Ultrasonic Level Sensors

Measuring principle

The level height is calculated from the time it takes for **ultrasonic** pulses to travel from the sensor to the surface of the medium and back. Chemical and physical properties of the medium do not influence the **measurement** result. Therefore, aggressive and abrasive, viscous and adhesive media can be measured without problems.

Operation mode

This **continuous level measurement** is based on the travel time of **ultrasonic pulses** to the surface of the medium and back.
When installing the sensor, the typical block distance has to be considered. Rough liquid surfaces and the changed angle during filling and emptying granulated solids influence the reflection of the ultrasonic pulses and may impact measurement

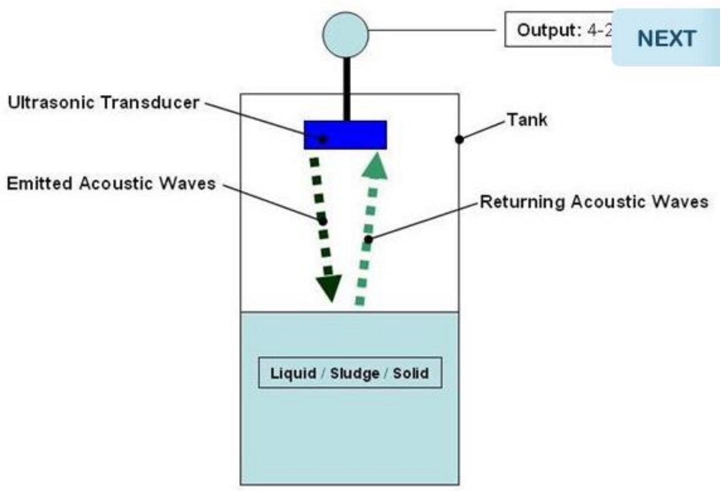
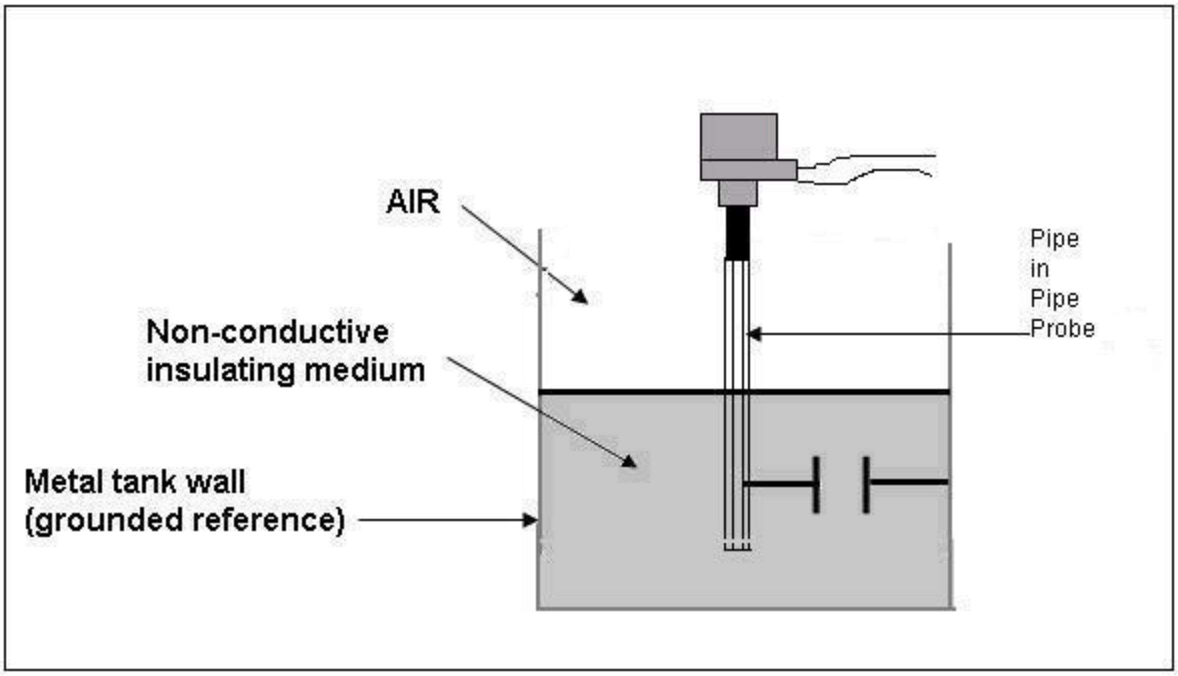


Fig.1.1 – Working of Ultrasonic Level Sensor

Capacitance Level Measurement:

Capacitive level transducer is an example of indirect measurement of level



Capacitance level sensors are used for wide variety of solids, aqueous and organic liquids, and slurries. The technique is frequently referred as **RF** as radio frequency signals applied to the capacitance circuit. The sensors can be designed to sense material with dielectric constants as low as 1.1 (coke and fly ash) and as high as 88 (water) or more. Sludges and slurries such as dehydrated cake and sewage slurry (dielectric constant approx. 50) and liquid chemicals such as quicklime (dielectric constant approx. 90) can also be sensed. **Dual-probe** capacitance level sensors can also be used to sense the interface between two immiscible liquids with substantially different dielectric constants.

