Level Sensors and their types.

GROUP NO. 17

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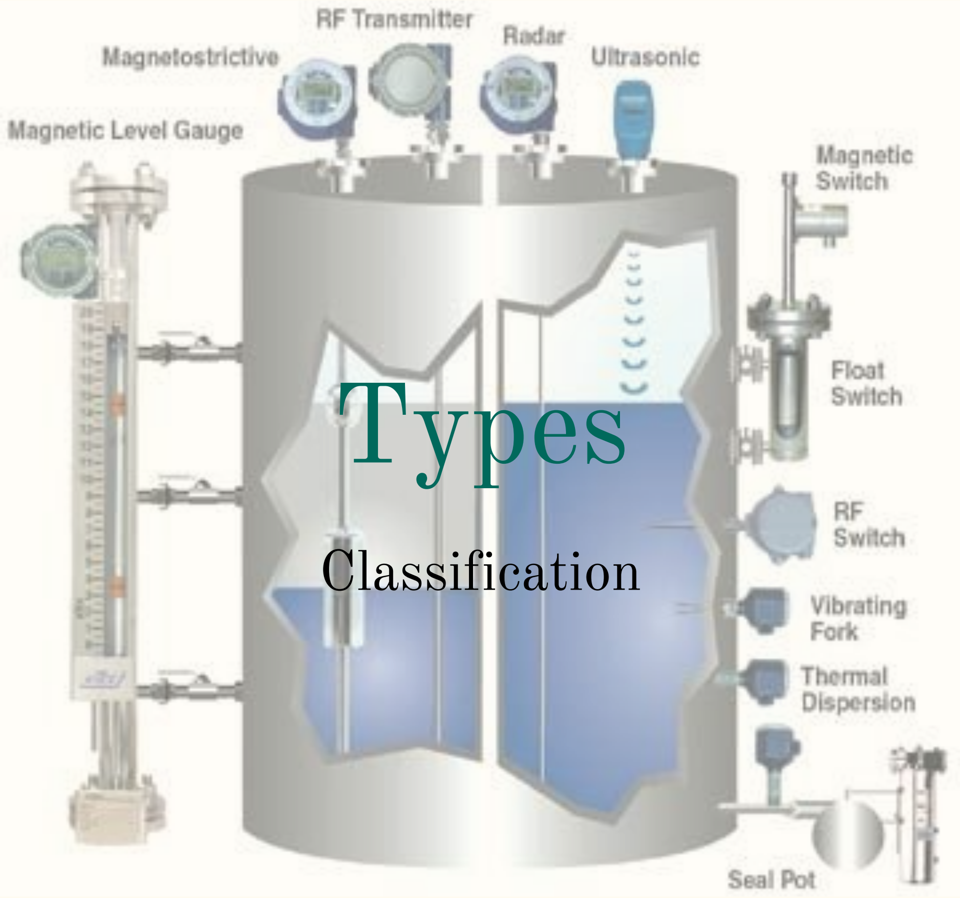
1. Types of Level Sensors.
2. The ranges of these sensors.
3. Applications of these.
4. Working Principles.

Level Sensors.

The detector is normally sensing the level of the interface between a liquid and a gas, a solid and a gas, a solid and a liquid, or possibly the interface between two liquids in an open or closed system.



Types

Classification

- Phase of Material.
- Nature of Measurement.
- Type of Measurement.
- Special Applications.

Phase of Materials

- The phase of materials generally decides the type of principle involved for the measurement.
- Solid state , Liquids, Fluid , Slurry , Granular, Powdered, Corrosive materials etc.



Solid Level Detection

Point Level Detection

1. Vibrating
2. Rotating paddle
3. Capacitance
4. Mechanical Float

Continuous level detection

5. Microwave (radar)
6. Optical
7. Ultrasonic

Liquid Level Detection

Point Level Detection

1. Magnetic/Mechanical Float
2. Pneumatic
3. Conductive

Both point and continuous level

4. Ultrasonic
5. Capacitance
6. Optical

Continuous Level Detection

7. Magnetostrictive
8. Differential Pressure Sensor
9. Air Bubbler

Working Principles

Mode of Level Sensing

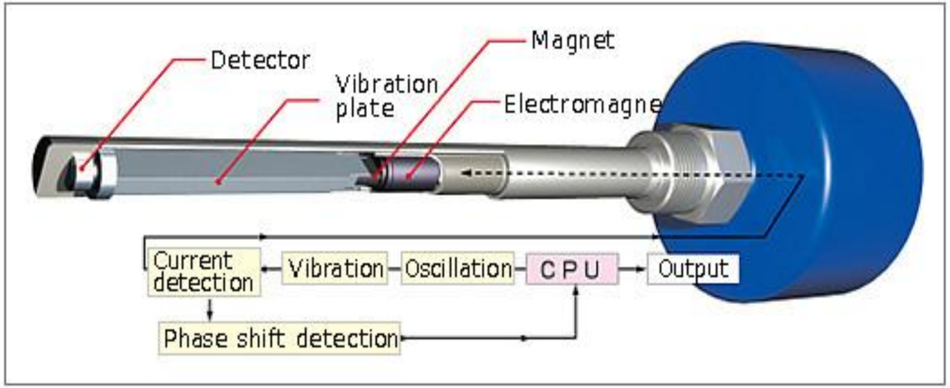
Sensing liquid levels fall into two categories; firstly, singlepoint sensing and secondly, continuous level monitoring.

