# Instrumentation-Sensors (what)

- Introduction: principles and fundamentals of Process Measurement and Instrumentation
- Pressure Measurement
- Flow Measurement
- **Level Measurement**
- Temperature Measurement
- Sensors

# Level Measurement

# What is Level Measurement?

- **Level measurement** is the process of determining and quantifying the height or level of a substance within a container, vessel, or tank.

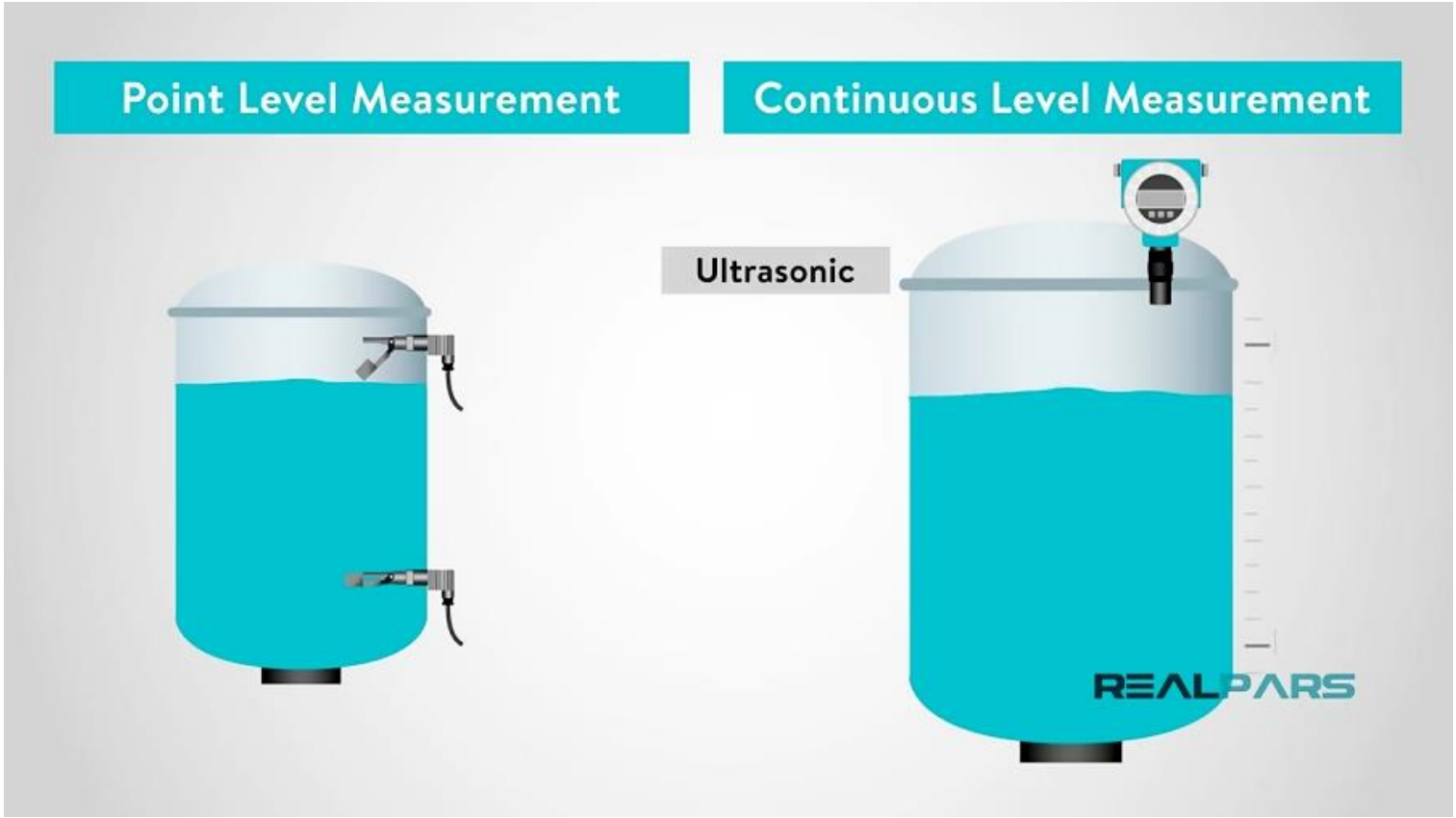
- It is a crucial aspect of various industrial processes and applications where the accurate measurement of liquid, solid, or slurry (boue) levels is essential for process control, inventory management, and safety.

# Applications in Industry

- It is used in a wide range of industries, including **chemical**, **pharmaceutical**, **oil and gas**, **water and wastewater**, **food and beverage**, and many others.
- The goal of level measurement is to obtain **real-time data** on the quantity of material present, ensuring that processes are efficiently managed and maintained within **desired operating parameters.**

# *Point level measurement Vs Continuous level measurement*

- ***Point level measurement:*** A method of level measurement where the only concern is whether the amount of material is within the desired limits.
- ***Continuous level measurement:*** A method of tracking the change of level over a range of values.



# Level Measurement Methods

- Level measurement methods provide a diverse range of techniques to meet specific application requirements across various industries.
- Each method utilizes unique principles to accurately measure the level of substances in containers or vessels.
- The choice of level measurement method depends on factors like **substance characteristics**, **container material**, **accuracy requirements**, **environmental conditions**, and **the specific application's demands**.


KM26 with MS41 Switch

KM26 with LMS100 Switch

# Commonly Used Level Measuring Devices

## Mechanical Level Instruments

- VISUAL INSPECTION
  - ✓ Sight glass indicator
  - ✓ Magnetically Coupled Level Gauges
  - ✓ Cable and Weight Systems
- PRESSURE
  - ✓ Hydrostatic Pressure
  - ✓ Bubblers
- FLOATS AND DISPLACERS
  - ✓ Floats
  - ✓ Displacers
- PADDLE WHEEL SWITCHES

## Electrical Level Instruments

- CAPACITANCE SENSORS
- CONDUCTIVITY AND INDUCTIVE PROBES
- PHOTOMETRIC SENSORS
- MAGNETOSTRICTIVE SENSORS
- THERMAL DISPERSION SENSORS

## Ultrasonic, Radar and Laser level Instruments

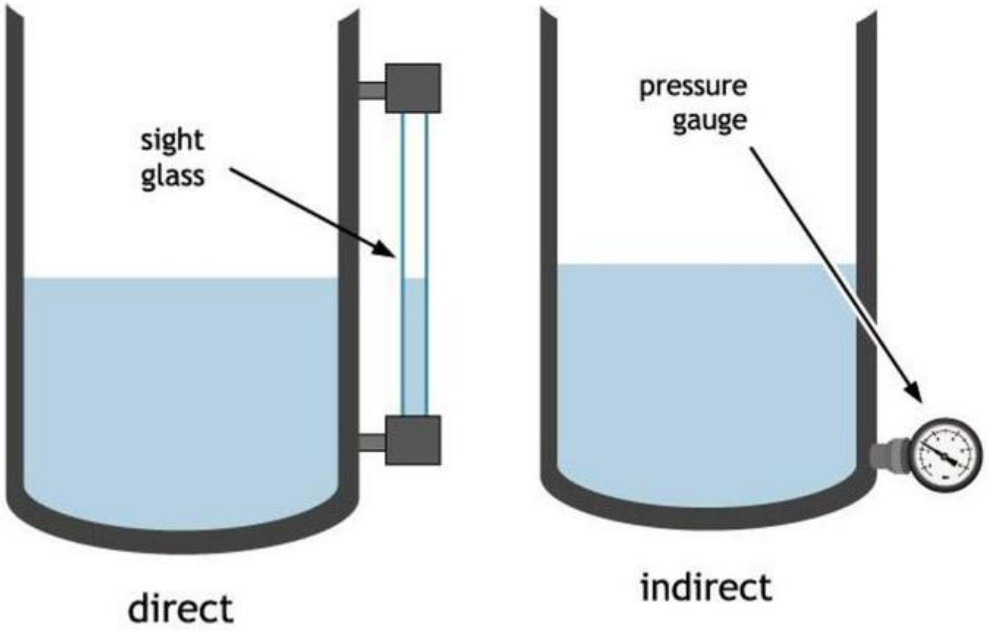
- ULTRASONIC SENSORS
- RADAR LEVEL SENSORS
- LASERS LEVEL INSTRUMENTS

## Nuclear level Instruments

# Direct and Indirect Level Measurement

**Direct Level Measurement:** is a straightforward process that relies on physical principles, such as fluid motions, floats, and thermal properties, to determine the level of a substance in a container.

