Level Measurement

Need for Level Measurement

Level measurement is important to monitor as well as measure quantitatively the liquid content in

- Pressure Vessels,Reservoirs,Tanks
- The liquid column height in open channel streams
- Level in fuel tanks of aircrafts

What is Level ?

- The liquid level is expressed in terms of length of the liquid column or in terms of the pressure the column exerts over a datum level

Methods of level Measurement

- Two methods are generally used in industries for measuring liquid level. These are
  - Direct Method
  - Indirect Method

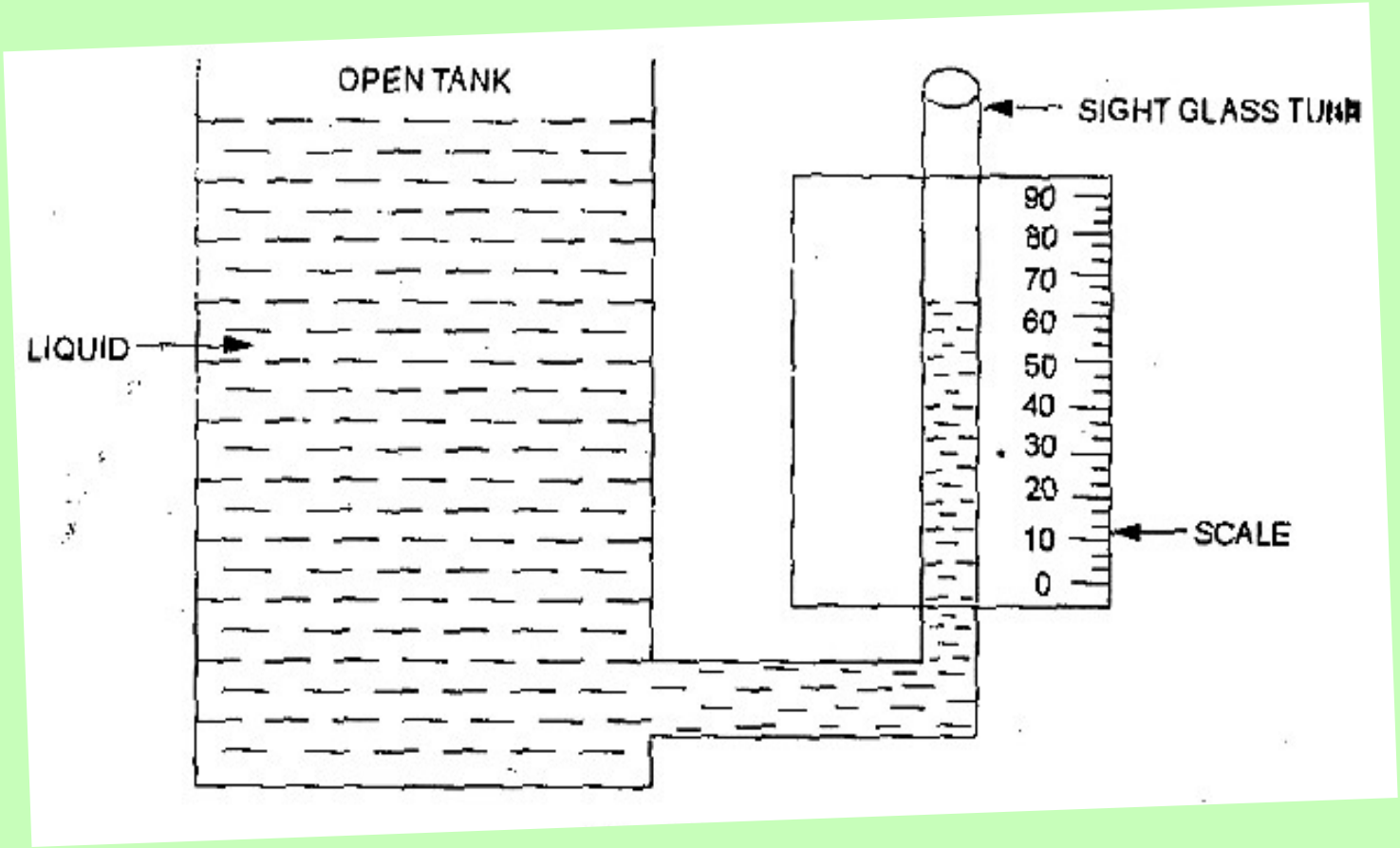
Direct Method

- This is the simplest method of measuring liquid level where the level is measured directly by means of the following liquid level indicators
    - Hook Type Level Indicator
    - Sight Glass Level Indicator
    - Float Type Level Indicator

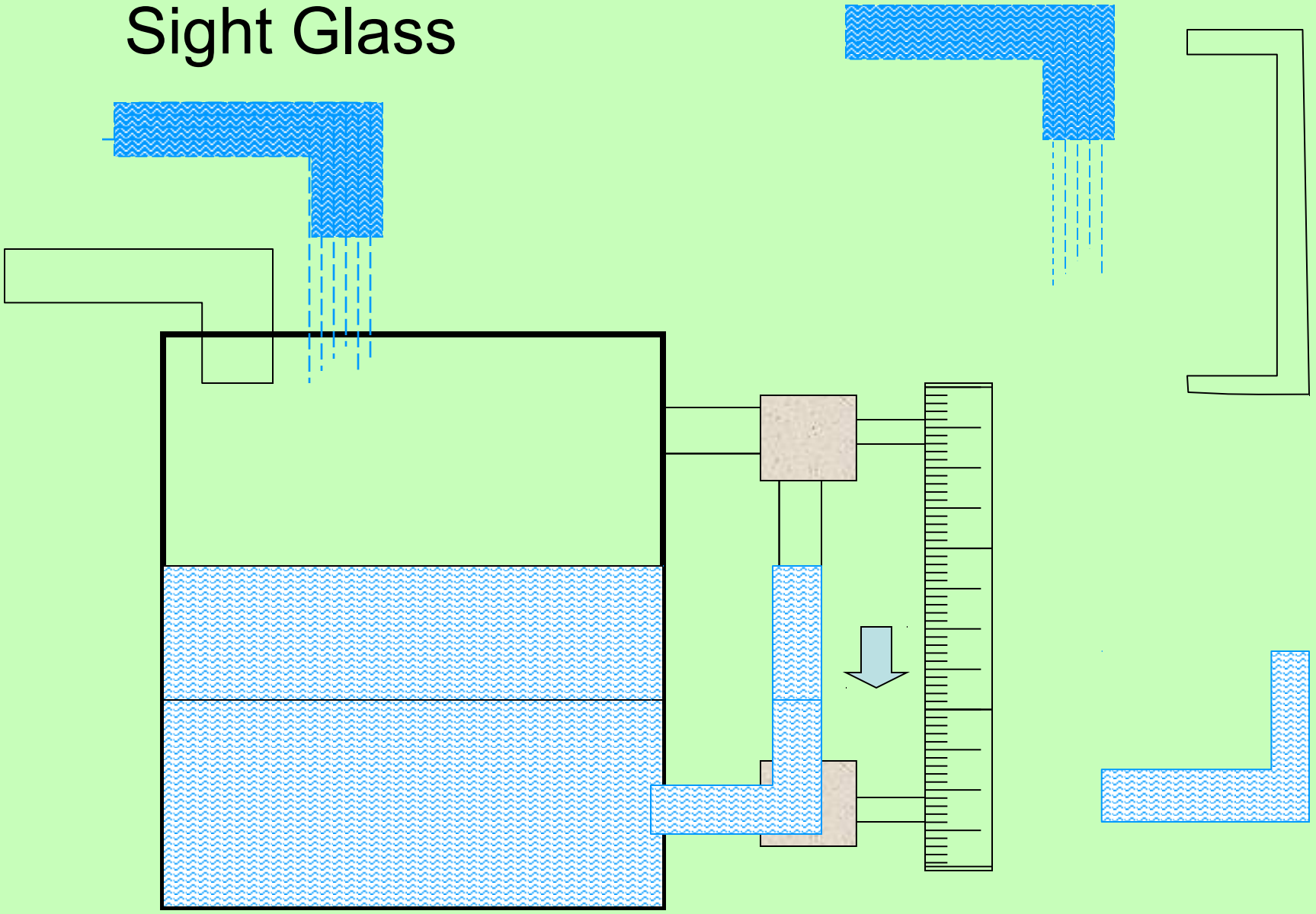
Sight Glass

- A sight glass (also called as gauge glass) is used for the continuous indication of liquid level within a tank or vessel