1. In the case of singlepoint sensing the actual level of the material is detected when it reaches a predetermined level, so that the appropriate action can be taken to prevent overflowing or to refill the container.

2. Continuous level monitoring measures the level of the liquid on an uninterrupted basis. In this case the level of the material will be constantly monitored and hence, the volume can be calculated if the cross-sectional area of the container is known.

Vibrating Level Sensor

- A tuning fork is suspended inside the system which is made to vibrate at its natural frequency using a piezoelectric crystal system.
- When the solid touches the tuning fork the frequency of vibration of the tuning fork changes which in turn induces a change in the electric signal of the crystal and the presence of the material is sensed that way.
- Its not affected by dust, humidity, temperature or pressure.
- It’s used only for solids and is highly sensitive.



Rotating Paddle Level Sensor

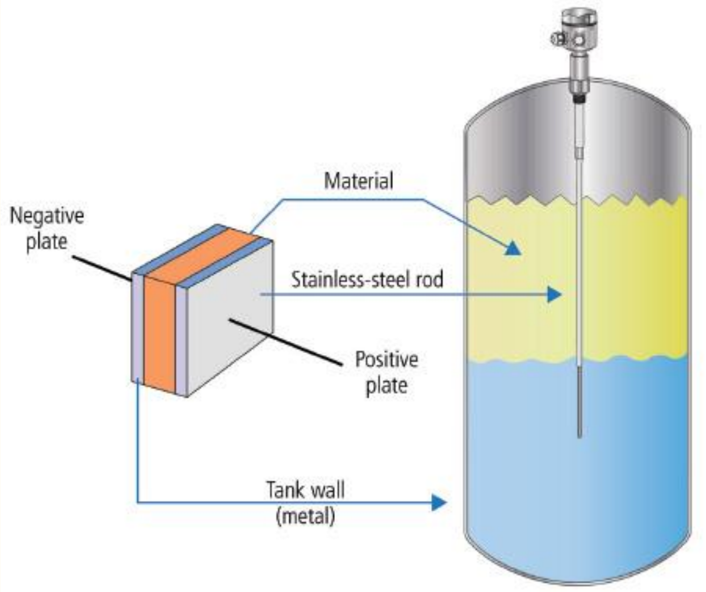
- It consists of a motor which rotates a paddle in absence of the solid.
- When the solid comes in contact with the sensor and prevents rotation of the paddle, the motor starts turning on its own axis and activates 2 micro switches.
- One micro switch activates a control circuit and the other one turns off the power to the motor. As the level of liquid goes down the power supply gets turned back again.
- They can be used in harsh environments and are highly reliable, durable and easy to use.

Mechanical and Magnetic Float Sensor

- It works on the principle of buoyancy. The float has a certain weight and a cable or chain tied at the bottom of it.
- When the float reaches to a certain level, the chain is pulled upwards from a sleeve which triggers the control circuit to regulate the flow of the substance.
- In case of magnetic float a magnet inside the float activates a reed switch(electronic switch sensing change in magnetic field) which again causes the flow regulation.
- Its used for point level detection only and liquids with high sp. gravity or viscosity can’t be measured.

Capacitance Level Sensor

- A probe is inserted inside the vessel and the capacitance between the probe and vessel walls is measured . The liquid/solid inside the vessel serves as a dielectric between two plates and the capacitance gets changed depending upon the level of material filled inside the tank.
- This type of sensor can be used when the dielectric constant of the material is known and is high enough to be detected.
- It is highly suitable in case of corrosive liquids due to no moving parts.
- But conditions like humidity, temperature etc. can change the dielectric constant of the medium and need to be controlled.



Capacitive

Capacitive probes can be used in nonconductive liquids and free flowing solids
for level measurement. Many materials, when placed between the plates of a capacitor, increase the capacitance by a factor m called the dielectric constant of the material. For instance, air has a dielectric constant of 1 and water 80. Figure 6.1*b* shows two capacitor plates partially immersed in a nonconductive liquid.