**Indirect Level Measurement:** involves measuring other quantities, such as volume, to determine the level of the substance in the container.



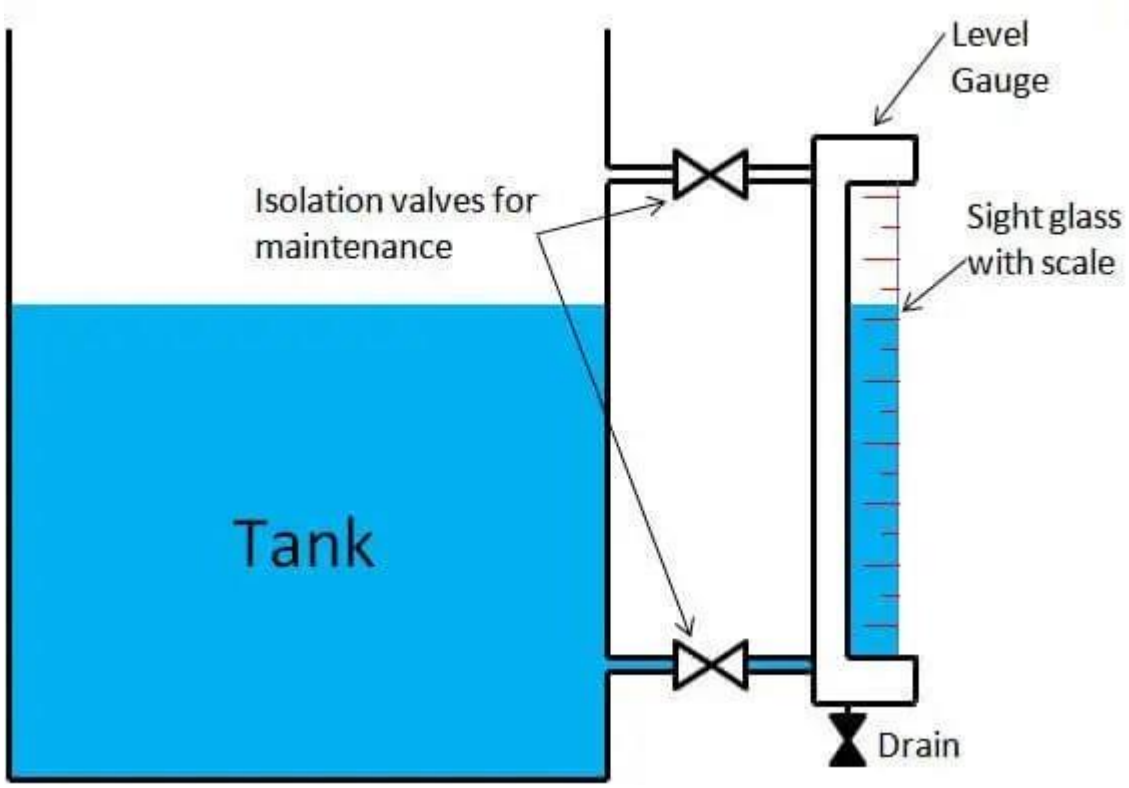
# Mechanical Level Instruments

# Mechanical Level Instruments

- VISUAL INSPECTION
  - ✓ Sight glass Level Gauge
  - ✓ Magnetic Level Gauge
  - ✓ Cable and Weight Systems
- PRESSURE
  - ✓ Hydrostatic Pressure
  - ✓ Bubblers
- FLOATS AND DISPLACERS
  - ✓ Floats
  - ✓ Displacers
- PADDLE WHEEL SWITCHES

# Sight Glass Level Gauge

A ***Sight Glass Level Gauge*** is a continuous level measuring instrument that consists of a glass tube connected above and below the liquid level in a tank and that allows the liquid level to be observed visually.




**Video Link:** https://youtu.be/IzqYvz6SWrY

# Sight Glass Level Gauge

## Advantages / desadvantages

## Advantages:

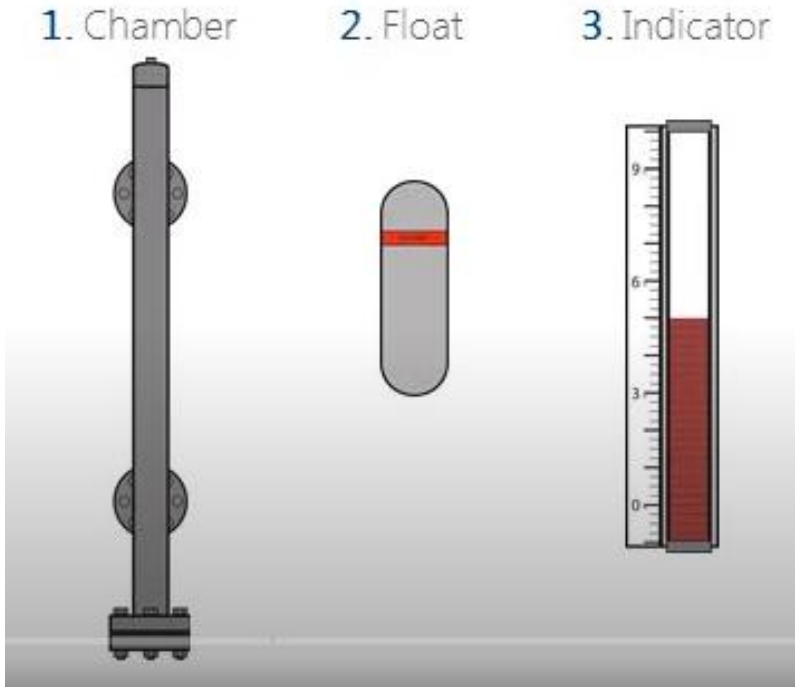
- No power required.
- Gauge glasses allow for direct reading.
- Special designs can be used in extreme conditions, up to 3000°C and 650 kg/cm².
- Glassless models offer corrosion resistance and are available in various materials.