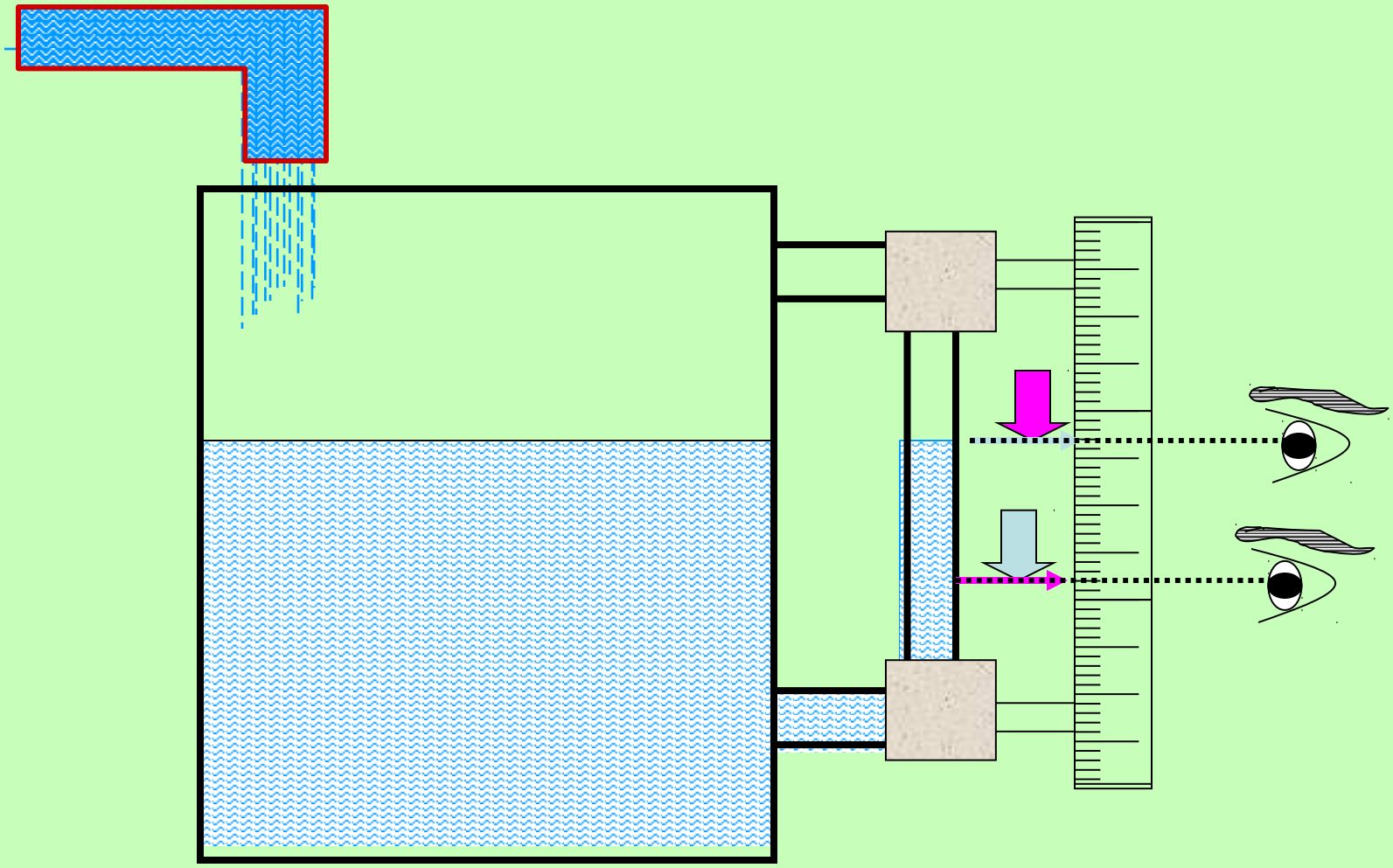
Sight glass


OPEN TANK
SIGHT GLASS TUBE
LIQUID
90
80
70
60
50
40
30
20
10
0
SCALE

Sight Glass



Sight Glass



Construction

- A sight glass instrument consists of a graduated tube of toughened glass which is connected to the interior of the tank at the bottom in which the liquid level is required

Working

- As the level of the liquid in the tank rises and falls, the level in the sight glass also rises and falls accordingly. Thus, by measuring the level in the sight glass the level of liquid in the tank is measured.

Ranges

- The standard practice is not to go for a glass tube of more than 900 mm length
- Two or more sight level gauges are provided at different levels if the height of the tank is more than 900 mm
- This gauge is made to withstand pressures of 350 psi of steam pressure at 252ºC or 1000 psi of liquid pressures

Advantages

- Direct reading is possible
- Special designs are available for use up to 316ºC and 10000 psi
- Glass less designs are available in numerous materials for corrosion resistance

Disadvantages

- Readings are noted where the tank is located which is not always convenient
- Since sight glasses are located on the outside the tanks, the liquid in the sight glass may freeze in cold weather even though the liquid inside the tank does not, and thus, it may cause error in the reading

Disadvantages

- Heavy, viscous liquids or liquids containing material which fall out of solution and clog the tube cannot be measured satisfactorily by a sight glass
- Overlapping gauges needed for long level spans
- Accuracy and readability depend on cleanliness of glass and fluid

Materials

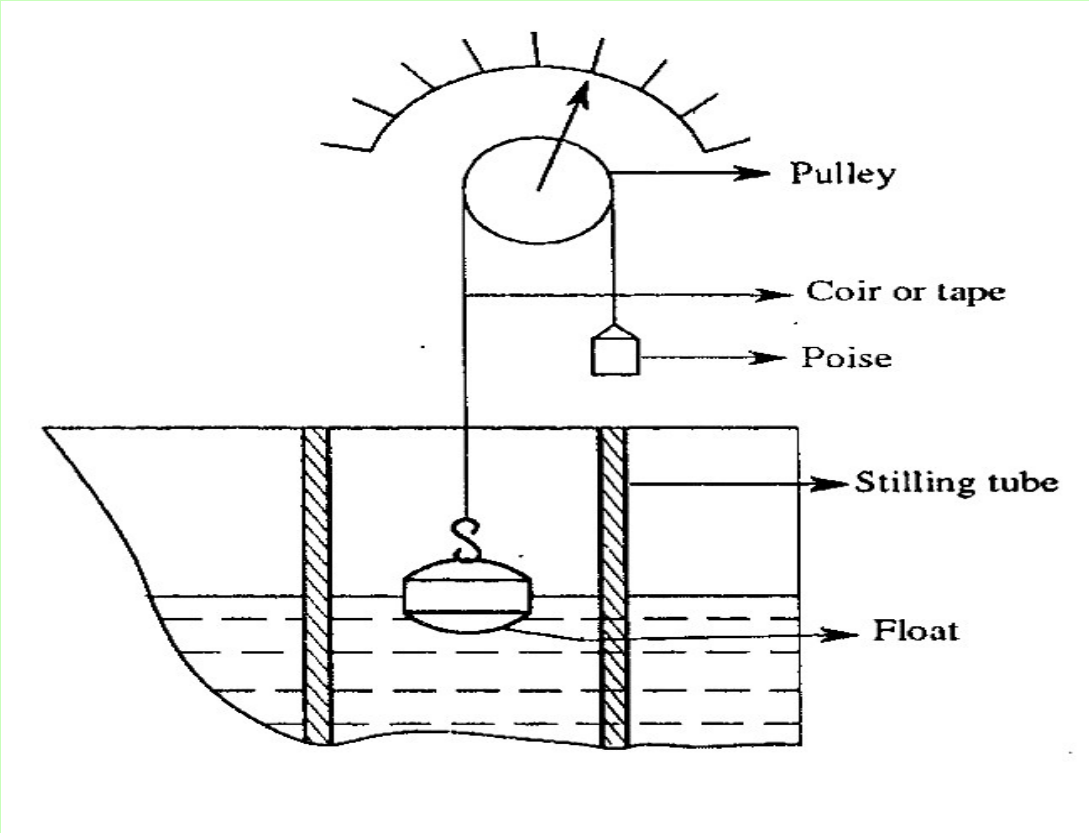
- Simple glass or plastic material is used up to 30kg/cm² pressure and 200ºc temperature
- A reflex type design where the tube is metal casting with a thick glass material is used up to 36kg/cm² pressure and 550ºc temperature