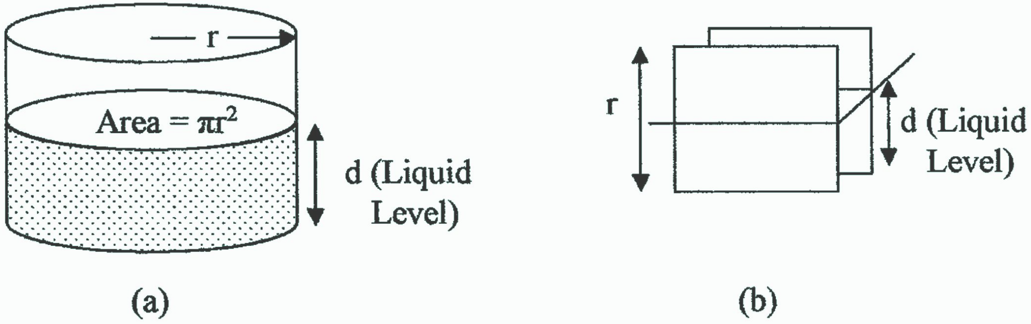


Figure 6.1 Shows the relation between (*a*) volume of liquid and the cross- sectional area and the liquid depth and (*b*) liquid level, plate capacitance, and a known dielectric constant in a nonconducting liquid.

liquid. The capacitance (Cd) is given by

$$Cd = Ca\mu\frac{d}{r} + Ca \tag{6.6}$$

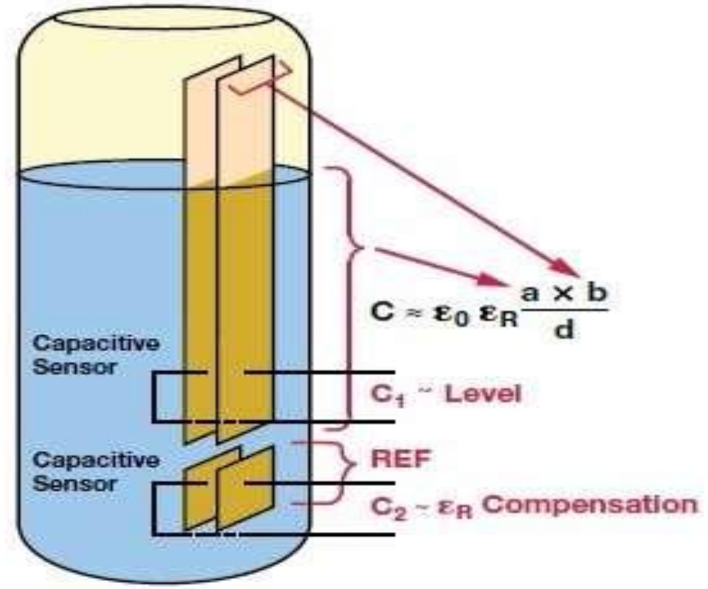
where Ca = capacitance with no liquid
μ = dielectric constant of the liquid between the plates
r = height of the plates
d = depth or level of the liquid between the plates

The dielectric constants of some common liquids are given in Table 6.1; there are large variations in dielectric constant with temperature so that temperature correction may be needed. In Eq. (6.6) the liquid level is given by

$$d = \frac{(Cd - Ca)}{\mu Ca} r \tag{6.7}$$

Capacitance Level Sensor

- This is a second type of capacitive sensor in which 2 plates are put inside the vessel and capacitance is calculated between them.
- The mathematical relation between capacitance and dielectric constant is shown in the picture where the product of relative permittivity and permittivity of vacuum gives us the dielectric constant (K).



Capacitive Level Sensing

Differential Pressure Principle

Level Formulas

Pressure is often used as an indirect method of measuring liquid levels.

Pressure increases as the depth increases in a fluid.

The pressure is given by

$\Delta p = g \, \Delta h$

where Δp = change in pressure

g = specific weight

Δh = depth

Note the units must be consistent, i.e., pounds and feet, or newtons and meters.

Buoyancy is an indirect method used to measure liquid levels. The level is determined using the buoyancy of an object partially immersed in a liquid.

The buoyancy B or upward force on a body in a liquid can be calculated from the equation

$B = g \times \text{area} \times d$ (6.2)

where area is the cross-sectional area of the object and d is the immersed depth of the object.

The liquid level is then calculated from the weight of a body in a liquid W_L,

which is equal to its weight in air ($W_A - B$), from which we get

The weight of a container can be used to calculate the level of the material

in the container. The volume V of the material in the container is given by

The weight of a container can be used to calculate the level of the material

in the container. The volume V of the material in the container is given by

$V = \text{area} \times \text{depth} = pr_2 \times d$

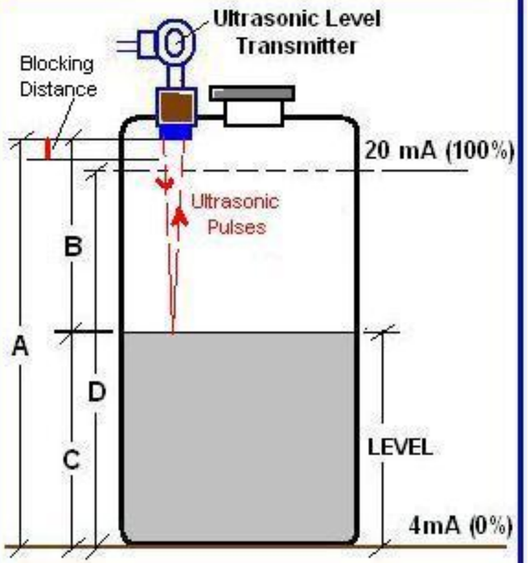
where r is the radius of the container and d is the depth of the material.

