A Practical Overview of Level Measurement Technologies

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Abstract:

There are multiple technologies available on the market to measure level. Each and every technology works, when applied properly. This presentation will discuss the strengths and weaknesses of RF Admittance, Capacitance, Ultrasonic, Radar, Nuclear, Differential Pressure, and Bubblers level measurement technologies.

Introduction

Level measurement for liquids, granulars, slurries and interfaces can be accomplished with several different level technologies. There are over 20 different technologies being offered on the market today. But how would you know which technology to turn to for your application? Obviously all technologies have (or had) their place, otherwise companies would not be in business today offering them. The truth is that every technology for level measurement works...when applied correctly (only used in the specific circumstances where they have a high probability of success). This paper will discuss the most popular level measurement technologies used in industry, outline their advantages and disadvantages, and tell you where they are best applied.

The Application Box Score

Included with the description of each technology is an application box score for the four categories of level measurement (Liquids, Granulars, Slurries and Interfaces). This gives you an at-a-glance overview of where the technology in question is best used.

Liquids — A dark box indicates that this technology is suitable for this category of level measurement.

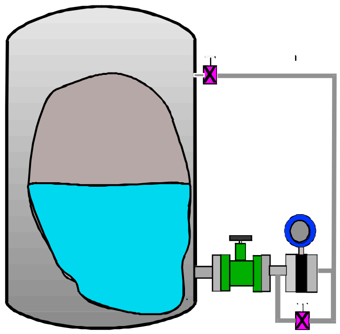
Granulars — A clear box indicates that this technology is not practical for this category of level measurement. This does not mean that people have not used this technology for measurement, but just that it is not practical. This could mean that there is excessive maintenance, excessive error, unreliable outputs, or it just simply doesn't work in this application based on the characteristics of the level measurement.

Slurries — A shaded box indicates that this technology can sometimes be applied to this application. But be careful. There are usually special considerations or additional maintenance needed.

Liquids	Granulars	Slurries	Interfaces

Example: The Application Box Score above indicates that the technology in question works on liquids. It needs special considerations or additional maintenance when used on slurries, and it is not practical for granulars or interfaces.

Differential Pressure



Liquids	Granulars	Slurries	Interfaces

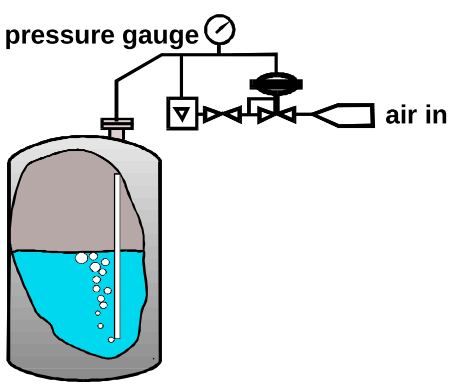
Theory
Perhaps the most frequently used device for the measurement of level is a differential pressure transmitter. This device does not really measure level. It measures the head pressure that the diaphragm senses due to the height of the material in the vessel multiplied by a second variable, the density of the product. This gives you the resultant force being exerted on the diaphragm, which is then translated into a measurement of level.

Advantages
A primary benefit of DP's is that it can be readily installed on a vessel. It can be easily removed using block valves.

Disadvantages
D/P transmitters subject to errors due to density variations of the liquid. Density variations are caused by temperature changes or change of product. These variations must always be compensated for if accurate measurements are to be made. DP's are primarily useful for clean liquids. They require two tank entrances, one of which is near the bottom where leaks are most problematic. D/P's should not be used with liquids that solidify as their concentrations increase. An example is paper pulp stock.[1]

Practical Notes
Fluid density must be stable if readings are to be accurate. A second d/p transmitter is required to measure density and then used to compensate for any changes. [2]To accommodate the measurement of light slurries, differential pressure transmitters are available with extended diaphragms that fit flush to the side of the vessel. However, certain materials which coat the diaphragm is in any way coated, it is subject to shifts in calibration and it can not be easily removed for maintenance.
Frequently, the measuring device is only one consideration in the total installation of the job. Although a D/P transmitter is often less expensive than other types of level sensors, there is usually considerable additional hardware and labor required to make a practical installation. The implementation of a stable, low pressure leg and 3 or 5 valve manifolds add considerable cost to the installation.