Float actuated Level indicator

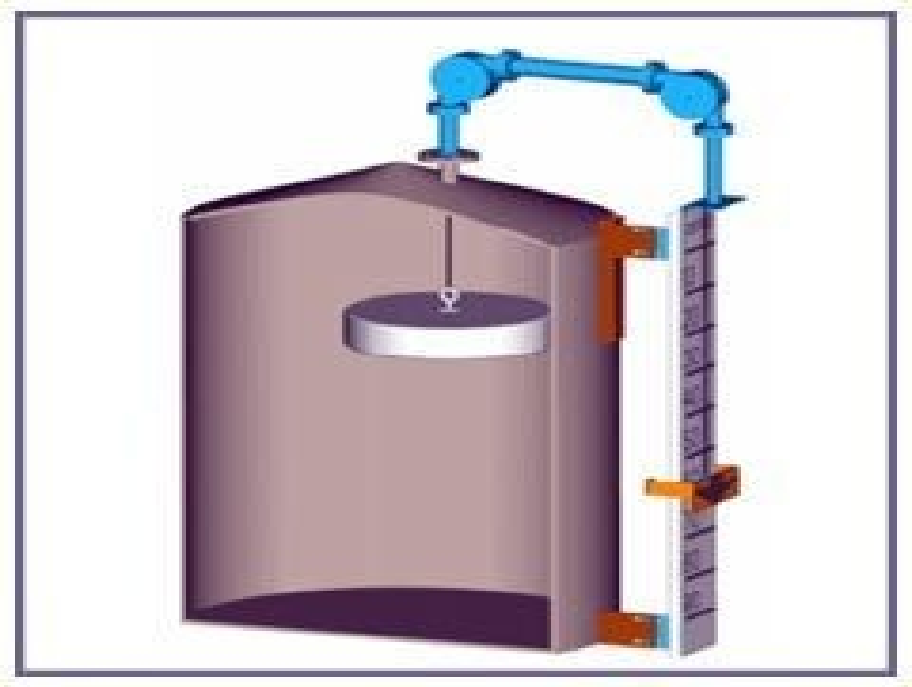
Float Actuated Level Indicator

- In this the float rests on the surface of liquid and follows the changing level of liquid.
- The movement of the float is transmitted to a pointer through a suitable mechanism which indicates the level on a calibrated scale.

Float Actuated Level Indicator



Float Actuated Level Indicator



Construction

- It consists of a float made of stainless steel or copper or phosphor bronze with nickel plating to avoid rusting which rests over the surface of the liquid
- The float movement is transmitted to the pointer by a stainless steel or phosphor bronze flexible cable wound around a pulley, and the pointer indicates liquid level

Types of floats

- The design of float is very important hence floats of the following shapes are used
  - Hollow metal spheres
  - Cylindrical shaped float
  - Disc shaped floats

Working

- When the liquid level rises or falls a buoyant force equal to weight of the displaced liquid is available
- It pushes the float up or down.
- The float movement is transmitted to a pointer through a suitable mechanism
- It indicates the level on a calibrated scale

Advantages

- Economical
- Reliable designs
- It is possible to read the liquid levels in tanks below ground level
- Operated at large temperature ranges

Disadvantages

- Limited to moderate pressures
- Float design should be considered for liquids with suspensions

Resistive type of level Indicator

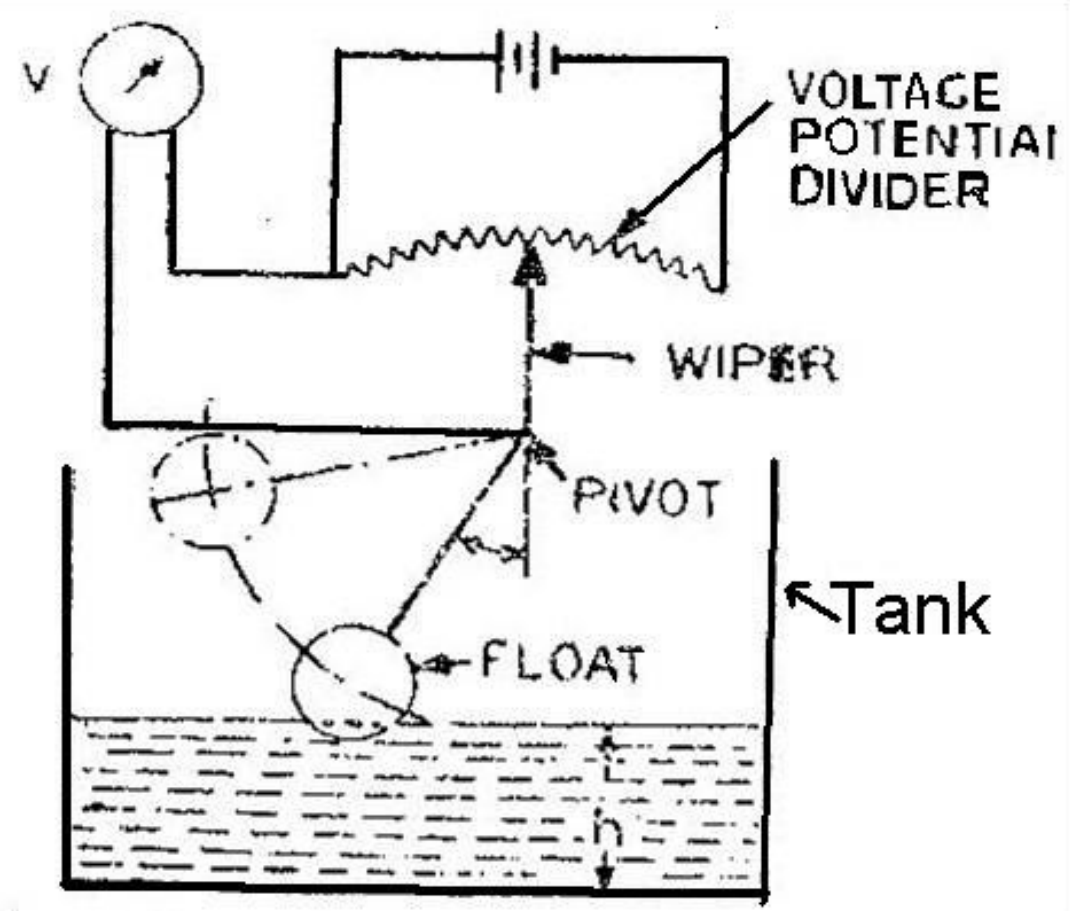
Resistive type of level Indicator

- This is an electrical method where the liquid level position is converted into an electrical signal

Principle of Resistive type Level Indicator

- The float acts as a primary transducer that converts liquid level variation into a suitable displacement
- This displacement is sensed by the secondary transducer such as a resistive potentiometric device
- The resistive potentiometer converts displacement into electrical signal