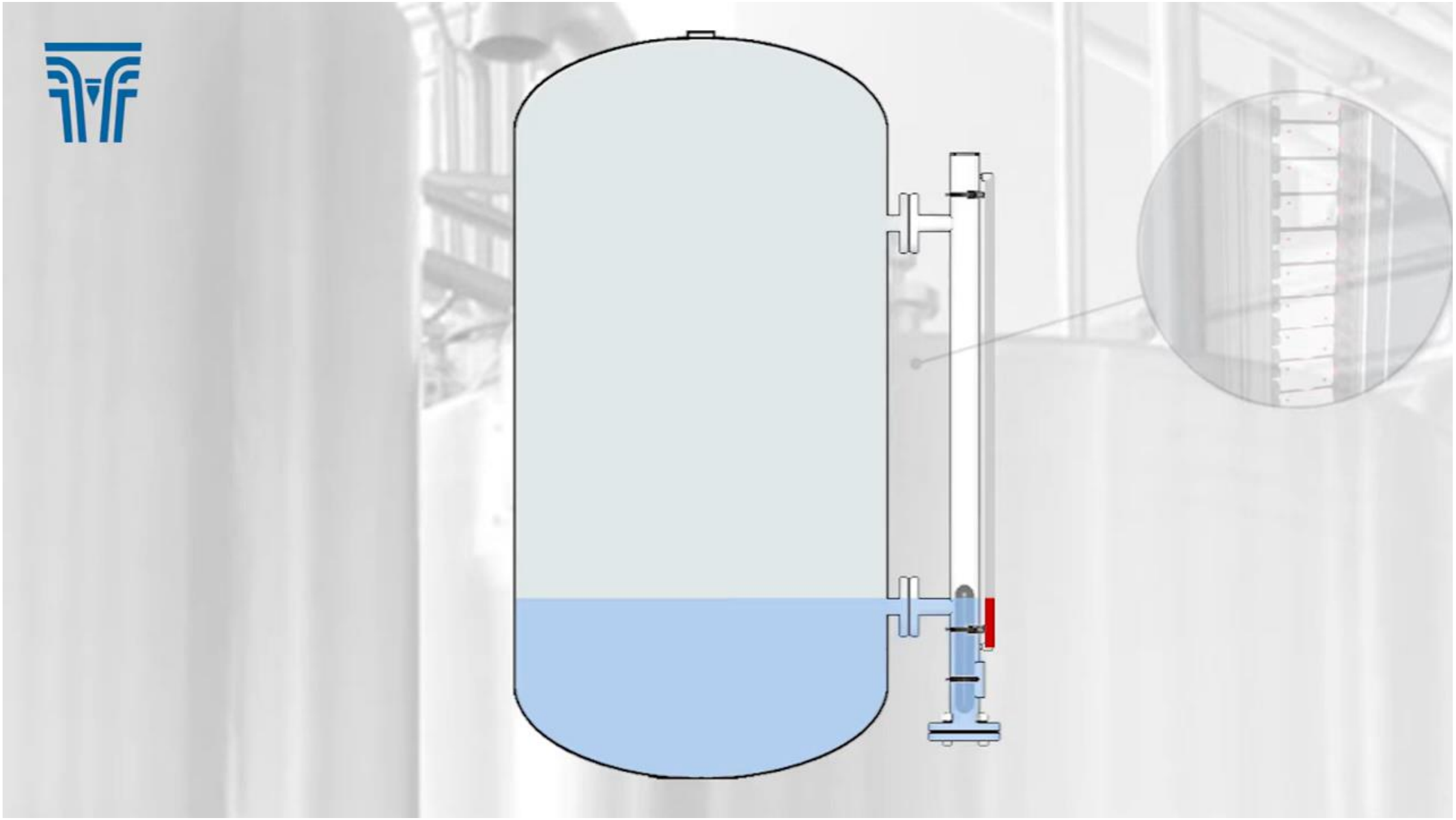
## Desadvantages:

- Dirty fluids may clog column.
- They are ineffective for measuring heavy, viscous liquids
- The external positioning of gauge glasses makes them susceptible to freezing in extreme weather, leading to inaccurate readings.

# Magnetic Level Gauge

A ***magnetic level gauge*** is a gauge that consists of a **stainless steel float** containing a **magnet riding** in a stainless steel tube where the level indicator consists of horizontally pivoted magnetized vanes painted yellow or white on one side and black on the other in a housing bolted to the level tube.





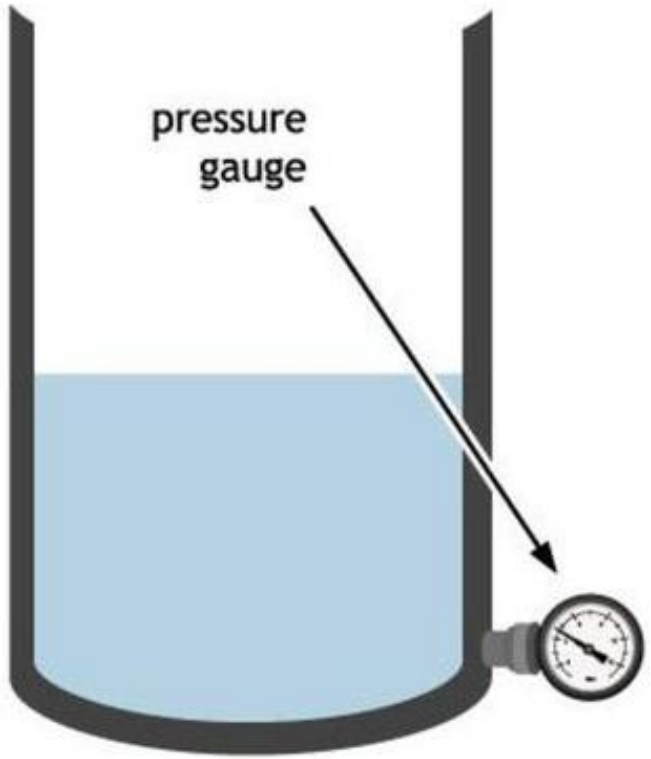
**Video Link:** https://youtu.be/bCfcH-Tlg-Y


Video Link: https://youtu.be/R1gbtd3wkBs

# Hydrostatic Level Indicator

**Hydrostatic level measurement** involves determining the **height** of a liquid using the **hydrostatic pressure** exerted by the liquid on its surface.

$$P = \rho \times g \times h$$



Video Link: https://youtu.be/T2OPoEod_jM

# Hydrostatic Level Indicator

## Advantages / desadvantages

## Advantages:

- **Simple and Reliable**
- **Wide Application Range:** They can be used in a variety of liquids
- **Low Maintenance:** minimal maintenance.
- **Cost-Effective**

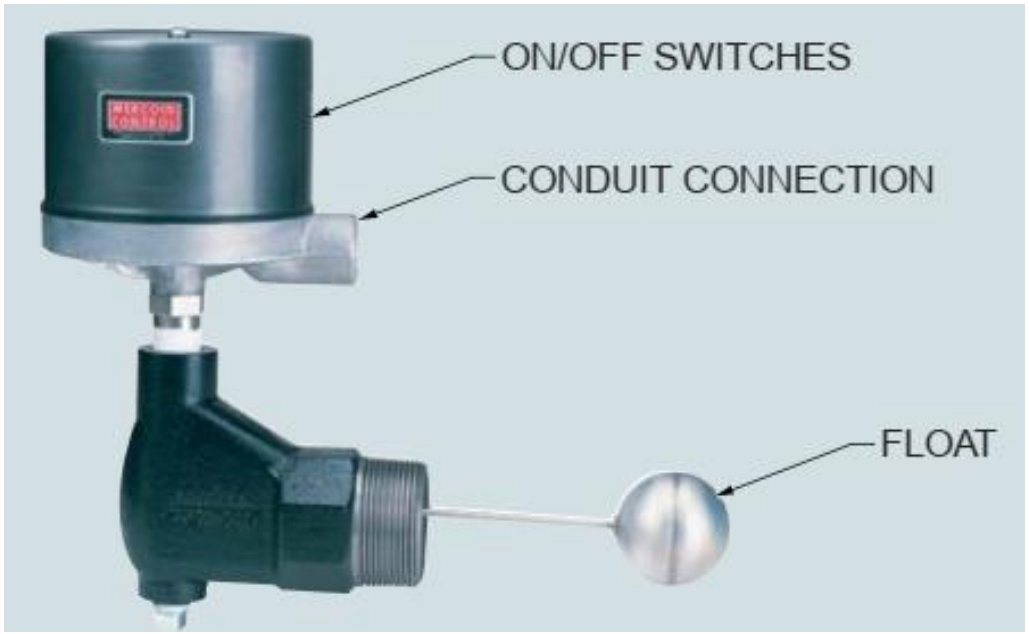
## Desadvantages:

