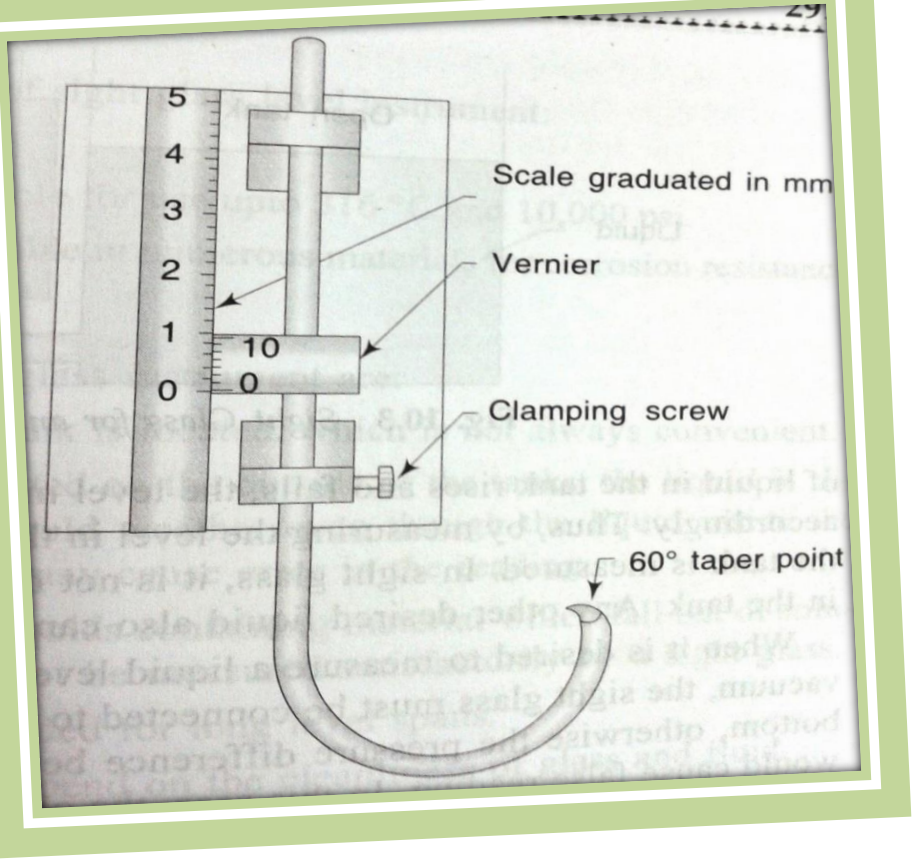
The measurement of industrial process level parameters is of great importance in the industrial field.

The level of liquid may affect both the pressure and the rate of flow in and out of the tank or vessel

There are two methods used in industries for the measuring liquid level:

1. Direct methods:
    1. Hook –type level indicator
    2. Sight glass
    3. Float type
2. Indirect methods:
    1. Hydrostatic pressure
        1. Pressure gauge method
        2. Air bellows method
        3. Air purge system
        4. Liquid purge system
    2. Electrical methods
        1. Capacitance level indicator
        2. Radiation level detector