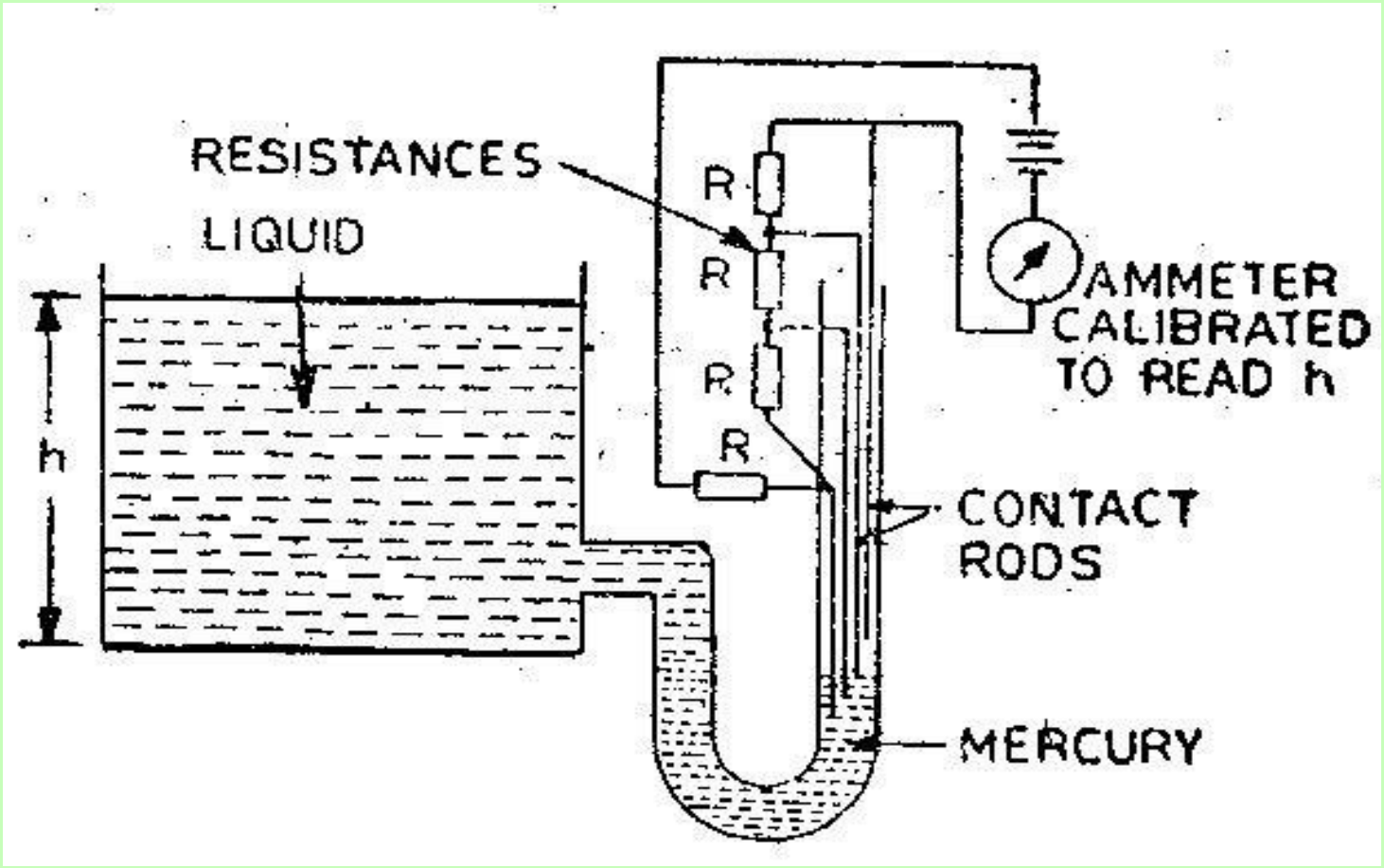
Float actuated type Resistive Level Indicator



Construction and Working

- The float begins to move As the liquid level changes
- The float displacement actuates the arm
- It causes the slider to move over the resistive element of the potentiometer
- The circuit resistance changes
- This resistance change is directly proportional to the liquid level in the tank

Fixed Resistive type of level Indicator



Construction and Working

- A number of contact rods are placed at various levels
- Mercury is used as conductor
- As head ‘h’ increases, the level of mercury rises above the datum
- It results in shorting of successive resistors R
- The ammeter reading increases
- It indicates the value of h directly

Advantages

- Continuous record of level is possible with addition of contact rods
- Uses low voltage to eliminate danger to the operators and to prevent arcing at the contact points
- Signal can be transmitted to any desired point

Advantages

- Can be used in pressurized containers without packing glands or shafts
- Simple to calibrate

Disadvantages

- Unsafe to use this transducer in explosive atmosphere due to arcing at the contact points
- Large number of contact rods are required
- The contact rods are corroded by corrosive liquids

Disadvantages

- Difficulty in measurement arises when there is saturated vapor over liquid phase
- Any changes in the conductivity of the liquid causes serious errors

Applications

- Used for indication and initiation of control action
  - To actuate valves or pumps
  - Warning lights and alarms depending on level

Capacitance Level Indicator

Capacitive Type of Level Indicator

- This is an electrical method for measuring and indicating liquid level in industries
- Types of Capacitive Methods
    - Variable Area Method
    - Capacitive Voltage Divider Method
    - Variable Dielectric Constant Method

Principle

The operation is based upon the familiar equation of a parallel plate capacitor given by

$$C = \varepsilon A/D$$

Where , C = Capacitance , in farad

ε = Dielectric Constant

A = Area of plate, in m^2

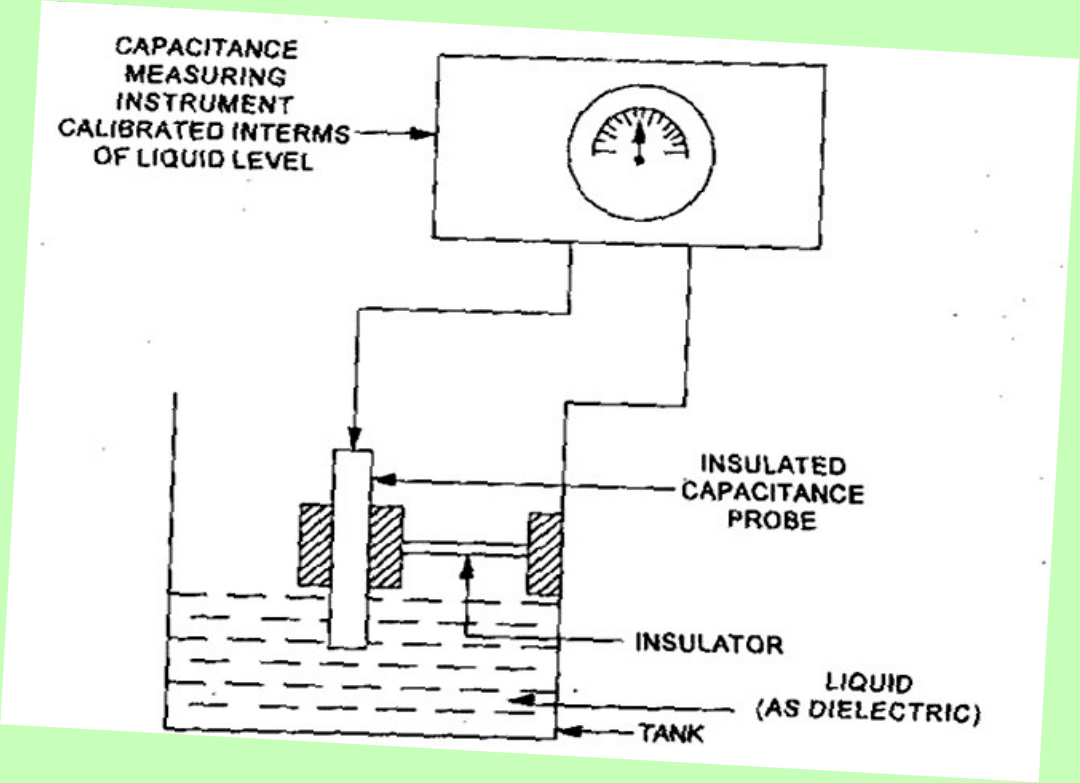
D = Distance between two plates, in m

Principle

- Therefore, if A and D are constant, then the capacitance is directly proportional to the dielectric constant, and this principle is used in the capacitance level indicators.