Bubblers



Liquids	Granulars	Slurries	Interfaces

Theory
This simple level measurement has a dip tube installed with the open end close to the bottom of the process vessel. A flow of gas (usually air) passes through the tube and when air bubbles escape from the open end, the air pressure in the tube corresponds to the hydraulic head of the liquid in the vessel. The air pressure in the bubble pipe varies proportionally with the change in head pressure.[3]

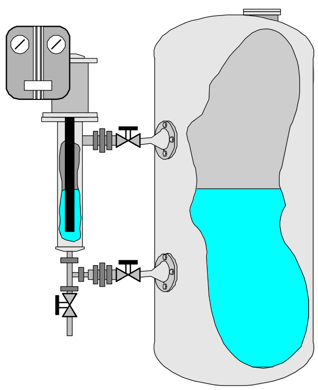
Advantages
Simplicity of design and low initial purchase cost are frequently given as advantages of bubblers, but this is somewhat misleading. The system consists of a pipe, an air supply, a pressure transmitter and a differential pressure regulator. The regulator produces the constant gas flow required to prevent calibration changes.

Disadvantages
Calibration is directly affected by changes in product density. It is frequently also necessary to periodically clean this device. The tip of the pipe can collect material from the process, solidify, and plug the hole. Bubblers are not suitable for use in non-vented vessels.

Practical Notes
Air lines should be heat-traced if freezing is possible. Calibrate at maximum temperature to avoid overfills. Accuracy depends on a stable air supply and is limited by the regulator, which may be $\pm$ 10% of full scale. In applications where the purge air is exposed to a hazardous substance, additional steps must be taken to contain any possible contamination.[4]

Displacers

Liquids	Granulars	Slurries	Interfaces



Theory
When a body is immersed in a fluid, it loses weight equal to the liquid weight displaced (Archimedes Principle). By detection of the apparent weight of the immersed displacer, a level instrument can be devised. If the cross sectional area of the displacer and the density of the liquid is constant, then a unit change in level will result in a reproducible unit change in displacer weight.[5]

Advantages
Work well with clean liquids and are accurate and adaptable to wide variations in fluid densities. Once set up, however, the fluids measured must maintain their density.

Disadvantages
Displacers are affected by changes in product density. Since the displacement of the body (it's weight loss) is equal to the weight of the fluid displaced. If the specific gravity changes, then the weight of the displaced material changes, thus changing the calibration. This is especially problematic in interface measurements, where both liquids increase or decrease density, while the signal is proportional to the density difference.

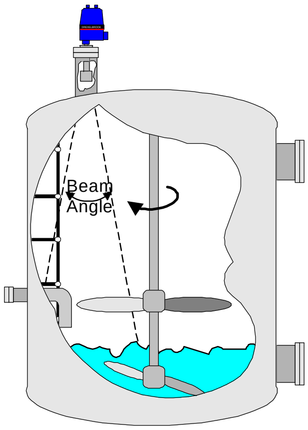
Because the displacer is in the process fluid, solids can deposit on it. This changes the effective displacement and causes a calibration shift.

Displacers are relatively expensive when placed in external cages. The level in the external cage does not always represent the level in the vessel, particularly with interfaces of two materials that are close in density.

Practical Notes
Displacers should only be used for relatively non-viscous, clean fluids. Best used for short spans. Spans of up to 40 feet are possible, but they become prohibitively expensive. Cost of installation is high and many refineries are now replacing displacers due to the inaccuracies experienced in density changes of the process materials.

Ultrasonic / Sonic

Liquids	Granulars	Slurries	Interfaces



Theory
Ultrasonic transmitters work on the principle of sending a sound wave from a peizo electric transducer to the contents of the vessel. The device measures the length of time it takes for the reflected sound wave to return to the transducer. A successful measurement depends on reflection from the process material in a straight line back to the transducer.