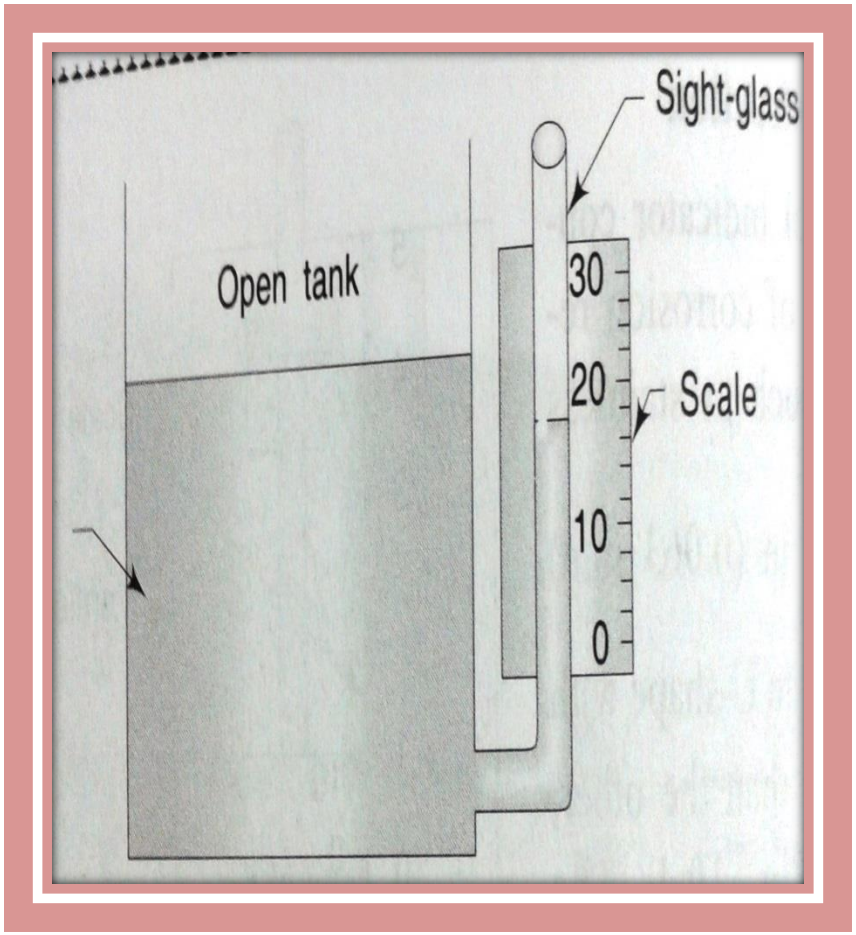
Hook type level indicator



- The level of liquid in an open tank is measured directly on a scale

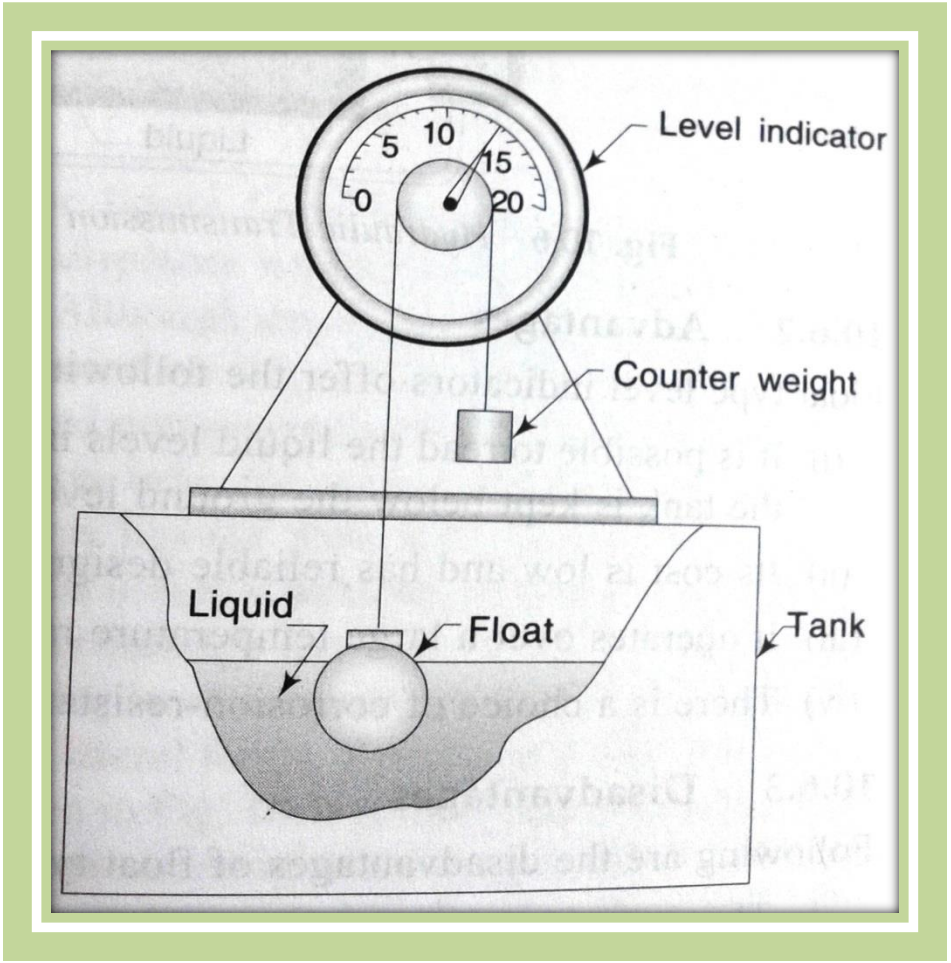
SIGHT GLASS

It is used for the continuous indication of the liquid level within a tank or vessel