Variable Area Method

- Used for measurement of levels of both solids and liquids



Construction

- The electrical conducting container holds the materials
- A metal rod completely covered by insulating material is placed inside the container
- The metal rod and the container walls form the two plates of the capacitor
- The insulating material forms acts as the dielectric medium

Working

- When the level of liquid in the tank rises the capacitance varies linearly with the height of the material
- The relationship between level of a liquid and the capacitance is given by :

$$C = 2\pi\varepsilon h/\log_e(d_2/d_1)$$

Where ε = permittivity of the insulator;F/m

h = height of the material ; m

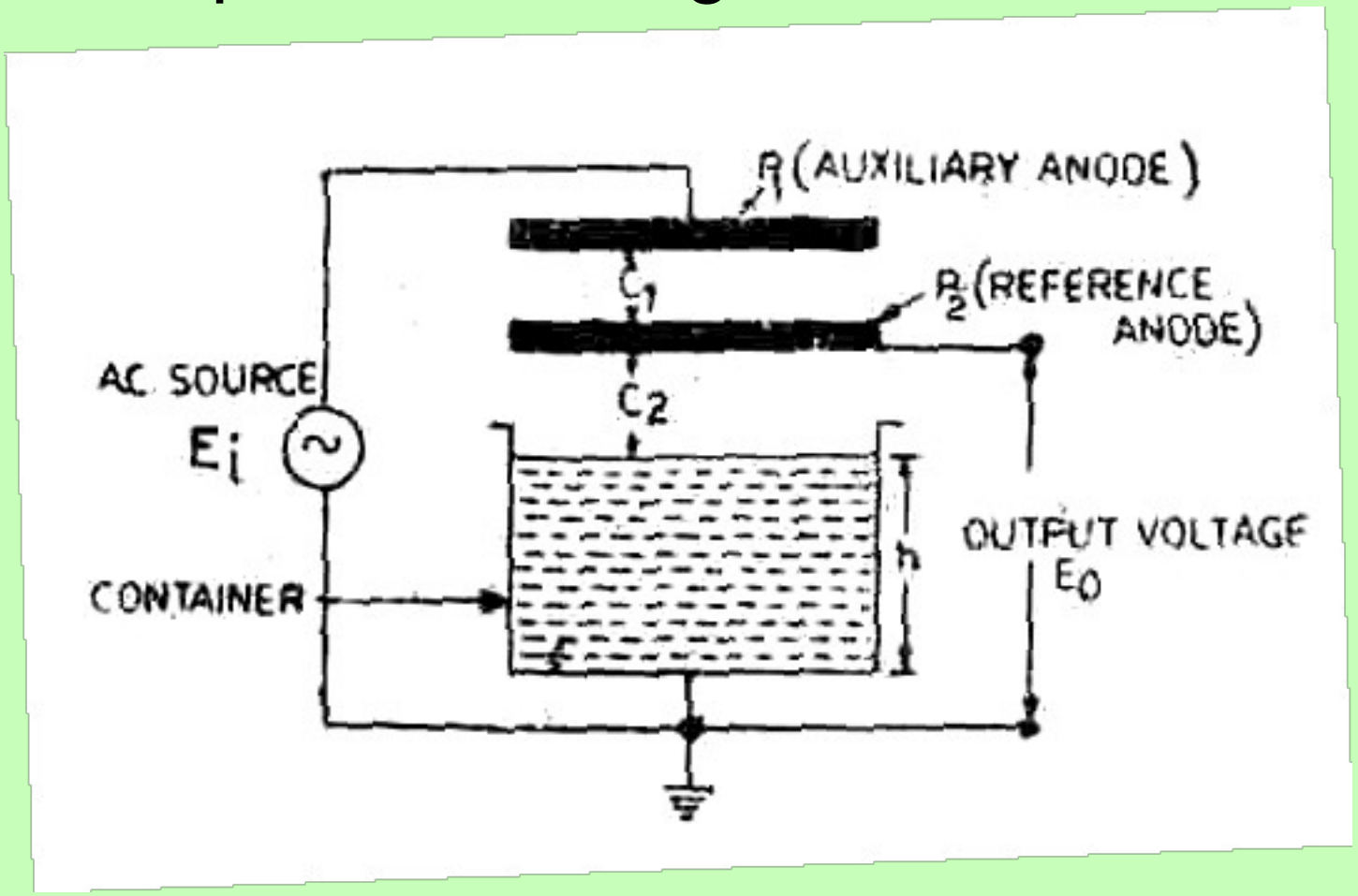
d_1 = diameter of the metal rod ; m

d_2 = diameter of the insulator ; m

Working

- The increase or decrease of the capacitance is measured and is displayed on the indicator calibrated in terms of liquid level

Capacitive Voltage Divider Method



Construction

- The liquid surface acts as one electrode for liquids whose conductivity is high
- The other electrode is a fixed reference plate parallel to the surface of the liquid
- An auxiliary electrode P_1 is placed at a fixed distance above the reference electrode P_2.

Construction

- The two electrodes P_1 and P_2 are electrically insulated from each other

- An ac voltage is applied between the liquid and the electrode P_1

Working

- As the level of the liquid in the tank varies the capacitance C_2 varies i.e. C_2 is inversely proportional to the distance between the liquid surface and electrode P_2
- The potential of electrode P_2 with respect to earth

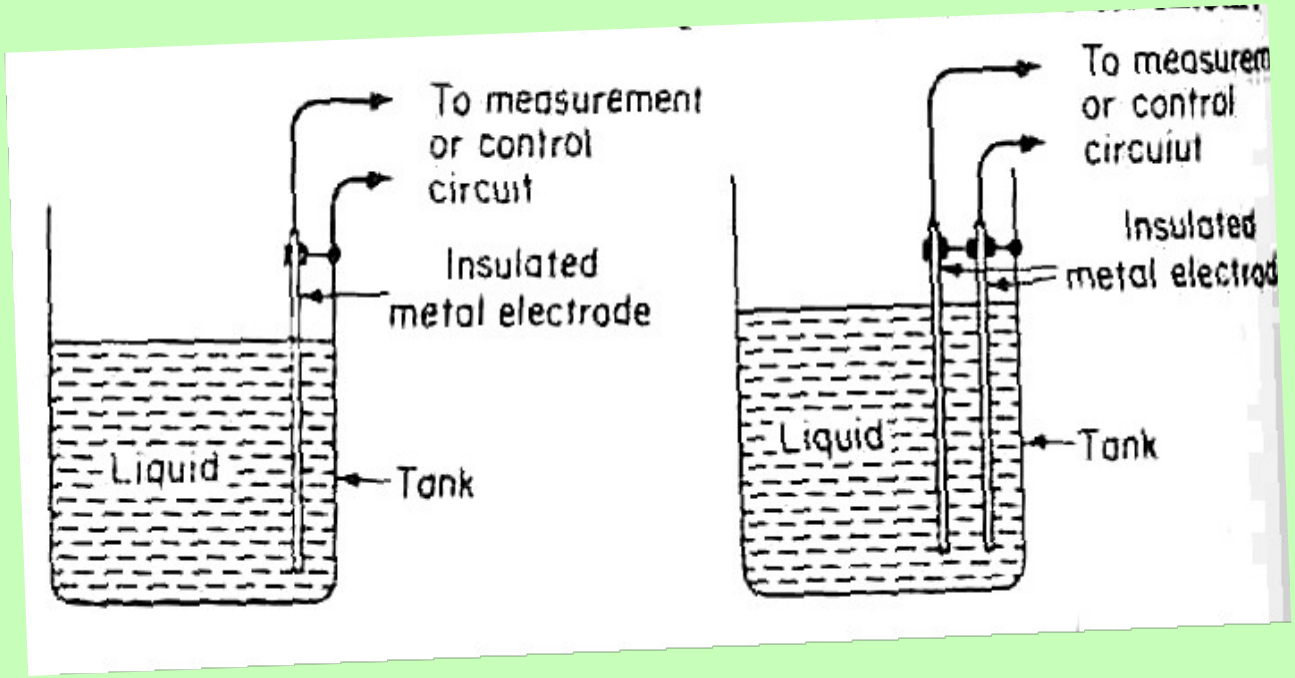
$$E_0 = E_i \quad C_1/(C_1+C_2) \text{ Volts}$$

Working

- The output voltage decreases with a rise of liquid level
- Therefore , a non-linear relationship exists between them.