The weight of material W in a container is given by

$W = gV$

Ultrasonic Level Sensor

The principle of operation of the ultrasonic sensor system is to use the ultrasonic pulses which are transmitted by the transducer to the surface to be monitored and are reflected back to the transducer, the time period between transmission and reception of the sound pulses is directly proportional to the distance between the transducer and surface.



A= Empty Distance, B=Distance of Sensor from Fluid Level
C= Fluid Level , D= Measurement Span

Ultrasonic Level Measurement

Fig - 1

A micro-controller computes this time period for all echoes received and analyses them to determine which is the correct reflection from the material surface, it uses this data as the basis for giving control outputs and displays in usable engineering units.

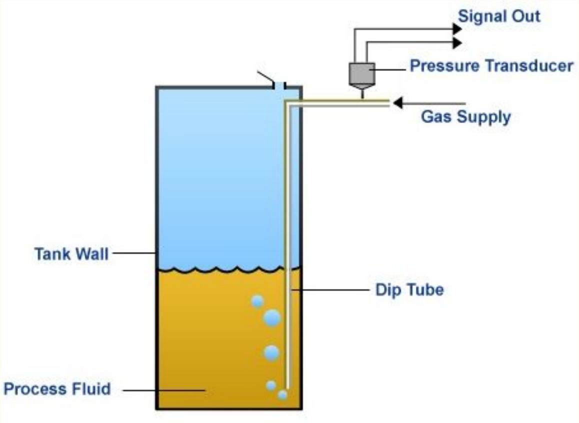
The distance D is determined from the velocity of sound and the time period t by the formula:

D= .t /2

Pneumatic

When the sensor is connected to a detection pipe and mounted on a tank as shown in Fig 2, the pressure applied to the pipe end (P) is gained by $P = \gamma h$; The upward force applied to diaphragm is $P \times A$, where A is the pressure receiving area of diaphragm. The microswitch activates when the following condition is met:

$\gamma hA > F + f$, where F is the force required to activate the switch, and f the total weight of diaphragm, pressure receiver and plunger.



They have a source of compressed air, an air flow restrictor, sensing tube, and pressure transmitter.

The device works with a small amount of air metered into a dip tube in the tank.

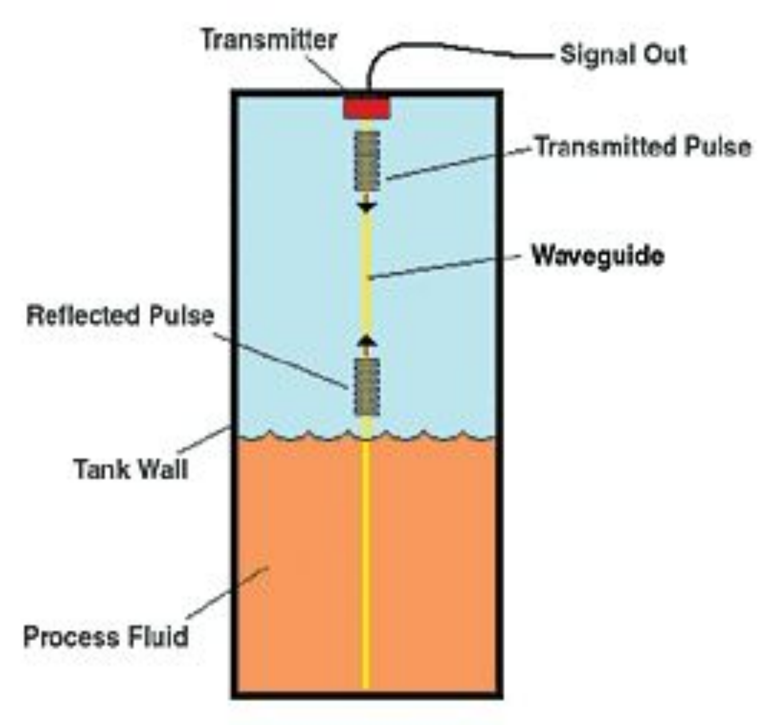
A pressure transducer monitors the air pressure in the tube to make sure the pressure in the tube equals the pressure at the bottom of the tank.

The liquid's level is determined by dividing the pressure inside the tube by the liquid's density.

The system is able to measure the liquid's level as directly proportional to the pressure as long as the material's density remains constant.