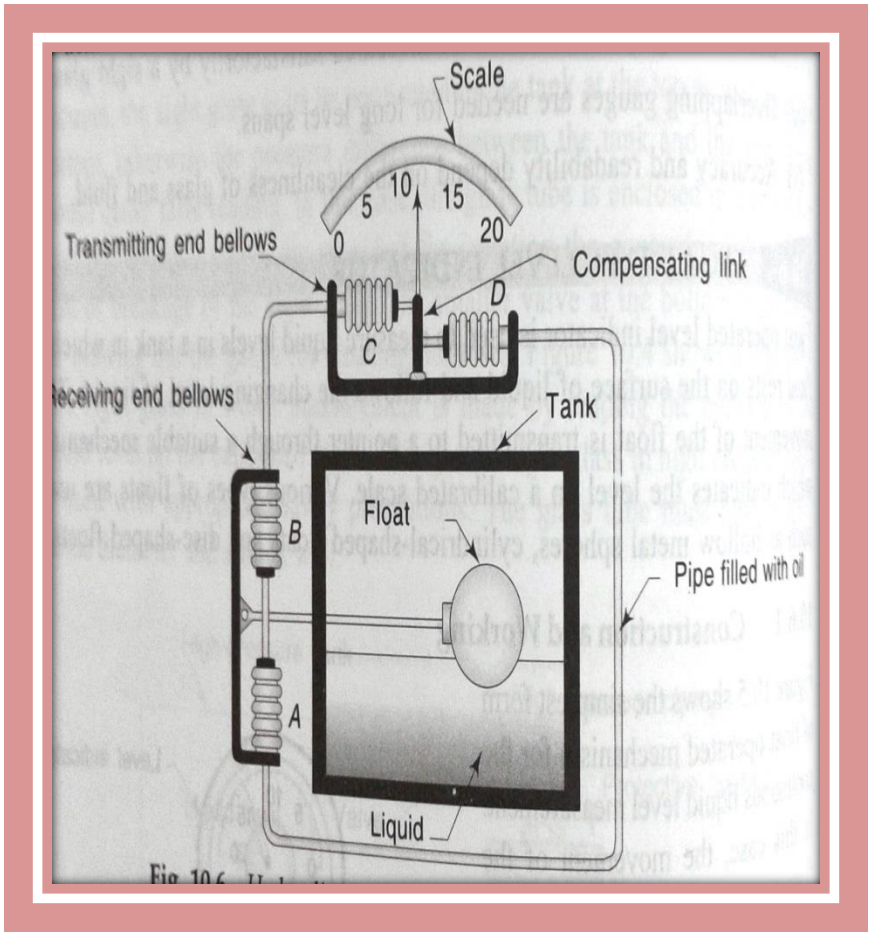


FLOAT TYPE LEVEL INDICATOR

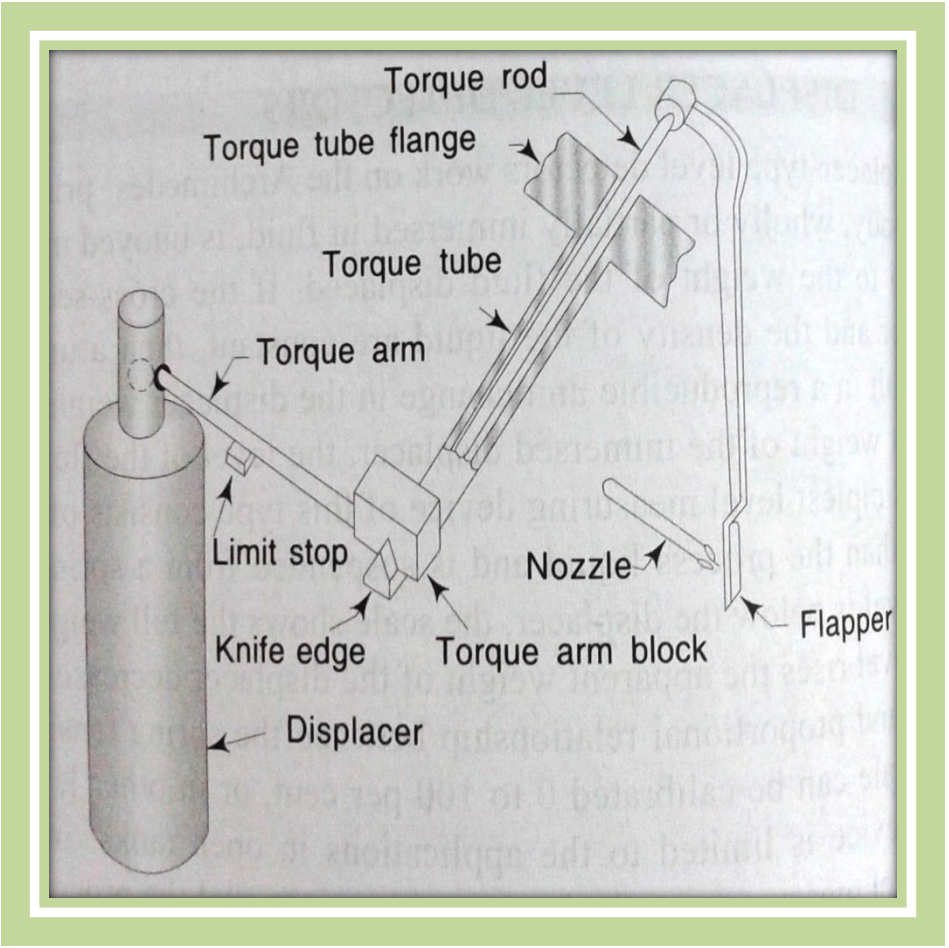
Float operated level indicator is used to measure liquid levels in a tank in which a float rests on the surface of liquid and follows the changing level of liquid