Variable Dielectric Constant Method

- If the liquid is non-conducting it is used as a dielectric in a capacitor



Construction

- An insulated metal electrode firmly fixed near and parallel to the metal wall of the tank
- The electrode and the tank wall form the plates of a parallel plate capacitor
- The liquid in between them acts as the dielectric material if the liquid is non-conductive

- If the liquid is conductive in nature,
- The metal rod and the liquid form the plates of the capacitor
- The insulation between them is the dielectric medium

Working

- The capacitance of this capacitor depends upon the height of the dielectric between the plates i,e the liquid level.
- As the level of the liquid increases the capacitance increases.
- Thus, the capacitance is proportional to the height of the liquid in the tank
- The capacitance thus measured is an indication of liquid levels.

Advantages

- Useful in small system.
- Very sensitive
- Moving parts are not exposed to fluid
- Suitable for continuous indication and/or control
- Remote adjustment of span and zero is possible
- Good for use with slurries
- Probe materials for most corrosive fluids are available

Disadvantages

- Performance is severely affected by dirt and other contaminants as they change the dielectric constant
- Changes in temperature affects the sensitivity
- Measured fluids must have proper dielectric strength
- Recalibration is required if measured materials changes in composition or moisture content
- Probe length and mounting must suit the tank

Nucleonic Level Gauges

Nucleonic Type of Level Detectors

- Radiation at different frequencies can be used for level measurement which include
  - Ultrasonic,
  - Radar (microwave),
  - Laser (infrared light),
  - Neutron and gamma radiation.

- These are used where other electrical methods would not survive

Radiation Phenomenon

- Atoms with same chemical behavior but with a different number of neutrons are called isotopes.
- Most elements have unstable (radio active) isotopes.
- The unstable isotopes disintegrate to form elements or stable isotopes

Radiation Phenomenon

- Radio active disintegration is accompanied by the emission of three different kinds of rays namely
    - Alpha(α) radiation,
    - Beta (β) radiation
    - Gamma (γ) rays

Selection of Nucleonic Particles

- The penetrating power of the three rays are approximately
- $\alpha = 1$
- $\beta = 100$
- $\gamma = 10000.$
- Since Gamma rays have greater penetrating power and cannot be deflected
- Hence gamma radiation sources are chosen for use in level detecting equipment