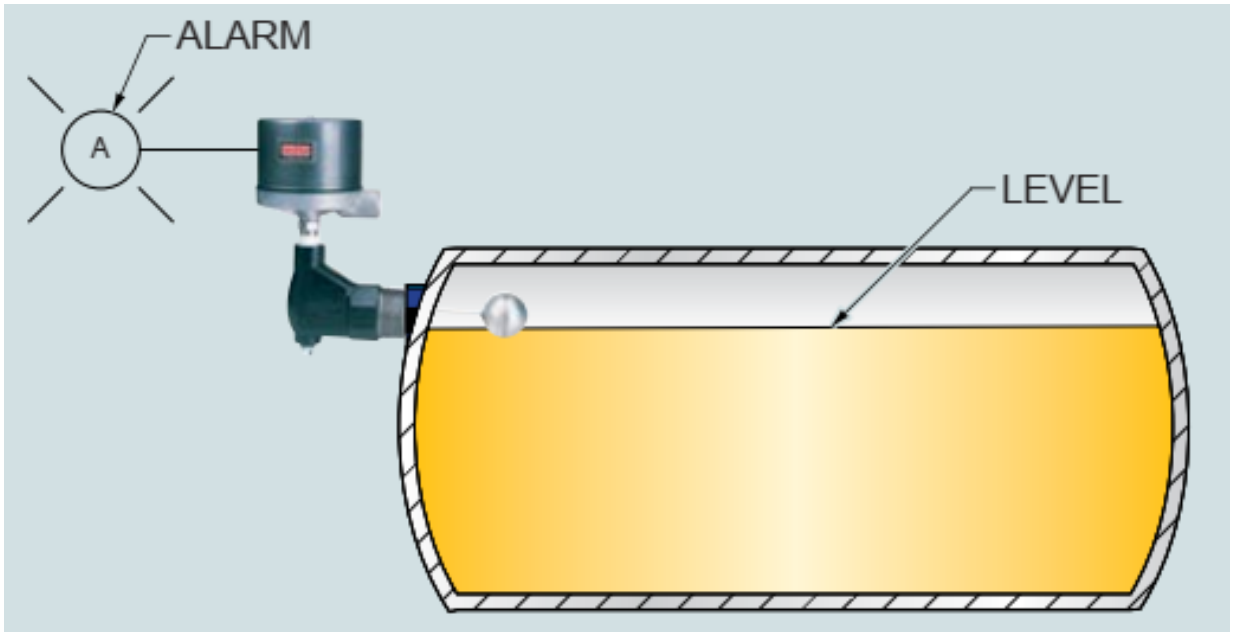
- **Sensitivity to Temperature and Pressure Changes**
- **Not Suitable for Certain Liquids:** Very thick or slurry-like liquids.
- **Limited Measurement Range:** They may not be effective for very tall tanks or those with high pressure.

# *FLOATS AND DISPLACERS*

# FLOATS

A ***float*** is a point level measuring instrument consisting of a hollow ball that floats on top of a liquid in a tank and is attached to the instrument.



LiquiLevel

CR system

Tank level indicator


Video Link: https://youtu.be/j06h8Dfia7c

# FLOATS

## Advantages / desadvantages

## Advantages:

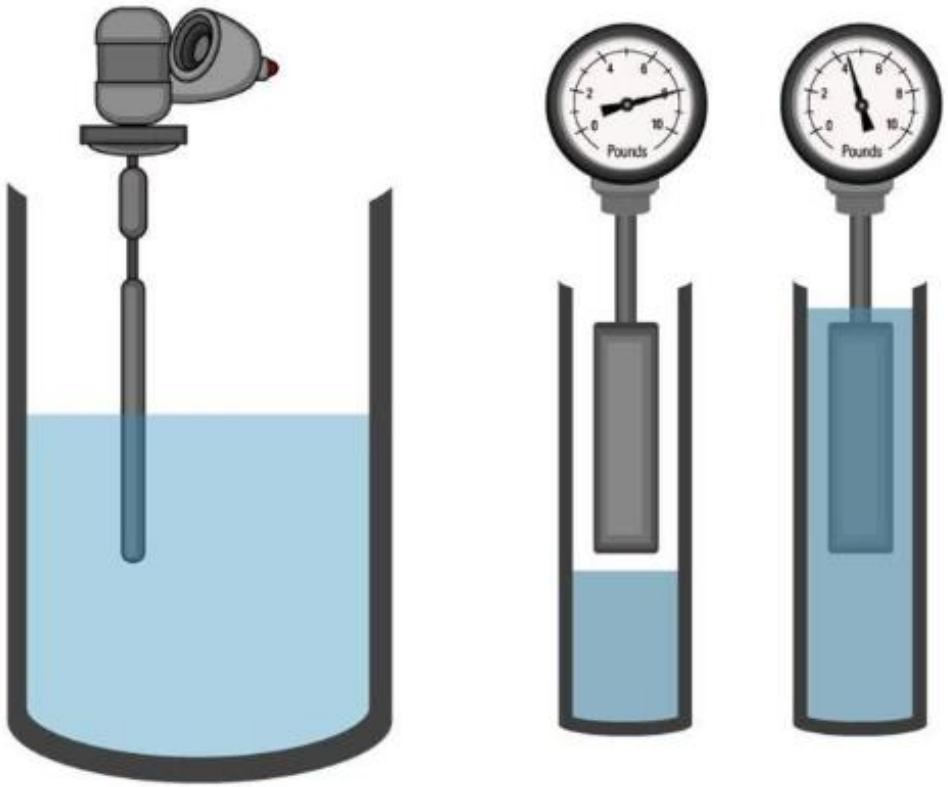
- **Simplicity :** Float level measurement systems are generally simple in design, making them easy to install and maintain
- **Cost-Effective**
- **Versatility:** Float devices can be used in a wide range of liquids, including corrosive and dirty fluids
- **Direct Measurement:** Float systems provide a direct physical measurement of the liquid level.

## Desadvantages:

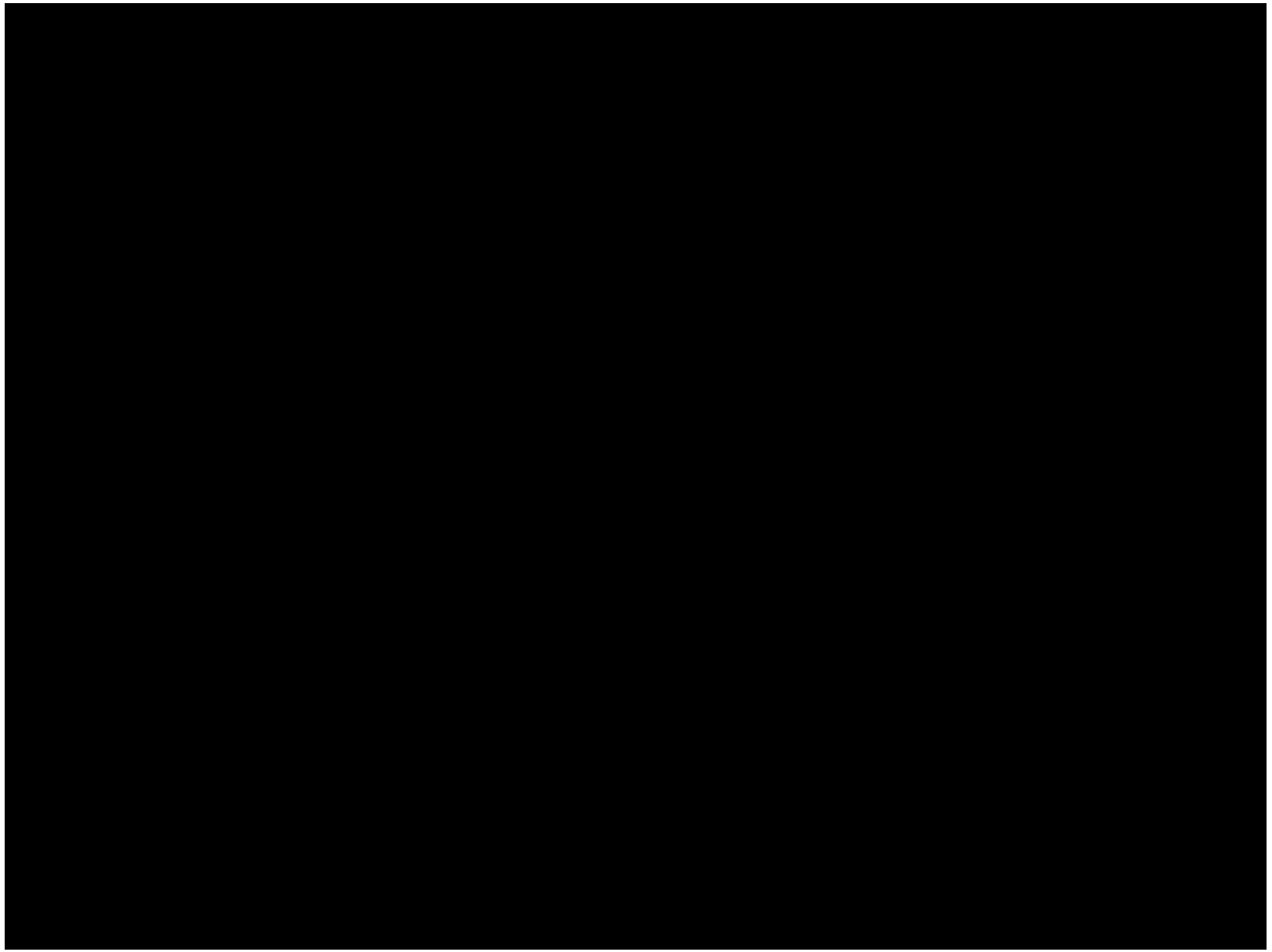
- **Limited by Physical Conditions:** Float systems might not function properly in conditions with high pressure, extreme temperatures.
- **Accuracy Issues:** These systems generally offer lower accuracy compared to more advanced technologies.
- **Maintenance Requirements:** Floats can become stuck or damaged, particularly in dirty or viscous fluids.