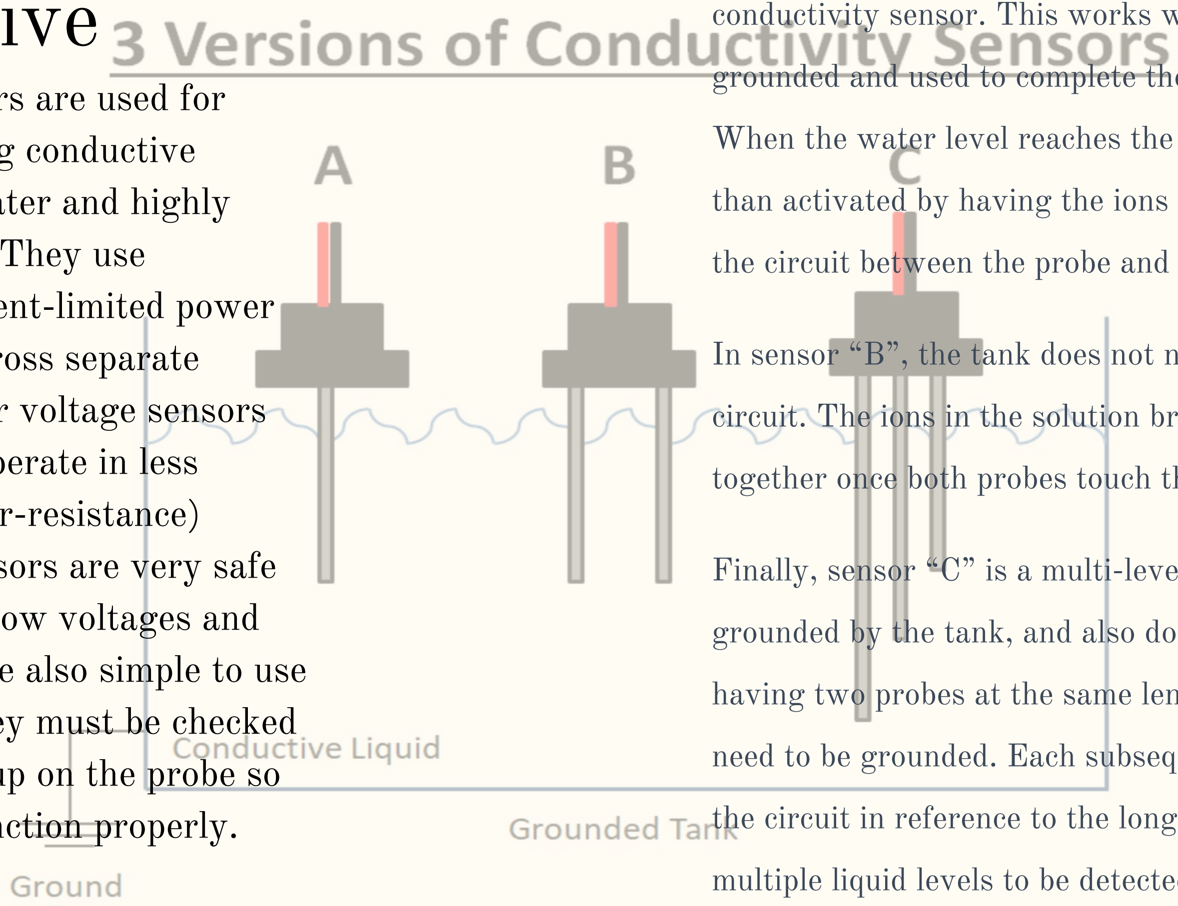
Microwave Level Sensor

- In this type, an electromagnetic pulse is sent from a transmitter located on the top of the vessel, which travels through the liquid, gets reflected back to the transmitter.
- Using the Doppler effect for microwaves and calculating the time taken for the pulse to come back, the level of the liquid is measured.
- As contact is not required for this sensor and the range is also quite high, it is highly suitable for corrosive liquids and dark/dusty or harsh environments as microwaves don’t need a medium to travel.



Conductive

Conductive sensors are used for point-level sensing conductive liquids such as water and highly corrosive liquids. They use low-voltage, current-limited power source applied across separate electrodes. Higher voltage sensors are designed to operate in less conductive (higher-resistance) media. These sensors are very safe due to the use of low voltages and currents. They are also simple to use and install but they must be checked for medium buildup on the probe so it continues to function properly.



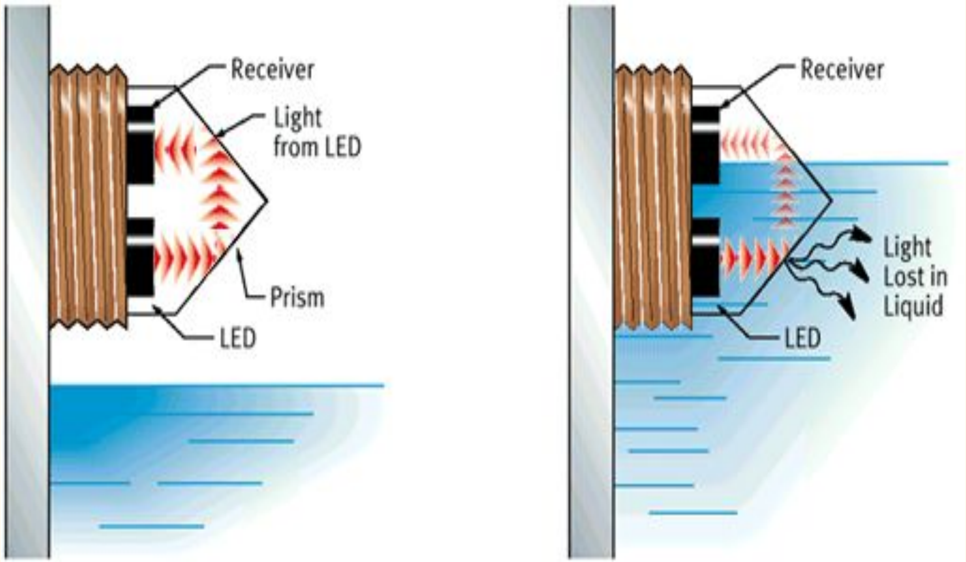
The diagram below shows three different variations of the conductivity sensor. Sensor “A” is a single level conductivity sensor. This works with a metal tank that is grounded and used to complete the circuit of the sensor. When the water level reaches the probe, the sensor is than activated by having the ions in the solution complete the circuit between the probe and the tank.