Nucleonic Type of Level Detector

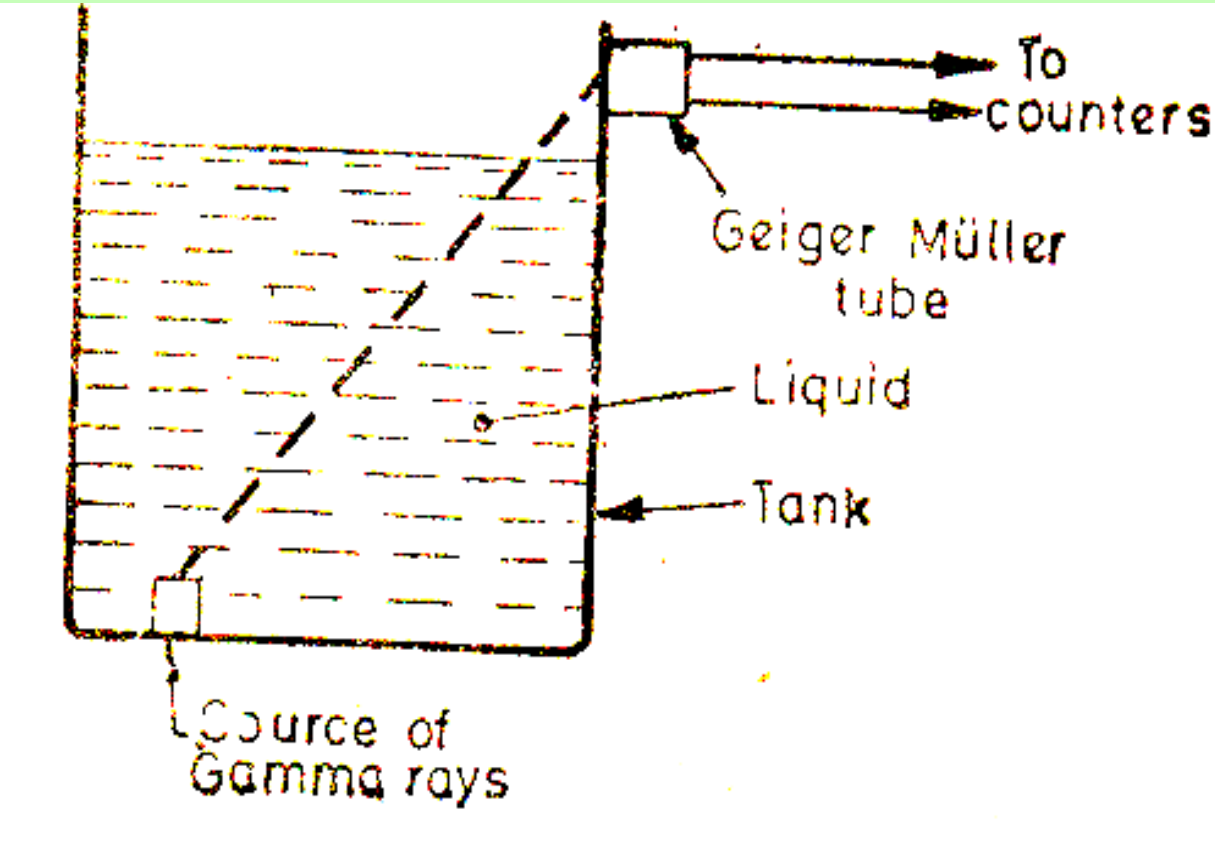


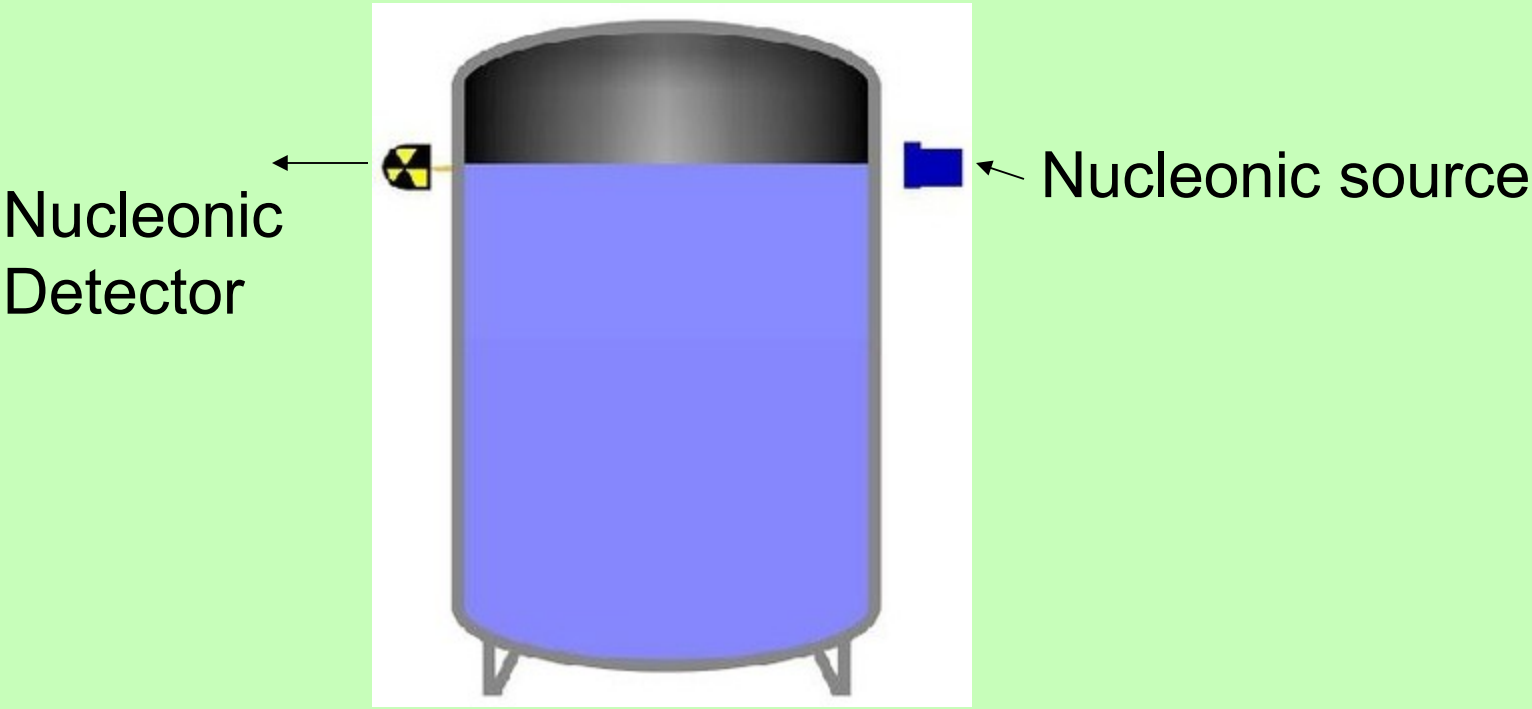
Fig : 1

Principle

- The gamma rays from the source are directed towards the detector after penetration through the thick walls of the tank whose energy level is greatly reduced.

- The radiation received at the gamma detector is inversely proportional to the
    - Thickness of the tank walls, and
    - Medium between the radiation source and the detector.

Nucleonic Type of Level Detector



Principle

- The thicker the medium between the source and detector the less radiation received by the detector and vice versa

Construction

- A source of gamma rays is placed at the bottom of the tank.

- Most commonly used sources of gamma rays are radioactive isotopes Co 60 (Cobalt) and Cs 137 (Cesium).

- A detector of gamma rays like a Geiger Muller tube or an ionization chamber is placed outside the tank near the top.

Working

- As the gamma rays penetrate the tank walls, the Geiger Muller tube senses the rays
- Greater the intensity of other (next) rays, the greater will be the output of this tube.
- The intensity of the rays will depend upon the liquid level
- When the tank is empty maximum radiation will reach the Geiger Muller tube

Working…

- When the liquid level rises, some of the radiation is absorbed by the liquid
- Then radiations reaching the tube will be reduced and hence its output is small
- The higher the level of the liquid in the tank, the greater is the absorption
- Hence lesser will be the output of the Geiger Muller tube.

Working…

- Thus the output of the Geiger Muller tube is inversely proportional to the liquid level.

- The output of the Geiger Muller tube is in the form of pulses which is counted by a suitable counter.

- Thus the counter is directly calibrated in terms of the liquid level.

Disadvantages

- The reading is affected by density change of liquid
- Radiation source holders may be heavy
- Cost is relatively high

Advantages

1. No physical contact with the liquid

2. They are suitable for molten metals as well as liquids of all types (corrosive, abrasive, highly viscous, adherent)

3. Useful at very high temperatures/pressures

4. They have good accuracy and response

5. No moving parts

Applications

- Non contact measurement of liquids and solids

- Radiation level detection is very appealing for
    - hard-to-handle,
    - toxic,
    - corrosive processes
- Because it does not require vessel wall penetrations

Ultrasonic Level Gauges

What are Ultrasonics ?

- Ultrasonic is a term used in acoustics to denote the frequencies which are beyond the range of human hearing

- Ultrasonic waves are sound waves of frequencies above about 20,000cycles/s

Ultrasonic type of level detectors

- Radiation at different frequencies can be used for level measurement which include
    - Ultrasonic
    - Radar (microwave)
    - LASER (infrared light)
    - Neutron and gamma radiation.
- These are used where other electrical methods would not survive.

Ultrasonic Type Of Level Detector

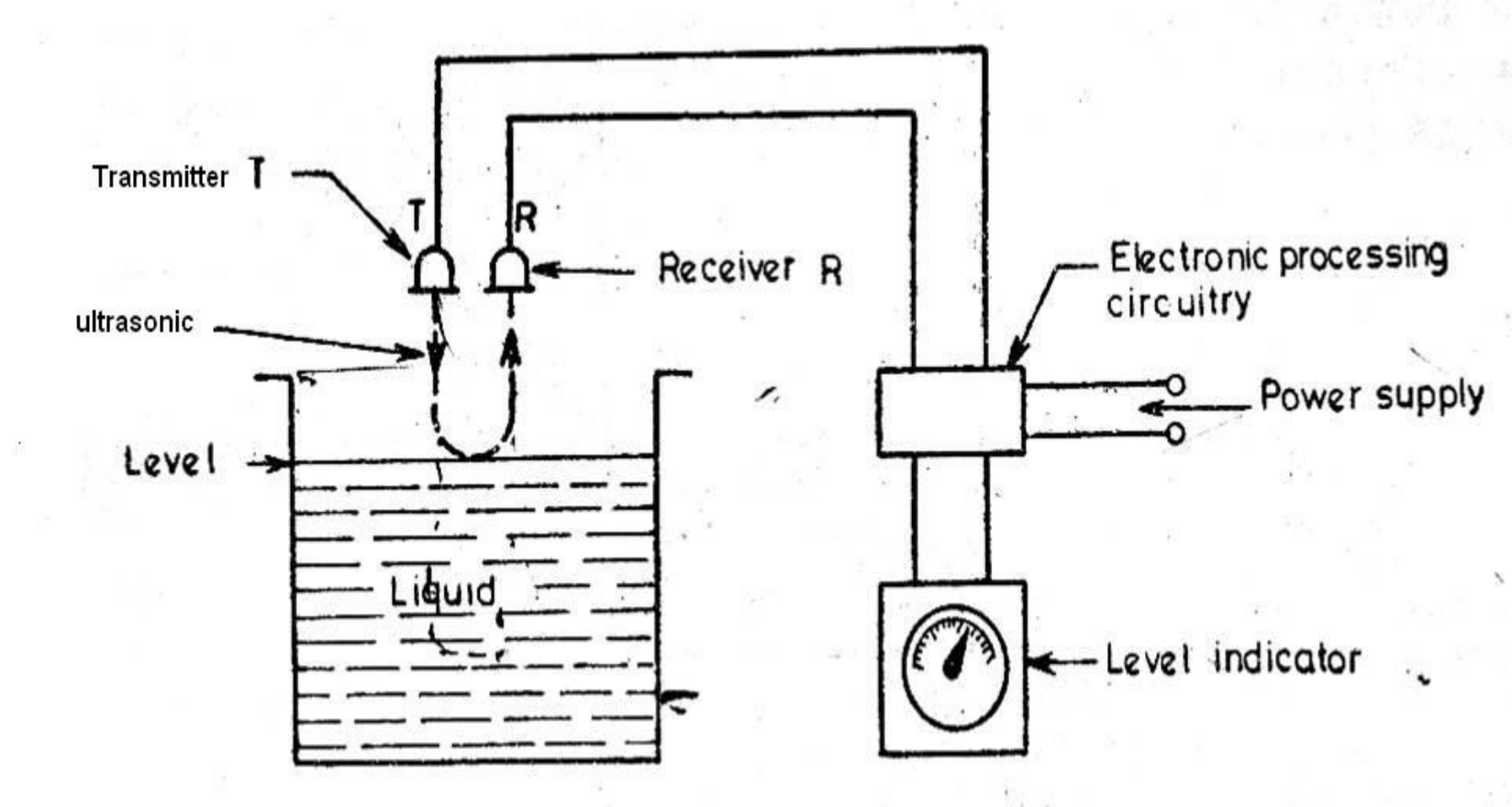


Fig : 1

Principle

- Sonic (9500 Hz) and ultrasonic level switches operate either by the absorption of acoustic energy
- it travels from source to receiver or by the attenuation (frequency change) of a vibrating diaphragm face, oscillating at 35,000 to 40,000 Hz