# Displacers

**Displacer:** A liquid level measuring instrument consisting of a floating cylindrical object, heavier than the liquid, that is immersed in the liquid and connected to a spring or torsion device that measures the buoyancy of the cylinder.



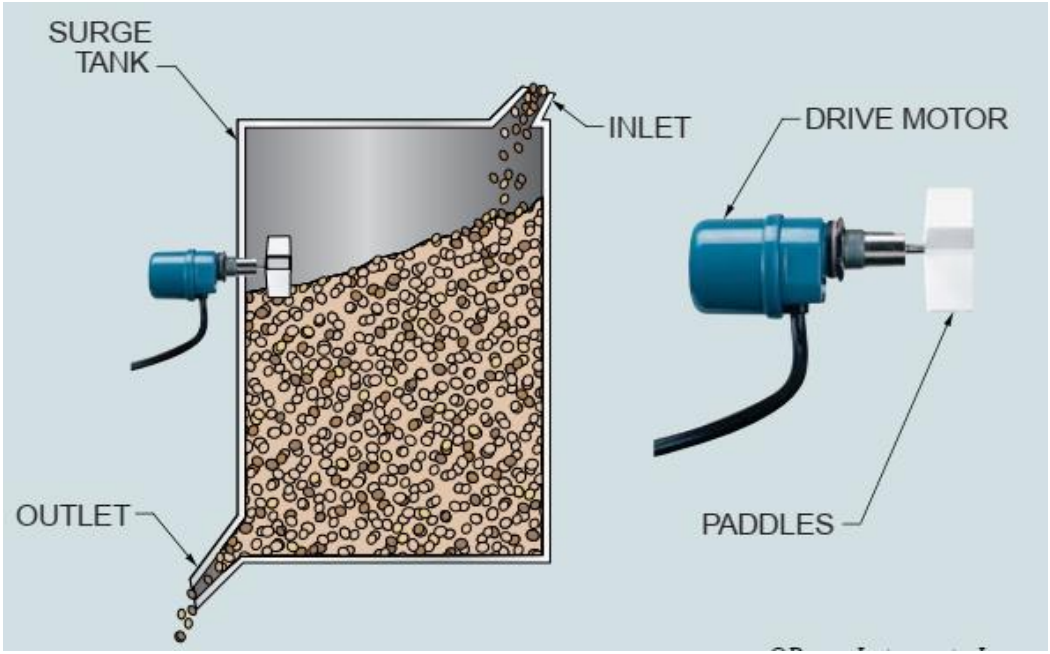
# Float Vs Displacer



Video Link: https://youtu.be/zgvhc9grwsQ

# Rotary Paddle Type Level Switch

- A *Rotary Paddle Type Level Switch* is a point level measuring device consisting of a drive motor and a rotating paddle wheel mounted inside a tank.
- As the level in the tank rises and touches the paddle wheel, the torque required to turn the paddle wheel increases.
- The increased torque activates a switch that can be used to stop or start equipment or signal an alarm.




Video Link: https://youtu.be/i5S9uD6YLD0

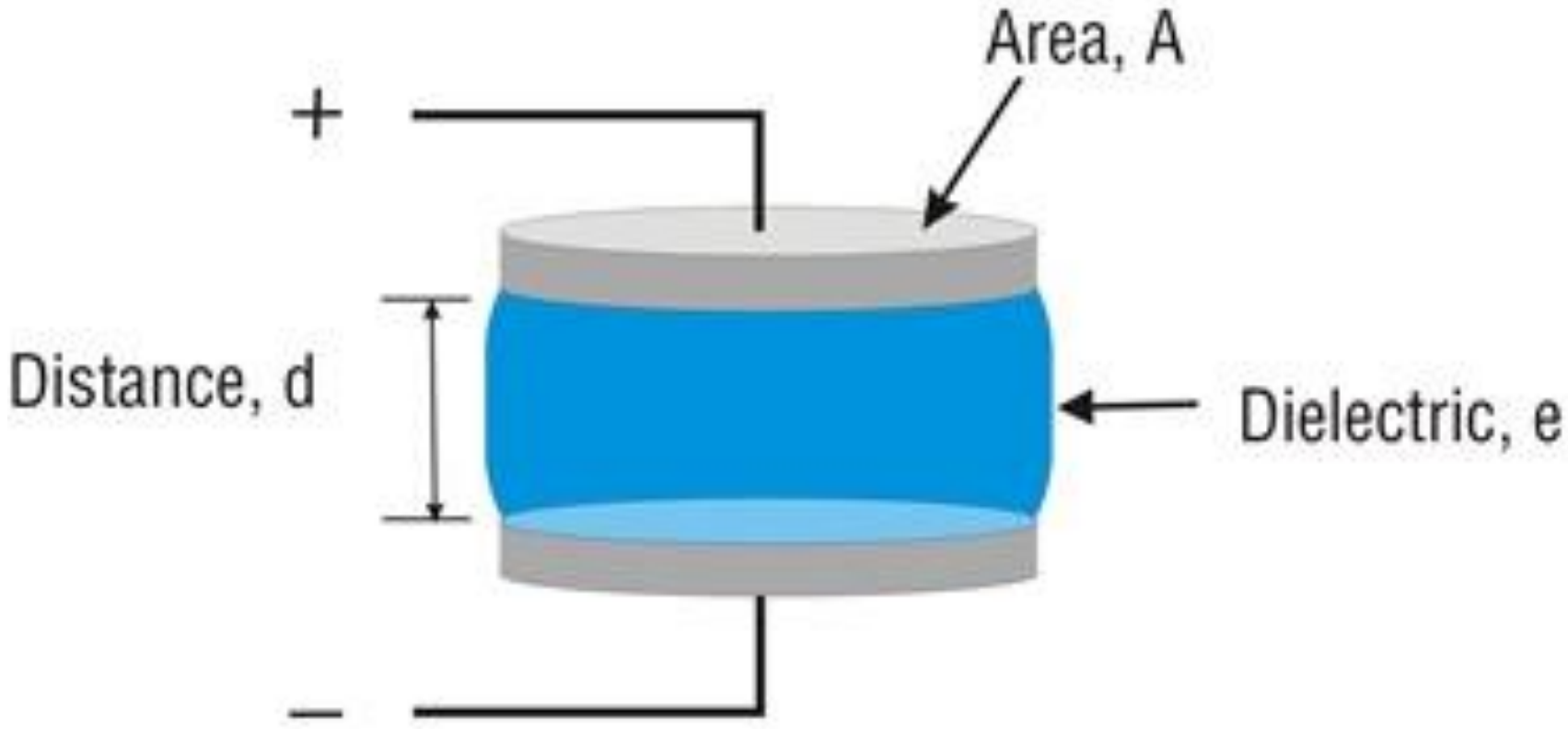
# Electrical Level Instruments

- CAPACITANCE SENSORS
- CONDUCTIVITY AND INDUCTIVE PROBES

# *Capacitance*

- ***Capacitance*** is the ability of an electrical device to store charge as the result of the separation of charge.
- ***Admittance*** is the ability of a circuit to conduct alternating current and is the reciprocal of impedance. A *capacitor* is an electrical device that stores electrical energy by means of an electrostatic fi eld.
- **A *dielectric*** is the insulating material between the conductors of a capacitor.