In sensor “B”, the tank does not need to complete the circuit. The ions in the solution bridge the two probes together once both probes touch the liquid.

Finally, sensor “C” is a multi-level sensor which can be grounded by the tank, and also doesn’t need to be. By having two probes at the same length, the tank will not need to be grounded. Each subsequent probe will complete the circuit in reference to the longest probe, allowing for multiple liquid levels to be detected on a single sensor.

Optical Sensor

- It consists of an Infrared LED and a receiver. The light emitted by the LED reflects back from two 45 degree inclined mirrors and is sent to the receiver.
- When the fluid comes in contact with the sensor, some of the light dissipates in the liquid causing a change in intensity of light reaching the receiver.
- A phototransistor senses this change in intensity and sends an electrical signal to the control circuit.
- It is very useful for high temperature environments, harsh conditions.



Magnetostrictive Level Probe Sensors

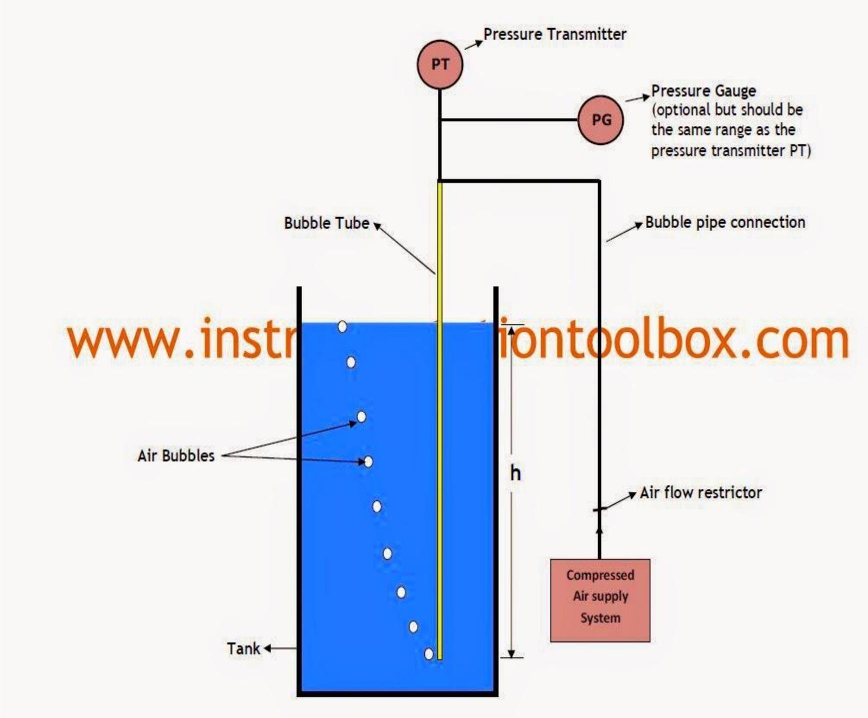
- This continuous liquid level solution is able to determine level within only a few millimeters.
- It works by using a ferromagnetic metal, which aligns itself with magnetic fields at the molecular level. By creating two competing magnetic fields, the magnetostrictive level sensor is able to generate a signal denoting the liquid level.
- **Working Principle:** Inside the probe tube there is a rigid wire made of magnetostrictive material. The sensor circuitry emits pulses of current through the wire, generating a circular magnetic field. The level transmitter is a magnet, which is integrated into the float. Its magnetic field magnetizes the wire axially. Since the two magnetic fields are superimposed, around the float magnet a torsion wave is generated which runs in both directions along the wire. One wave runs directly to the probe head while the other is reflected at the bottom of the probe tube. The time is measured between emission of the current pulse and arrival of the wave at the probe head. The position of the float is determined on the basis of the transit times.