Float type



Displacer level indicator

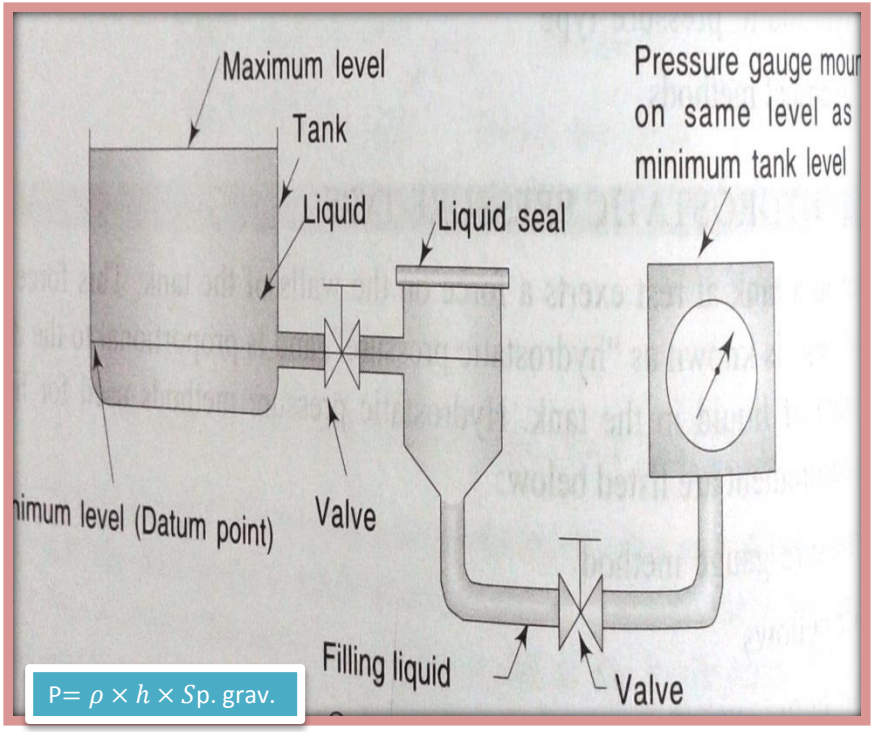


Hydrostatic type

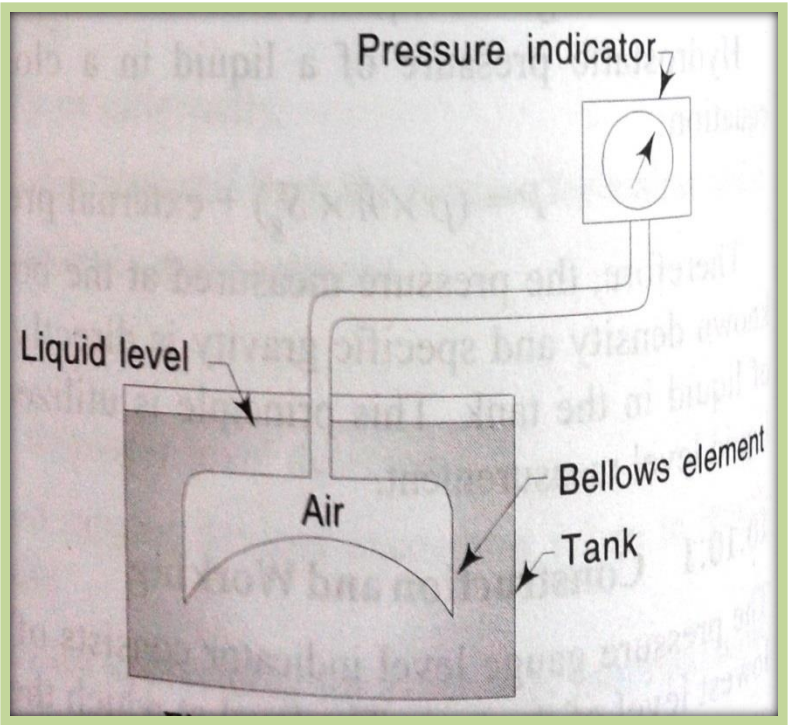
A liquid in a tank at rest exerts a force on the walls of the tank. This force in a liquid at rest is known as "hydrostatic pressure" and is proportional to the depth (or height) of liquid in tank