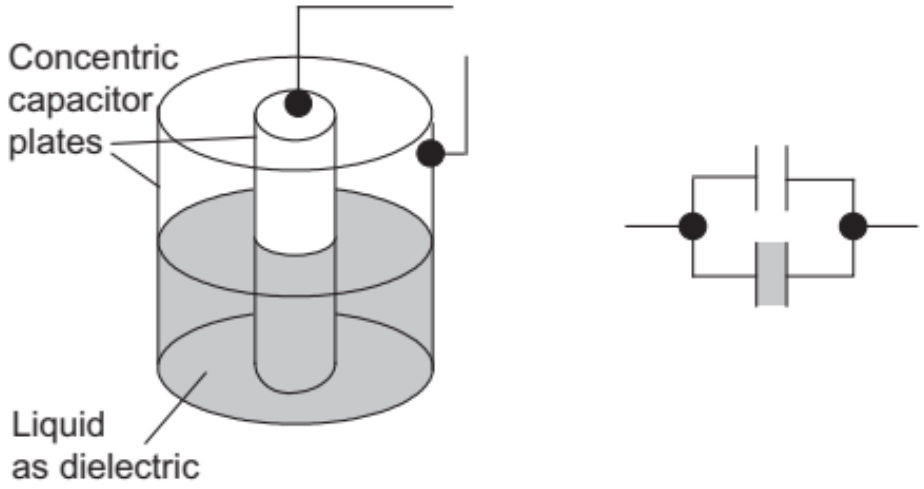
# Capacitance




Capacitance, C = (A *e) /d

# Capacitance Level Measurement

- *A common form of **capacitive level gauge** consists of two concentric conducting cylinders, or a circular rod inside a cylinder, acting as capacitor plates with the liquid between them acting as the dielectric of a capacitor.*
- The arrangement consists essentially of two capacitors in parallel, one formed between the plates inside the liquid and the other from that part of the plates in the air above the liquid.
- A change in the liquid level changes the total capacitance of the arrangement.

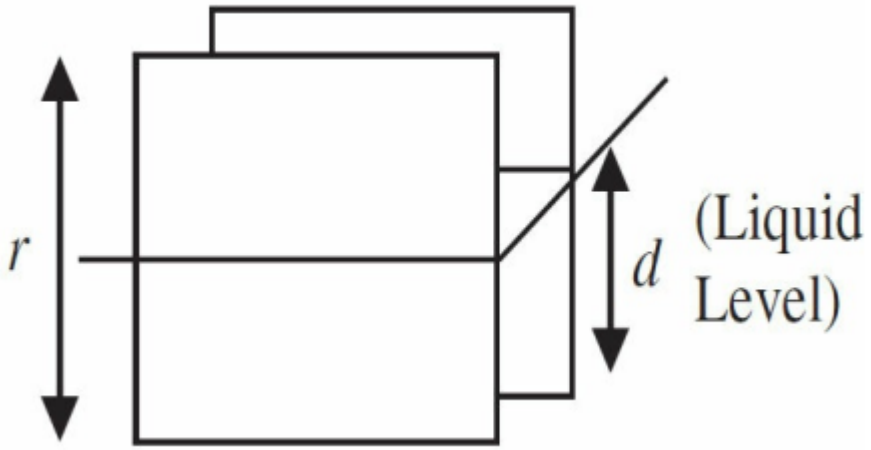


# Capacitance Level Measurement

The capacitance ($C_d$) is given by

$$C_d = C_a \mu \frac{d}{r} + C_a$$

where $Ca$ = capacitance with no liquid
$\mu$ = dielectric constant of the liquid between the plates
$r$ = height of the plates
$d$ = depth or level of the liquid between the plates




$$d = \frac{C_d + C_a}{\mu C_a} r$$

The capacitance can be measured using a capacitance bridge circuit.

# Capacitance Level Measurement

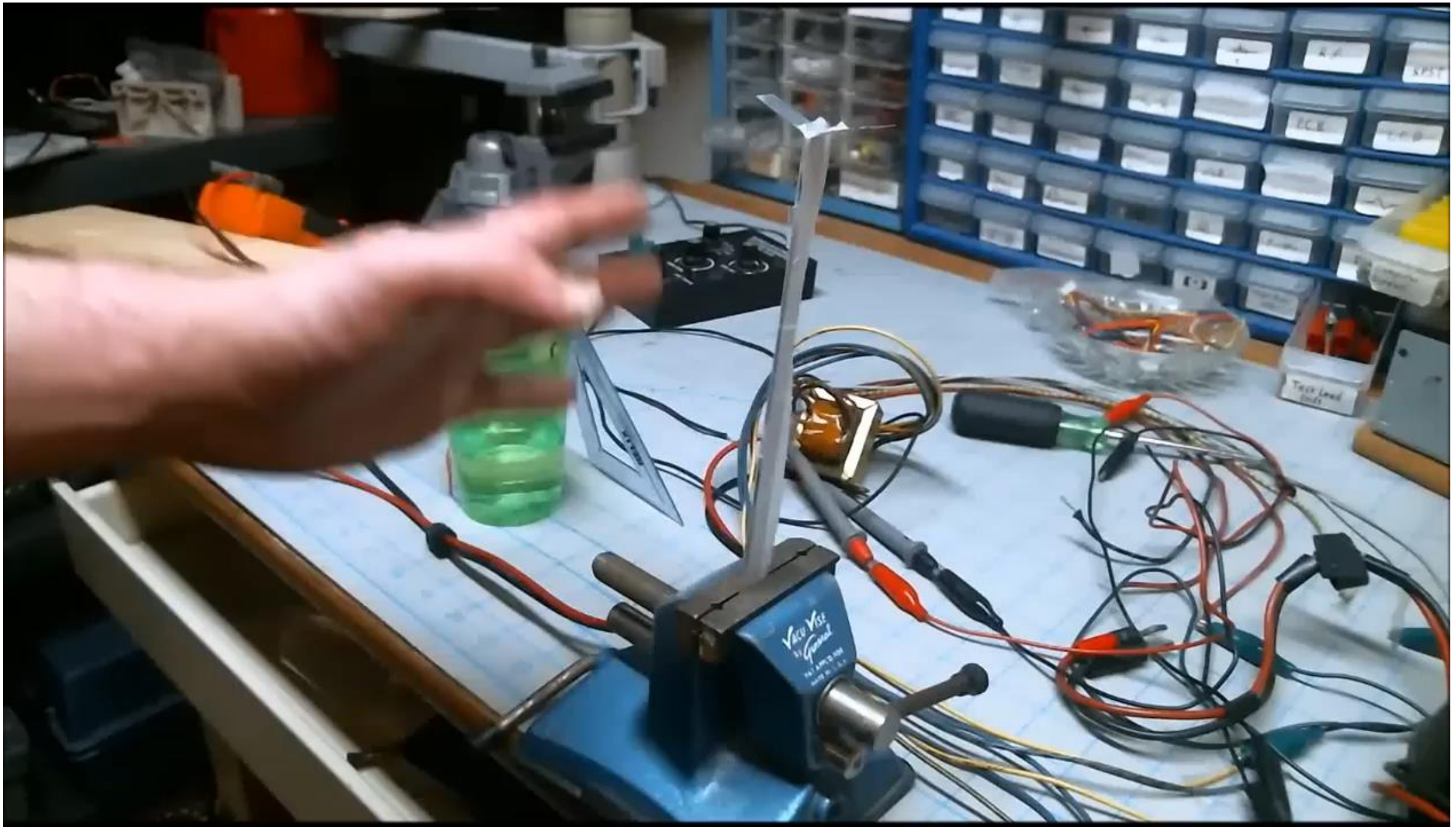
## Dielectric Comparison

| Material | Dielectric Constant* |
|---|---|
| Vacuum | 1 |
| Acetone | 21 |
| Ammonia (-27°F) | 22 |
| Calcium Carbonate | 9.1 |
| Ethanol | 24 |
| Freon 12 | 2.4 |
| Kerosene | 1.8 |
| Methanol | 33 |
| Naphthalene | 2.5 |
| Sand | 3.5 |
| Sugar | 3.0 |
| Toluene | 2.4 |
| Water | 80 |
| Water (212°F) | 48 |