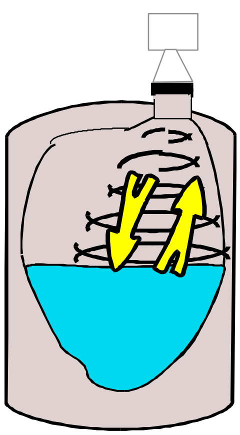
Advantages
The appeal of ultrasonics is that the transducer does not come in contact with the process material and does not contain any moving parts. A single top-side tank penetration makes leaks improbable.

Disadvantages
There are various influences that affect the return signal. Things such as dust, heavy vapors, surface turbulence, foam and even ambient noise can affect the returning signal.. Temperature can also be a limiting factor in many process applications.

Practical Notes
Successful measurement depends on the transmitter being mounted in the correct position so that the internal structure of the vessel will not interfere with the signal path. To ignore obstructions in the tank, tank mapping has been developed. Tank mapping lets you take a "sonic snapshot" of an empty tank. A sound burst is sent down by the transducer and the echo is recorded as a signature of the tank. Any obstructions in the tank will send an echo and create a profile. Later on, this signature or profile, is locked into the ultrasonic unit's memory so it will not respond to echoes created by these obstructions.

Radar

Liquids	Granulars	Slurries	Interfaces



Theory
Two technologies on the market are frequency modulated continuous wave (FMCW) or pulsed wave time of flight. FMCW is fast enough for tank gauging, but normally too slow to measure the turbulent surfaces encountered in agitated process applications. The sensor emits a microwave pulse towards the process material. This pulse is reflected by the surface of the material and detected by the same sensor which now acts as a receiver. Level is inferred from the time of flight (transmission to reception) of the microwave signal. Microwave "echoes" are evaluated by sampling echoes and building up a retarded profile of the echoes.[6]

Advantages
This non-contact technology produces highly accurate measurements in storage tanks and some process vessels. Radar is an excellent, but fairly expensive technology ($5k to $10k per point) for continuous level measurements when applied to tank gaging and inventory control. Several manufacturers have reduced the cost / price of the technology with a process radar offering. This system doe not have the accuracy (and associated cost) of radar used for inventory control. The system has very high accuracy, ignores vapors and is immune to most physical characteristics of the material measured, other than dielectric constant.

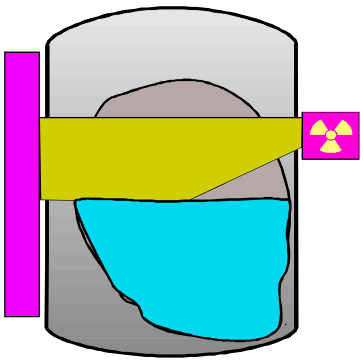
Disadvantages

It's primary disadvantage is cost, which can be justified for tank gaging and inventory control. The pressure ratings on the radar antenna is limited and these devices cannot measure interfaces.

Practical Notes

In the case of hydrocarbons, an accurate water bottoms measurement must be made for accurate inventory control. Typically, another technology, such as RF Admittance is used to make the interface measurement between water and hydrocarbons. Some installations, such as floating roof tanks, require the installation of a very precise gaging tube Inconsistencies on the internal surface of the gaging tube can cause erroneous echoes.

Nuclear



Liquids	Granulars	Slurries	Interfaces

Theory

Nuclear level controls are used for continuous measurements, typically where most other technologies are unsuccessful. Radioisotopes used for level measurement emit energy at a fairly constant rate and in a random fashion. Gamma radiation, which is present in high-energy, short-wave lengths produce a great penetrating power and are used for level measurement. Different radioactive isotopes are used, based on the penetrating power needed to "see" through the process vessel. The radiation from the source penetrates through the vessel wall and process fluid. A detector on the other side of the vessel measures the radiation field strength and infers the level in the vessel. The percentage of transmission decreases as the level increases.[7]