Bubbler Tube System for level measurement

- In a Bubbler level gauge, a bubbler tube is used to measure and indicate level.
- The level bubbler functions by forcing a gas (compressed air) at a near constant flow rate out the bottom of an open tube (dip tube) submerged in liquid. The back pressure in this tube is measured. With the liquid's density known, the level can be calculated using the back pressure and density. A pressure transmitter converts the back pressure to provide a 4-20ma output to a controller, which calculates the liquid's level.
- In more detail, a compressed air source is supplied to a filter/regulator. The Filter/Regulator provides a filtered and reduced supply of air pressure to the constant flow controller. The controller maintains a near constant volumetric rate of flow set to 1SCFH, regardless of various process or supply pressures. This constant flow of compressed air flows through the flow controller through a rotameter (that displays the flow rate) to the dip tube.
- The hydrostatic back pressure of the dip tube is measured by the gauge pressure transmitter, which sends a 4-20ma signal. This signal can used to control a pump, sound alarms or can be sent to a programmable logic controller for further use in controlling functions of a process.

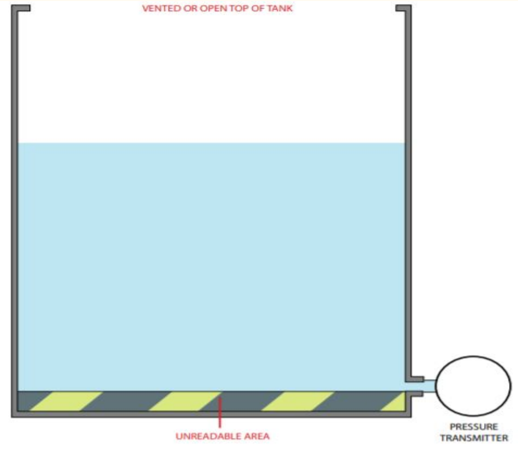
BUBBLER APPLICATIONS:

- The level bubbler can be used to monitor in-take screens for debris and initiate an airburst backwash. This is done by placing a dip tube on each side of the screen and when the pressure differential between the two reaches a certain point, a backwash can be initiated to clean the screens. This system is a called a Differential Level Bubbler.
- The level bubbler can be used to measure the level of the wet well to control the intake pumps.
- The level bubbler can be used to measure levels in all types of liquids such as sanitary waste stations.
- The level bubbler can be a retrofit replacement for ultrasonic level transmitters.

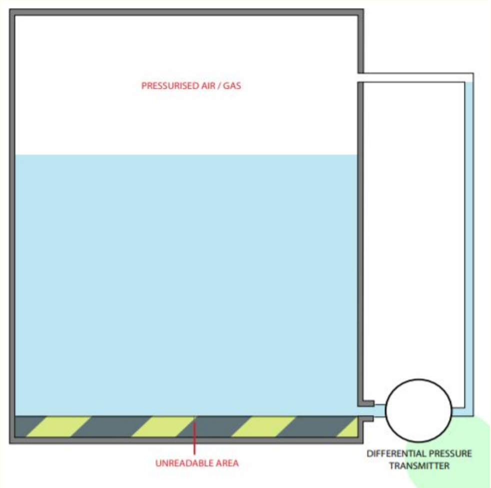


Hydrostatic Level Sensor

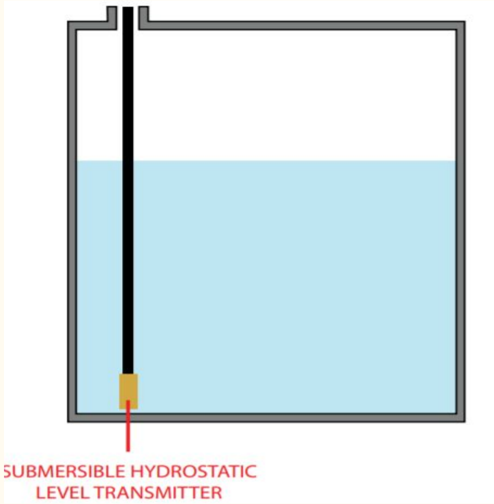
- A hydrostatic level sensor is a submersible pressure transmitter that has a pressure diaphragm where the inner side of the diaphragm is vented to atmospheric pressure through a vent tube in the cable and the outer side is in contact with the liquid and measuring the static pressure of the liquid column above the transmitter.
- This static pressure is basically caused by the weight of the fluid on top of the transmitter and is used to calculate the level of the liquid.
- **Side/Bottom Mounted for Liquids in Unpressurised Vessels:**You attach a pressure transmitter to the lowest point on your tank. The weight of the water above the tank creates a head pressure which is measured by the transmitter - this translates to an exact measurement of the liquid level.
- **Side/Bottom Mounted for Liquids in Pressurised Vessels:**using a differential pressure transmitter rather than a gauge pressure transmitter allows you to read the difference between tank and liquid pressure, giving you a extremely accurate indication.
- **Drop-In Sensing for Liquids:**Hydrostatic level sensing effectively ‘weighs’ the column of water directly above the sensor.By using a drop-in sensor that dangles from the top of the tank from a waterproof electrical cable, you can sense depth in vessels such as pits and rivers, or any other body of liquid that can not be easily accessed from the sides.