*at 68°F unless noted

Dielectric Constant of Some Common Materials


Video Link: https://youtu.be/0du-QU1Q0T4




Video Link: https://youtu.be/nO_GJJ6HfTI

# Capacitance Level Measurement

## Advantages / desadvantages

### Advantages:

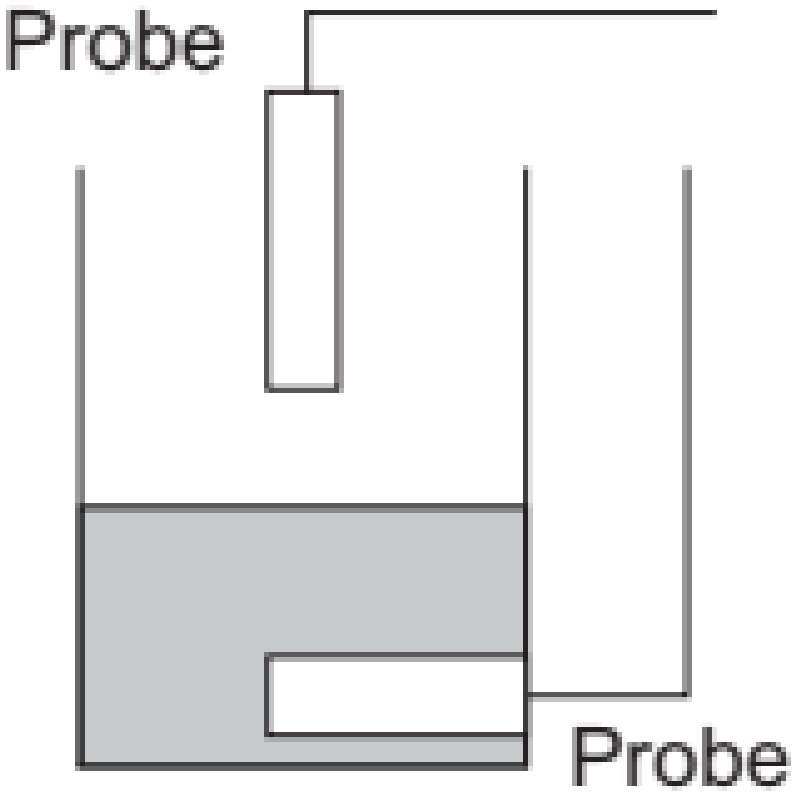
- Small
- Less expensive
- Invasive to the product
- Accurate
- Have no moving parts

### Desadvantages:

- Have to be calibrated
- Detect certain liquids and solids

# Electrical Conductivity Level Indicator

- A point level measuring system consisting of a circuit of two or more probes or electrodes, or an electrode and the vessel wall where the material in the vessel completes the circuit as the level rises in the vessel.
- Conductivity level probes can only be used with conductive liquids.



Video Link: https://youtu.be/c4NGp-QI4gw

# Electrical Conductivity Level Indicator

## Advantages / desadvantages

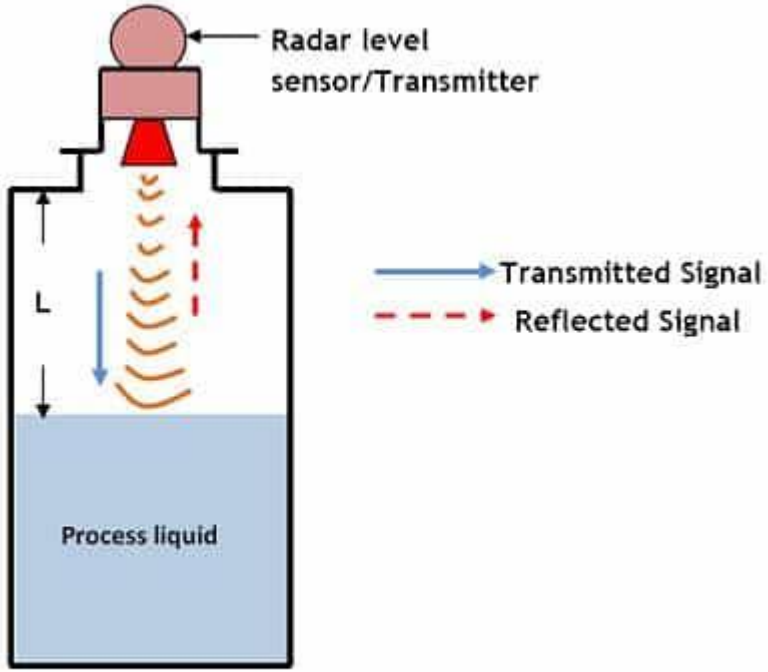
| Advantage | Disadvantage |
| --- | --- |
| No Moving Parts | |
| Low Cost | Only Conductive Liquids |
| Easy to Use | Probe will Erode |

# Ultrasonic, Radar and Laser level Instruments

- RADAR LEVEL SENSORS
- ULTRASONIC SENSORS

# RADAR LEVEL SENSORS

- **Most Used in Industry**
- **Application**: Widely used in both **liquid and solid level measurements**, especially in harsh environments.
- **Principle**: These sensors use microwaves (radio waves) to detect the level by measuring the time it takes for the emitted waves to return after reflecting off the surface.




# RADAR LEVEL SENSORS

## Advantages / desadvantages

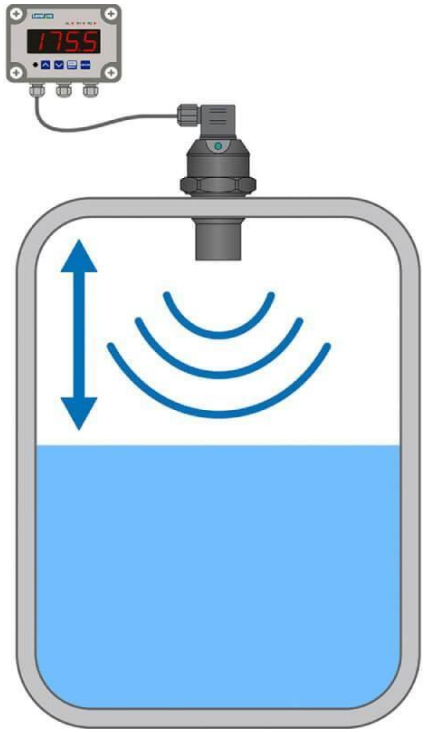
| Advantages | Disadvantages |
| --- | --- |
| Non-contact measurement | Higher initial cost |
| High accuracy (±1 mm) | Requires skilled installation and calibration |
| Wide measurement range (up to 80+ m) | Potential signal interference from obstructions |
| Resistant to dust, vapor, and foam | Not ideal for highly conductive surfaces |
| Low maintenance with no moving parts | Performance may be affected by dense foam |

# ULTRASONIC SENSORS

**Moderately Used in Industry**

•**Application**: Commonly used for **liquid level measurement** in open tanks, sumps, and wastewater applications.

•**Principle**: These sensors use sound waves to determine the distance between the sensor and the surface of the liquid. The time delay between transmission and reception of sound waves is used to calculate the level.