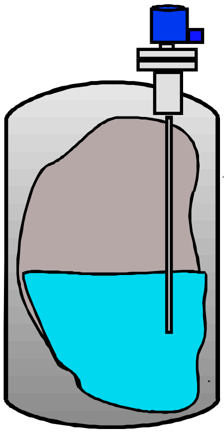
Advantages

There are a number of situations that cause nuclear transmitters to be considered over other technologies. These controls are extremely suitable for applications involving high temperatures and pressures or corrosive materials within the vessel. No tank penetration is needed. The nuclear system requires that a radio-active source be mounted on one side of the vessel, and a radiation detector or receiver is mounted on the other side. The source is such that it can penetrate the vessel walls, shoot through the material and be received by the detector. The amount of signal arriving at the detector is proportional to level.

Disadvantages

There are a number of compensating factors that seem to prevent nuclear from becoming a truly universal technology. One factor is high cost which is estimated at 2-4 times that of other technologies. Licenses, approvals, and periodic inspections are required. Radiation sources are expensive and difficult to dispose of. The radiation symbol found on these controls frequently strikes fear in the heart of uninitiated plant personnel. There are some other considerations regarding the accuracy, linearity, and rate of response are generally not as good as other technologies.

RF Admittance & Capacitance



Liquids	Granulars	Slurries	Interfaces

Theory
A constant voltage is applied to a rod or cable (sensing element) in the process. The radio frequency current which results is monitored to infer the level of the process material.

Advantages
RF Admittance / Capacitance of are by far the most versatile technologies for continuous level measurement and handles a wide range of process conditions anywhere from cryogenics to 1000 degrees F and from vacuum to 10,000 psi pressure. Aside from the electronic circuit technology, sensing element design is very important to handle these process conditions. There are no moving parts to wear, plug, or jam. There is only a single tank penetration, usually at the top of the tank, above the actual process level.

Disadvantages
RF admittance is an intrusive technology. Insulating granular measurements require special considerations, such as the moisture range and location of the sensing element to minimize errors caused by probe movement.

Practical Notes

Capacitance measurements are subject to large errors caused by conductive coatings. Admittance technology avoids this problem by correcting the output for coatings. For insulating materials with changing dielectric constants, the measurement can only be made reliably if the material being measured is homogeneous and the dielectric constant is the same every where in the measuring vessel. A second sensor is added to monitor the dielectric constant and then compensate the calibration based on this information. Smart transmitters are available that need no calibration, since they constantly re-calibrate themselves, based on the dielectric constant monitoring. Knowledge of the approximate electrical character of the process material is key to optimum performance.

Summary

The many level technologies which exist in the market place today all work. If they did not work, companies would not be able to stay in business manufacturing them, and other companies would not be buying them. The important thing to remember is that all technologies work when applied properly. Special consideration must always be given to the principle of operation, and where the limitations of each technology lie. The correct selection of a technology and then the subsequent correct application of the technology will make the level measurement a successful one.

Below is a summary list of the general application of the technologies discussed in this paper.

	Liquids	**Granulars**	**Slurries**	**Intefaces**
RF Admittance				
Ultrasonic				
Radar				
Differential Pressure				
Displacers				
Bubblers				
Nuclear				

Code Key	**O.K.**	**Use Caution**	**Not practical**

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[1], "Feature Report - On the Level" Sarah Parker, Rosemount Measurement Division, Chemical Engineering, May, 1995, McGraw-Hill Publication

[2] , "Feature Report - On the Level" Sarah Parker, Rosemount Measurement Division, Chemical Engineering, May, 1995, McGraw-Hill Publication

[3] "Air Bubblers", Instrument Engineer's Handbook, Bela G. Liptak, Editor, P,135.

[4] "Feature Report - On the Level" Sarah Parker, Rosemount Measurement Division, Chemical Engineering, May, 1995, McGraw-Hill Publication

[5] "Displacement Level Devices", Instrument Engineer's Handbook, Bela G. Liptak, Editor, P,135.

[6] "Microwaves for level measurement - why and where?", Dr. Peter Berrie, Instrumentation & Control, December 1995, p. 75

[7] "Industrial Level Measurement", Donald R. Gillum, ISA, 1984, pp.88-89.