Construction

- An Ultrasonic transmitter receiver is mounted on the top of tank for measurement of level of either solids or liquids

- The output from the transmitter receiver is connected to appropriate electronic circuitry to the display device

Working

- The acoustic wave sent by the source (transmitter-T)
- It is reflected at the interface and received by the receiving crystal R
- As the level of the liquid changes the time taken by the beam changes
- this time is a measure of the distance traveled by the beam

Working

- The time ‘t’ between transmitting and receiving a pressure pulse is proportional to the distance between the ultrasonic set and surface of the contents of the tank
- The time t is a measure of the level of liquid in the tank

Advantages

1. No physical contact with the process material
2. The absence of moving parts
3. The reliability of the reading is unaffected by changes in the composition, density, moisture content, electrical conductivity or dielectric constant of the process fluid

Disadvantages

- Ultrasonic level transmitter is just as good as the echo it receives. The echo can be weak due to dispersion and absorption. The energy content of the echo will be further reduced if the bin is tall, if the vapor space is dusty, or if it contains foam or other sound-absorbing materials such as water vapors or mists

- The reflective properties of the process surface results in errors in the output

Applications

- Wetted and non contacting switch and transmitter applications for liquid level or interface and solids level measurement
- Used as open-channel flow monitors

Level Switches

Level Switches

- Level switches are used to regulate the level of liquids in tanks at desired point.

- The level switches are of various types.

  Float level switches.

  Displacer type of level switches.

  conductivity and Field effect level switches.

  Microwave level switches.

Principle of Operation

- In a float-type level sensor the buoyancy force holds the float on the surface of the liquid.
- The float carries a member having a magnetic coupling with a transduction element (coil, magnetic reed, or Hall-effect switch)
- The element is mounted on the outside wall of the tank
- It can be actuated by the proximity of the float.

Principle of Operation…

- In some designs, the float mechanically links the switching mechanism through the sealing in the wall (e.g., bellows).
- The switching system can respond to the restraining force
- The force is developed by a spring element
- The spring element is connected to the float or by an actuator of a force-balance servo system.

Float Materials & Design

- Standard floats are normally
  - spherical or cylindrical for top mounted design
  - spherical or oblong for side mounted designs
- Spherical floats are available from 3 to 7 inches (76 to 178 mm) in diameter.
- The small diameter floats are used in higher density materials
- Whereas the larger floats are used for liquid-liquid interface detection

Materials…

Materials used are

- Brass
- Copper
- stainless steel
- Monel
- Polypropylene
- other plastics

Magnetic Float Operated Switch

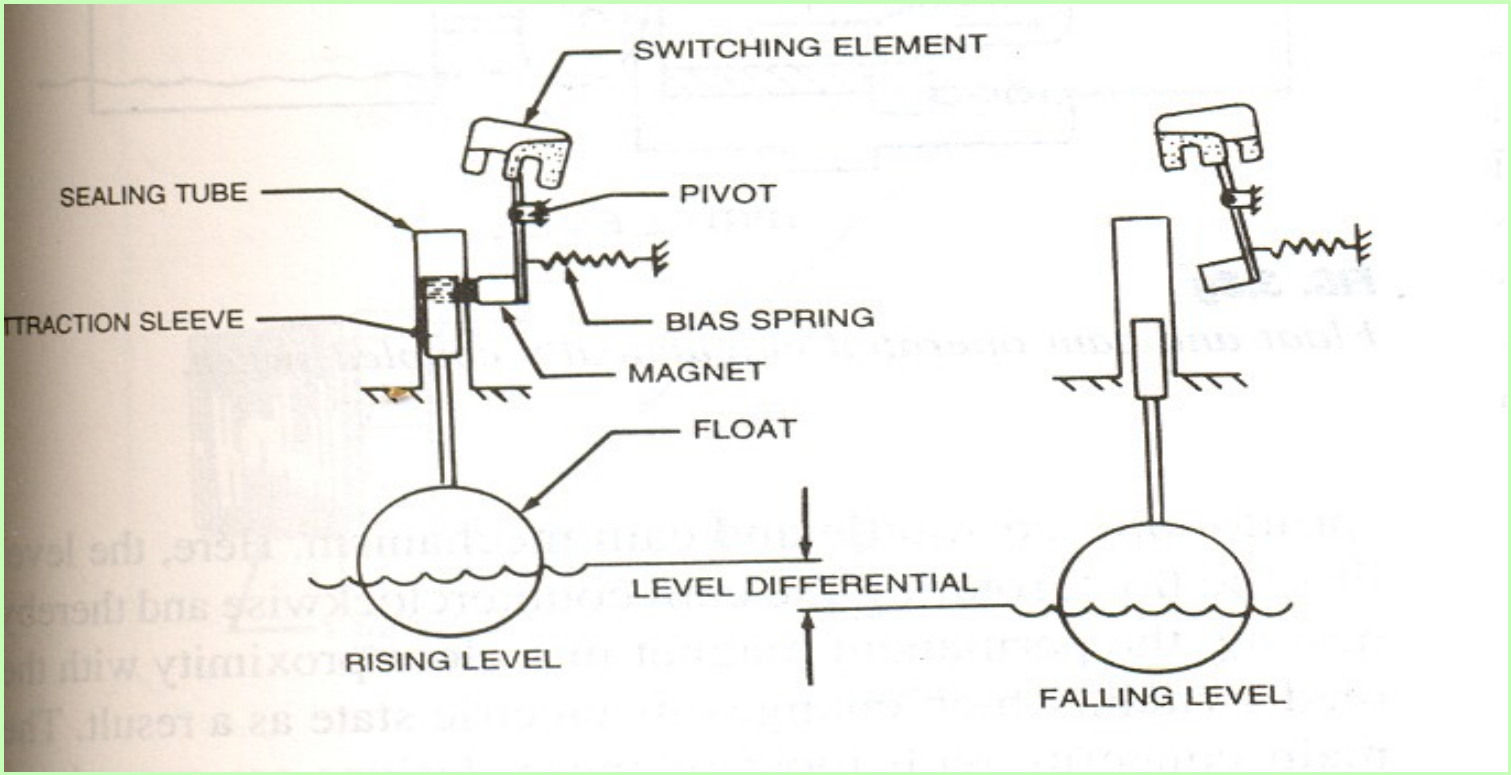


Fig : 1

Construction

- Consists of a magnetic piston or sleeve carried by a float
- The piston moves in a non magnetic enclosure to which a permanent magnet is attached.
- The magnet is attached to the crank lever which is spring loaded which carries a mercury switch
- The mercury switch is used to start and stop a pump motor for refilling the tank

Working

- When the level of the liquid is high enough, the magnetic piston or sleeve moves into the field of a permanent magnet

- The magnet is attracted towards the sleeve and it rests against the enclosure tube

- When the level falls the sleeve moves down and after a certain stage goes outside the field of the magnet .

Advantages

- Continuous level indication is possible
- Low cost
- Reliable

Disadvantages

- In some applications the size of the float is too large
- Cannot be used in dirty liquids as the moving parts are exposed to the process
- Ferrous metal particles in the process can interfere with proper switch operation