# ULTRASONIC SENSORS

## Advantages / desadvantages

| Advantages | Disadvantages |
| --- | --- |
| Non-contact measurement | Affected by temperature and pressure changes |
| Cost-effective compared to radar | Limited range (up to 15-30 meters) |
| Easy to install and configure | Performance impacted by foam, vapor, and turbulence |
| Suitable for clear liquids | Not suitable for solids or highly viscous materials |
| Low maintenance requirements | Accuracy can decrease in extreme environments |


Video Link: https://youtu.be/QterBt_Ht6k

# MCQ questions

# MCQ questions

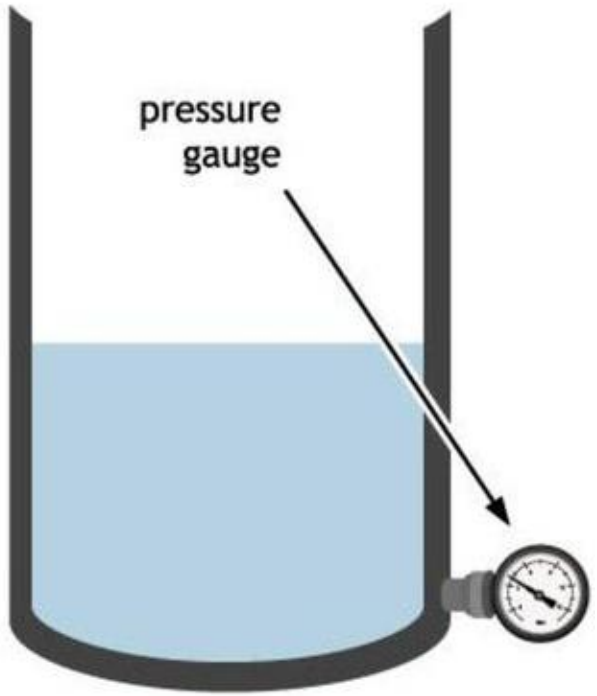
**1.** The level of  liquid under pressure can be determined using

a. bubbler system

b. differential pressure manometer

c. diaphragm box system

d. air-trap system




This device is commonly used to measure the level of a liquid by comparing the pressure exerted by the liquid column to a reference pressure, which allows for the calculation of the liquid level. The differential pressure manometer is a standard instrument for this purpose, particularly in industrial applications where precise liquid level measurements are necessary.

# MCQ questions

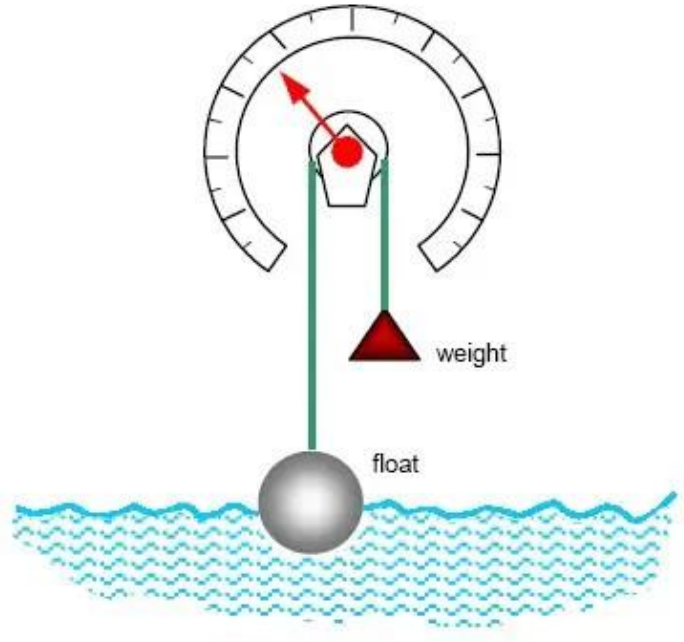
**2.** The most common application of float system is

a. To monitor the fuel tank level in motor vehicle

b. To monitor the flow of solid

c. To monitor the flow of liquid

d. All of these




Float systems are widely used in automotive fuel tanks to determine the amount of fuel remaining. A float, typically made of foam or hollow metal, is attached to an arm connected to a variable resistor or a similar sensor. As the fuel level changes, the float rises or falls, changing the resistance in the circuit, which can be translated into a fuel level indication on the vehicle's dashboard.

# MCQ questions

**3.** Hydrostatic Pressure type level indicator is a

a) Direct method

b) Indirect method

c) Both a) and b)

d) None of these

# MCQ questions

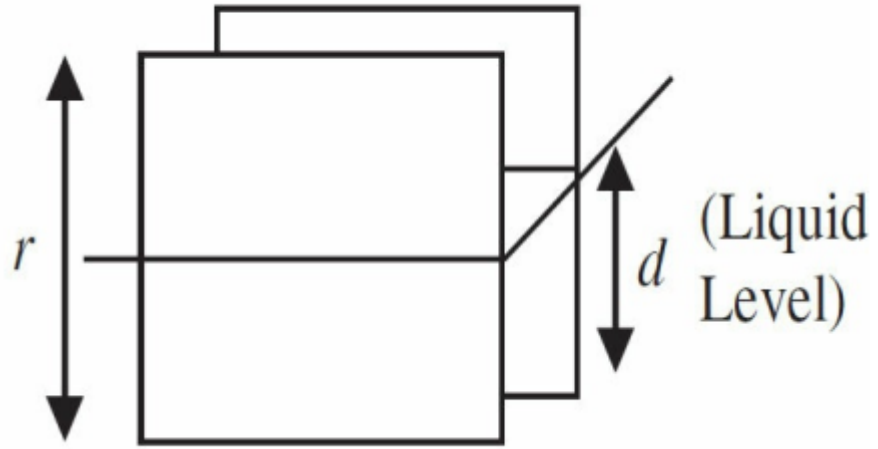
**4.** Capacitive devices are used for the level measurement of

a) Only liquid

b) Solid in powdered form

c) Both (a) and (b)

d) None of these




Capacitive level measurement devices can be used to measure the level of both liquids and solids in powdered or granulated form. They work by detecting the change in capacitance caused by the change in the level of the material within a container or space.

# MCQ questions

**5/** Suppose a storage vessel holds a liquid of **unpredictable** density. Identify which level measurement technology will not maintain accurate measurement of liquid height in the vessel as the liquid density changes:

a. Differential pressure manometer

b. Displacer

c. Float

Differential pressure manometers measure the pressure exerted by the column of liquid, which is directly dependent on the density of the liquid. If the liquid density changes, the pressure measurement will also change, even if the actual level of the liquid remains the same, leading to inaccurate level measurements. Displacers and floats respond to the buoyant force, which is a function of the volume of liquid displaced, and are less affected by density changes for level measurement.

# MCQ questions

**6.** Which of the following conversions take place in float element?

a) Level to force

b) Level to voltage

c) Level to displacement

d) None of the mentioned

A float element translates the level of the liquid into a mechanical displacement. As the level changes, the float moves up or down, and this movement is often mechanically linked to a device that can convert it into another form of signal, such as a change in resistance, current, or voltage for display or control purposes.

# MCQ questions

**7.** Which of the following level measurement technologies cannot be adapted to measure the level of solid (powder) in a vessel?

a) Displacer

b) Float

c) Rotary Paddle Type Level Switch

d) None of the above

This technology relies on buoyancy, which is not applicable for measuring the level of solids like powders in a vessel.

# MCQ questions

**8.** Which of the following represents pressure of a liquid column with constant density?

a) ρgh

b) ρh

c) ρg

d) None of the mentioned

This formula calculates the hydrostatic pressure exerted by a column of liquid due to its own weight.

# MCQ questions

**9.** For float element, uniformity of density is important.

a) True

b) False

# MCQ questions

**10.** Which of the following is direct method of level measurement?

1.Sight glass system

2.Hydrostatic Level Indicator

3.Capacitive Level Measurement

# MCQ questions

**11.**The inductive level transducers are mainly used for measurement of level of liquids which are:

1.non-conductive

2.conductive

3.Both (1) and (2)

4.viscous

# MCQ questions

**12.** What is the level of liquid in a vessel under a pressure of 43,17 kPa, if the liquid has a density of 0,881 g/mL?

a) 3 meters

b) 4 meters

c) 5 meters

d) 6 meters