Side/Bottom Mounted for Liquids in Unpressurised Vessels



Side/Bottom Mounted for Liquids in Pressurised Vessels



Drop-In Sensing for Liquids

Comparison Table for Liquid Level Sensors

Table 4: Orientation Table for Selecting Level Sensors

TDR = Time Domain Reflectometry; PDS = Phase Difference Sensors; AS = in % of actual span; E = Excellent; FS = in % of full scale; F = Fair; G = Good; L = Limited; P = Poor; UL = Unlimite

TYPE	MAX. TEMP. (°F)	AVAILABLE AS NONCONTACT	INACCURACY (1 in. = 25.4 mm)	APPLICATIONS								LIMITATIONS
				LIQUIDS					SOLIDS			
				CLEAN	VISCOUS	SLURRY/SLUDGE	INTERFACE	FOAM	POWDER	CHUNKY	STICKY	
Air Bubblers	UL		1-2% FS	G	F	P	F					Introduces foreign substance into process; high maintenance
Capacitance	2,000		1-2% FS	G	F-G	F	G-L	P	F	F	P	Interface between conductive layers and detection of foam is a problem
Conductivity Switch	1,800		⅛ in	F	P	F	L	L	L	L	L	Can detect interface only between conductive and nonconductive liquids. Field effect design for solids
Diaphragm	350		0.5% FS	G	F	F			F	F	P	Switches only for solid service
Differential Pressure	1,200		0.1% AS	E	G-E	G	P					Only extended diaphragm seals or repeaters can eliminate plugging. Purging and sealing legs are also used
Displacer	850		0.5% FS	E	P	P	F-G					Not recommended for sludge or slurry service
Float	500		1% FS	G	P	P	F					Moving parts limit most designs to clean service. Only preset density floats can follow interfaces
Laser	UL	X	0.5 in	L	G	G		F	F	F	F	Limited to cloudy liquids or bright solids i tanks with transparent vapor spaces
Level Gages	700		0.25 in	G	F	P	F					Glass is not allowed in some processes
Microwave Switches	400	X	0.5 in	G	G	F	G		G	G	F	Thick coating is a limitation
Optical Switches	260	X	0.25 in	G	F	E	F-G	F	F	P	F	Refraction-type for clean liquids only; reflection-type requires clean vapor space
Radar	450	X	0.12 in	G	G	F	P		P	F	P	Interference from coating, agitator blades, spray, or excessive turbulence
Radiation	UL	X	0.25 in	G	E	E	G	F	G	E	E	Requires NRC license
Resistance Tape	225		0.5 in	G	G	G						Limited to liquids under near-atmospheric pressure and temperature conditions
Rotating Paddle Switch	500		1 in						G	F	P	Limited to detection of dry, non-corrosive, low-pressure solids
Slip Tubes	200		0.5 in	F	P	P						An unsafe manual device
Tape-Type Level Sensors	300		0.1 in	E	F	P	G		G	F	F	Only the inductively coupled float is suite for interface measurement. Float hangup i a potential problem with most designs
Thermal	850		0.5 in	G	F	F	P	F				Foam and interface detectiom is limited by the thermal conductives involved
TDR/PDS	221		3 in	F	F	F			G	G	F	Limited performance on sticky process materials
Ultrasonic	300	X	1% FS	F-G	G	G	F-G	F	F	F	G	Presence of dust, foam, dew in vapor space; sloping or fluffy process material interferes with performance
Vibrating Switches	300		0.2 in	F	G	G	F		F	G	G	Excessive material buildup can prevent operation

Comparison Table for Solid Level Sensors

Sensor Type	Level Range Detected	Accuracy	Pressure Range (Bar)	Temperature ^{o}C
Plumb Bob	To 300m	±1 to 10cm	To 2	-40 to +400
Capacitance/RF Switches	Switch to 300m	±3 to 20mm	Vacuum to 1400*	-269 to +850
Capacitance/RF Continuous	To 45m	±0.5 to 2%	Vacuum to 1400	-269 to +850
Nuclear Radiation	Switch or 4.5m	±3 to 10mm or ±1-2%	External	-40 to +250 with cooling
Microwave Barrier	To 40m (diam.)	75mm	External	-30 to +60
Rotating Paddle	Switch to 8m	±3cm	Vacuum to 10	-50 to +650
Tilt Switches	Switch to 25m	Tilt variable	Atmosphere	To +500
Vibrating Element	Switch to 40m	±3 to 20mm	To 25	-20 to +135
Ultrasonic Switches	Switch to 7m	±0.5 to 5mm	To 380*	-210 to +230
Ultrasonic Continuous	To 60m	±0.1 to 1.5%	To 15*	-40 to +150
Radar Continuous	To 200m	±1mm	Vacuum to 64*	-162 to +250
Laser Continuous	To 150m	±2 to 50mm	*	-30 to +60
Guided Wave	To 60m	±0.25%	Vacuum to 14	-50 to +260
Diaphragm Switch	Switch	±2 to 15cm	ATM to 2	To +250
Resistance Tape	To 30m	±0.5cm	To 10	-30 to +110

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