PRESSURE GAUGE METHOD

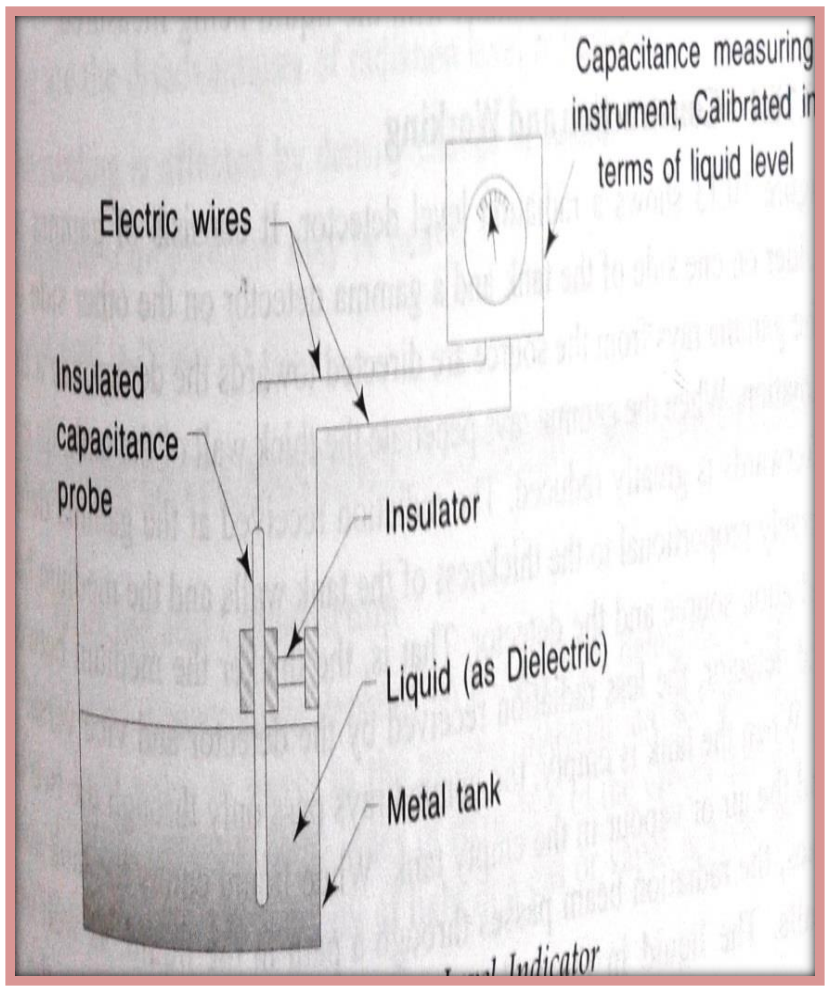
The pressure measured at the bottom of tank containing a liquid of known density and specific gravity is directly proportional to the height or level of liquid in the tank