Since capacitance level sensors are electronic devices, phase modulation and the use of higher frequencies makes the sensor suitable for applications in which dielectric constants are similar.

Working Principle:

The principle of capacitive level measurement is based on change of capacitance. An insulated electrode acts as one plate of capacitor and the tank wall (or reference electrode in a non-metallic vessel) acts as the other plate. The capacitance depends on the fluid level. An empty tank has a lower capacitance while a filled tank has a higher capacitance.

A simple capacitor consists of two electrode plate separated by a small thickness of an insulator such as solid, liquid, gas, or vacuum. This insulator is also called as dielectric.

Value of C depends on dielectric used, area of the plate and also distance between the plates.

$$C = E\,(K\,A/d)$$

Where:

C = capacitance in picofarads (pF)

E = a constant known as the absolute permittivity of free space

K = relative dielectric constant of the insulating material

A = effective area of the conductors

d = distance between the conductors

This change in capacitance can be measured using AC bridge.

Measurement:

Measurement is made by applying an RF signal between the conductive probe and the vessel wall.

The RF signal results in a very low current flow through the dielectric process material in the tank from the probe to the vessel wall. When the level in the tank drops, the dielectric constant drops causing a drop in the capacitance reading and a minute drop in current flow.

This change is detected by the level switch's internal circuitry and translated into a change in the relay state of the level switch in case of point level detection.

In the case of continuous level detectors, the output is not a relay state, but a scaled analog signal.

Level Measurement can be divided into three categories:

- Measurement of non-conductive material
- Measurement of conductive material
- Non-contact measurement

Non-conducting material:

For measuring level of non conducting liquids, bare probe arrangement is used as liquid resistance is sufficiently high to make it dielectric. Since the electrode and tank are fixed in place, the distance (d) is constant, capacitance is directly proportional to the level of the material acting as dielectric.

Conducting Material:

In conducting liquids, the probe plates are insulated using thin coating of glass or plastic to avoid short circuiting. The conductive material acts as the ground plate of the capacitor.

Proximity measurements (Non-contact type measurements):

In Proximity level measurement is the area of the capacitance plates is fixed, but distance between plates varies.

Proximity level measurement does not produce a linear output and are used when the level varies by several inches.

Advantages of Capacitive level measurement:

1. Relatively inexpensive
2. Versatile
3. Reliable
4. Requires minimal maintenance
5. Contains no moving parts
6. Easy to install and can be adapted easily for different size of vessels
7. Good range of measurement, from few cm to about 100 m
8. Rugged
9. Simple to use
10. Easy to clean

11. Can be designed for high temperature and pressure applications.

Applications:

Capacitance Level Probes are used for measuring level of

1. Liquids
2. Powered and granular solids
3. Liquid metals at very high temperature
4. Liquefied gases at very low temperature
5. Corrosive materials like hydrofluoric acid
6. Very high pressure industrial processes.

Disadvantages:

Light density materials under 20 lb/ft3 and materials with particle sizes exceeding 1/2 in. in diameter can be a problem due to their very low dielectric constants (caused by the large amount of air space between particles).

Level Measurement Using Radiation

Certain types of nuclear radiation easily penetrates the walls of industrial vessels, but is attenuated by traveling through the bulk of material stored within those vessels. By placing a radioactive source on one side of the vessel and measuring the radiation making it through to the other side of the vessel, an approximate indication of level within that vessel may be obtained. Other types of radiation are scattered by process material in vessels, which means the level of process material may be sensed by sending radiation into the vessel through one wall and measuring back-.scattered radiation returning through the same wall

The four most common forms of nuclear radiation are alpha particles (α), beta particles (β), gamma rays (γ), and neutrons (n). Alpha particles are helium nuclei (2 protons bound together with 2 neutrons) ejected at high velocity from the nuclei of certain decaying atoms. They are easy to detect, but have very little penetrating power and so are not used for industrial level measurement. Beta particles are electrons1 ejected at high velocity from the nuclei of certain decaying atoms. Like alpha particles, though, they have little penetrating power and so are not used for industrial level measurement. Gamma rays are electromagnetic in nature (like X-rays and light waves) and have great penetrating power. Neutron radiation also penetrates metal very effectively, but is strongly attenuated and scattered by any substance containing hydrogen (e.g. water, hydrocarbons, and many other industrial fluids), which makes it almost ideal for detecting the presence of a great many process fluids. These latter two forms of radiation (gamma rays and neutrons) are the most common in industrial measurement, with gamma rays used in through-vessel applications and neutrons typically used in backscatter .applications

