Guided Wave Radar vs.
Differential Pressure Transmitters for Liquid Level Measurement

Although still the mainstay in liquid level measurement, Differential Pressure transmitters are gradually losing ground to Guided Wave Radar transmitters…

Bob Botwinski, Guided Wave Radar Product Manager
Magnetrol International, Inc.

Guided Wave Radar vs.
Differential Pressure Transmitters for Liquid Level Measurement

Introduction

Differential pressure transmitters were first implemented in the 1950s but are still one of the most commonly used technologies for measuring liquid level in process industries. In many areas of the industrial level measurement market—including chemical, petrochemical, refining, and electric power generation—differential pressure transmitters have captured the vast majority of level applications; and still represent the largest worldwide sales volume of process level measurement equipment. Their popularity and installed base is so prevalent because DP transmitters are versatile, cost-effective, and due to their long history, plant personnel are familiar with their operation.

Over the years, however, newer level measurement devices have emerged and are consistently capturing market share from older technologies which utilize mechanical and pressure-based measurement—including DP transmitters. Technologies such as Non-Contact Radar, RF Capacitance, Ultrasonic, Magnetostrictive, and Guided Wave Radar employ the latest microprocessor-based digital electronics. By incorporating internal diagnostics, these devices have improved the control, analysis, communication, and overall reliability of fluid level management systems.

Although DP transmitters presently remain the dominant instrument for level measurement, their worldwide market share is expected to steadily erode in the presence of growing demand for the newer level measurement technologies. Manufacturers, keenly aware of the market shift at play, are allocating significant research and development assets to ensure that these newer technologies continue to offer additional performance, functionality, affordability, and ease of use.

Leading the assault is Guided Wave Radar (GWR), which is among the most versatile of technologies now being used for liquid level measurement. It is also one of the newest and fastest growing technologies, having gained tremendous acceptance due to the significant advantages it offers over other level measurement devices. Not only does GWR usually outperform conventional level measurement technologies, a GWR radar transmitter is extremely compact and easy to install and operate. The latest generation of Guided Wave Radar transmitters is a formidable contender as a potential market-wide replacement to the universally entrenched differential pressure transmitters.

Guided Wave Radar vs.
Differential Pressure Transmitters for Liquid Level Measurement

Differential Pressure (DP) Transmitters

DP transmitters were originally developed for flow measurement, but have been adapted for fluid level applications over the years. DP transmitters infer liquid level by measuring hydrostatic head pressure (the pressure exerted by a column of liquid in the vessel). It is important to note that these devices convert the DP cell reading into a liquid level based on an assumed stable liquid density or specific gravity (SG) inside of the vessel.

In an open-tank DP application, the level can be determined by simply measuring pressure at the bottom of a tank. This is possible because the pressure at any point in a liquid of known density is determined by the height of the liquid above that point. The technique measures the static head of the liquid as compared to atmospheric pressure. This relationship is straightforward as each foot of water exerts a pressure of .433 pounds per square foot (psf). By monitoring pressure, one can easily determine the level of liquid in a tank.

If the application is in a closed tank, the high-pressure side of a differential pressure sensor is connected to the bottom of the tank, with the low-pressure side connected to the vapor space at the top of the enclosed vessel. These two cells measure the pressure difference between two points and send a differential pressure reading to the plant control system. The arithmetic difference between these values is used to determine the liquid level. This can be an inherently unreliable and inaccurate method because it is an inferred level based on two different measurements.

Since the hydrostatic head generated by a column of liquid is dependent on the density of the fluid, the accuracy of a liquid level inferred from a hydrostatic head measurement is dependent on the accuracy of the fluid density used in the level calculation. Measured pressure difference is a true indication of level only if the fluid density is constant.

The ramifications of this become apparent when one considers the fact that the SG of a liquid varies with temperature. Therefore, in order to obtain the highest precision in level measurement, density changes resulting from temperature shifts must be compensated for. In other words, SG must be expressed with relation to the actual temperature of the measured liquid and pressure (if any) of gasses above the liquid. Any change in temperature, or significant changes in pressure, will cause a shift in a liquid's SG, resulting in reduced measurement accuracy. Since fluid density also varies with the type of liquid, measurement inaccuracies may also occur if the media inside the vessel changes. *Figure 1* shows the saturated steam curve as an example. This graph shows how the specific gravity of water changes with temperature.