AIR BELLOWS

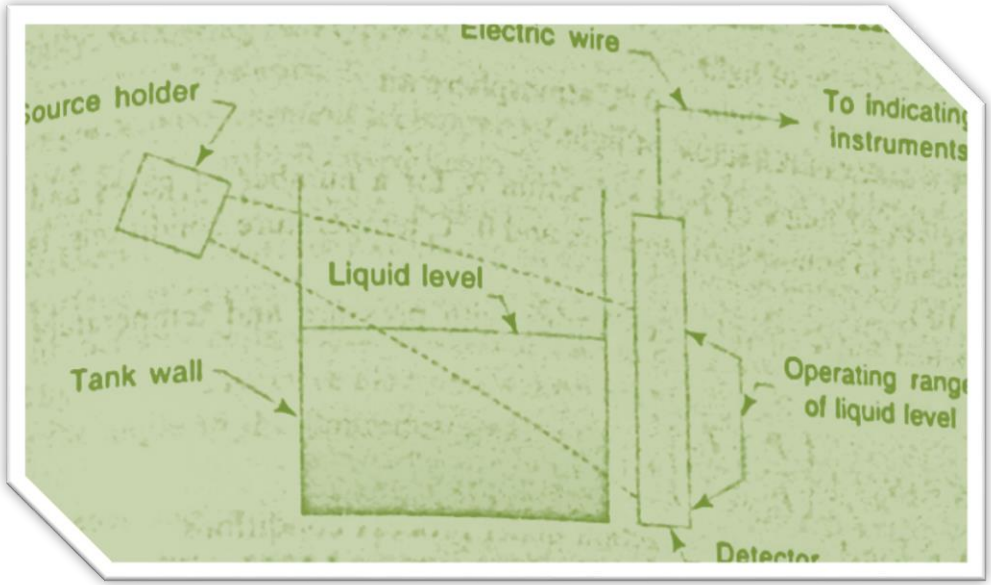


ELECTRICAL TYPE

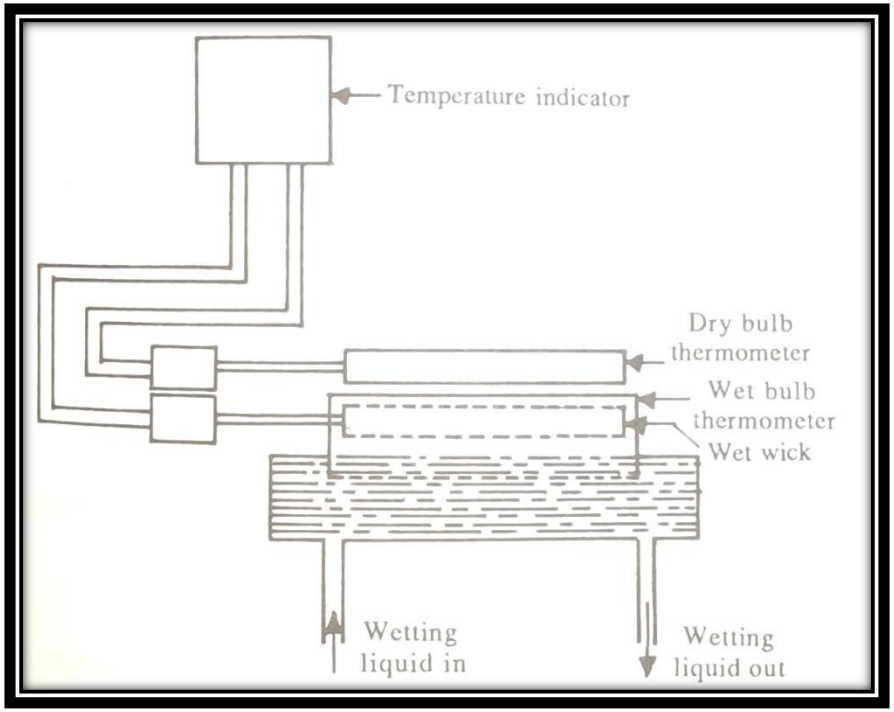


- When the level of liquid in the tank rises the capacitance increases
- When the level of liquid in the tank decreases the capacitance also decreases
- **Advantages**
  - Very useful in small scale
  - Very sensitive
  - Suitable for continuous indication / control
- **Disadvantages:**
- Measured fluid must have proper dielectric qualities
- Prob length and mounting must suit the tank

RADIATION LEVEL DETECTOR



Humidity Measurement



Advantages:

- Its accuracy is superior to other humidity sensors
- Easy repair at the minimum cost
- Comparatively low cost

Disadvantages:

- Accuracy decrease 20% relative humidity
- WBT's below 00C cannot be recorded accurately due to freezing of the circulating water
- It cannot be used in closed volumes

- Humidity refers to the amount of water vapor present in air or gas
- Humidity can measure by
  - Psychrometer
  - Hygrometers
- It consists of two separately filled thermal systems one for DBT measurement and other for WET
- The DBT thermometer bulb is kept bare in the gas vapor mixture while the WBT thermometer bulb is covered by a wick which is maintained wet by a liquid vapor is present in the gas
- Both the bulbs are mounted adjacent to each other so that the same vapor mixture passes over them at the rate of 4-10m/s.
- These bulbs are connected to pressure spring by capillary tubings
- The pressure spring show DBT and WBT of the mixture

1. Industrial Instrumentation & Control,2e ; Author, S. K. Singh ; Publisher, McGraw-Hill Education (India) Pvt Limited, 2003
2. Process Instrumentation and control (A.P. Kulkarni)