Nuclear radiation sources consist of radioactive samples contained in a shielded box. The sample itself is a small piece of radioactive substance encased in a double-wall stainless steel cladding, typically resembling a medicinal pill in size and shape. The specific type and quantity of radioactive source material depends on the nature and intensity of radiation required for the application. The basic rule here is that less is better: the smallest source capable of performing the measurement task is .the best one for the application

Common source types for gamma-ray applications are Cesium-137 and Cobalt-60. The numbers represent the atomic mass of each isotope: the sum total of protons and neutrons in the nucleus of each atom. These isotopes' nuclei are unstable, decaying over time to become different elements (Barium-137 and Nickel-60, respectively). Cobalt-60 has a relatively short half-life of 5.3 years, whereas Cesium-137 has a much longer half-life of 30 years. This means radiation-based sensors using Cesium will be more stable over time (i.e. less calibration drift) than sensors using Cobalt. The trade-off is that Cobalt emits more powerful gamma rays than Cesium, which makes it better suited to applications where the radiation must penetrate thick process vessels or travel long .(distances (across wide process vessels

One of the most effective methods of shielding against gamma ray radiation is with very dense substances such as lead or concrete. This is why the source boxes holding gamma-emitting radioactive pellets are :lined with lead, so the radiation escapes only in the direction intended

These "sources" may be locked out for testing and maintenance by moving a lever that hinges a lead shutter over the "window" of the box. This lead shutter acts as an on/off switch for the radioactive source. The lever actuating the shutter typically has provisions for lock-out/tag-out so a maintenance person may place a padlock on the lever and prevent anyone else from "turning on" the source during maintenance. For point-level (level switch) applications, the source shutter acts as a simple simulator for either a full vessel (in the case of a through-vessel installation) or an empty vessel (in the case of a backscatter installation). A full vessel may be simulated for neutron backscatter instruments by placing a sheet of plastic (or other hydrogen-rich substance) between the .source box and the process vessel wall

The detector for a radiation-based instrument is by far the most complex and expensive component of the system. Many different detector designs exist, the most common at the time of this writing being ionization tubes such as the Geiger-Muller (G-M) tube. In such devices, a thin metal wire centered in a metal cylinder sealed and filled with inert gas is energized with high voltage DC. Any ionizing radiation such as alpha, beta, or gamma radiation entering the tube causes gas molecules to ionize, allowing a pulse of electric current to travel between the wire and tube wall. A sensitive electronic circuit detects and counts these pulses, with a greater pulse rate corresponding to a greater intensity of detected .radiation

Neutron radiation is notoriously difficult to electronically detect, since neutrons are non-ionizing. Ionization tubes specifically made for neutron radiation detection do exist, and are filled with special substances known to react with neutron radiation. One example of such a detector is the so-called fission chamber, which is an ionization chamber lined with a fissile material such as uranium-235 (235U). When a neutron enters the chamber and is captured by a fissile nucleus, that nucleus undergoes fission (splits into separate pieces) with a subsequent emission of gamma rays and charged particles, which are then detected by ionization in the chamber. Another variation on this theme is to fill an ionization tube with boron trifluoride gas. When a boron-10 (10B) nucleus captures a neutron, it transmutates into lithium-7 (7Li) and ejects an alpha particle and several beta particles, both of which cause detectable ionization in the .chamber

The accuracy of radiation-based level instruments varies with the stability of process fluid density, vessel wall coating, source decay rates, and detector drift. Given these error variables and the additional need for NRC (Nuclear Regulatory Commission) licensing to operate such instruments at an industrial facility, radiation instruments are typically used where no other instrument is practical. Examples include the level measurement of highly corrosive or toxic process fluids where penetrations into the vessel must be minimized and where piping requirements make weight-based measurement impractical (e.g. hydrocarbon/acid separators in alkylation processes in the oil refining industry), as well as processes where the internal conditions of the vessel are too physically violent for any instrument to survive (e.g. delayed coking vessels in the oil refining industry, where the coke is “drilled” out .(of the vessel by a high-pressure water jet

Beta particles are not orbital electrons, but rather than product of ١ elementary particle decay in an atom’s nucleus. These electrons are spontaneously generated and subsequently ejected from the nucleus of the .atom