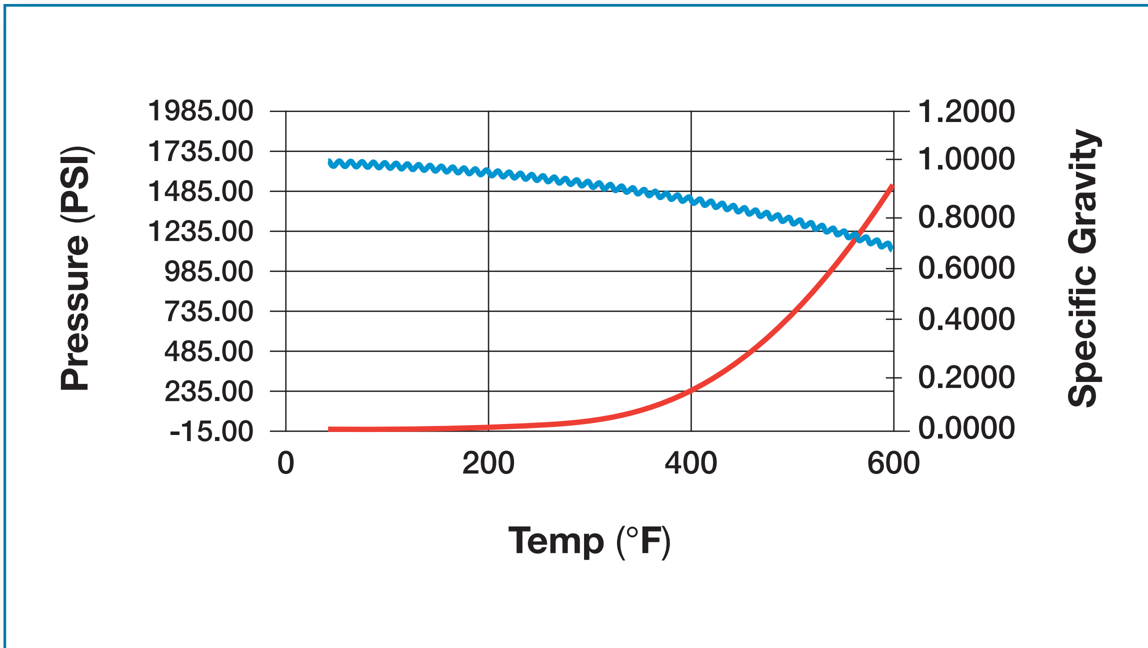

***Figure 1**: Saturated Steam Curve vs. Specific Gravity of Water*

Other aspects of DP transmitters which can be problematic include:

- Calibration and re-calibration difficulties
- Condensation in remote capillary tubing causing measurement errors
- Viscous and dirty media require expensive diaphragm seals that need periodic flushing
- Not suitable for mounting to an external chamber or cage
- Potential for leaks due to side mounting near tank base
- No ability to do interface measurement
- Cumbersome installations on heated vessels due to steam/electric tracing.

In spite of these issues, the predominance of DP level sensing for liquid level applications can be attributed to a number of factors including their relatively low initial cost, industry familiarity, ease of installation, and the availability of a wide variety of materials and process connections.

Guided Wave Radar vs. Differential Pressure Transmitters for Liquid Level Measurement

Guided Wave Radar (GWR)

Guided Wave Radar (GWR) is an invasive liquid level measurement method that utilizes a rod or cable to guide high frequency, electromagnetic waves as they travel down from the transmitter to the material being measured.

GWR is based upon the principle of Time Domain Reflectometry (TDR), which is an electrical measurement technique that has been used by the telephone and power transmission industries for decades to determine underground cable faults. With TDR, a pulse is transmitted down the suspect cable and a reflection results at the point where the cable has an open or short circuit. By measuring the time from the transmitted pulse until the echo returns, the distance to the reflecting object can be easily calculated knowing the signal is travelling at the speed of light.

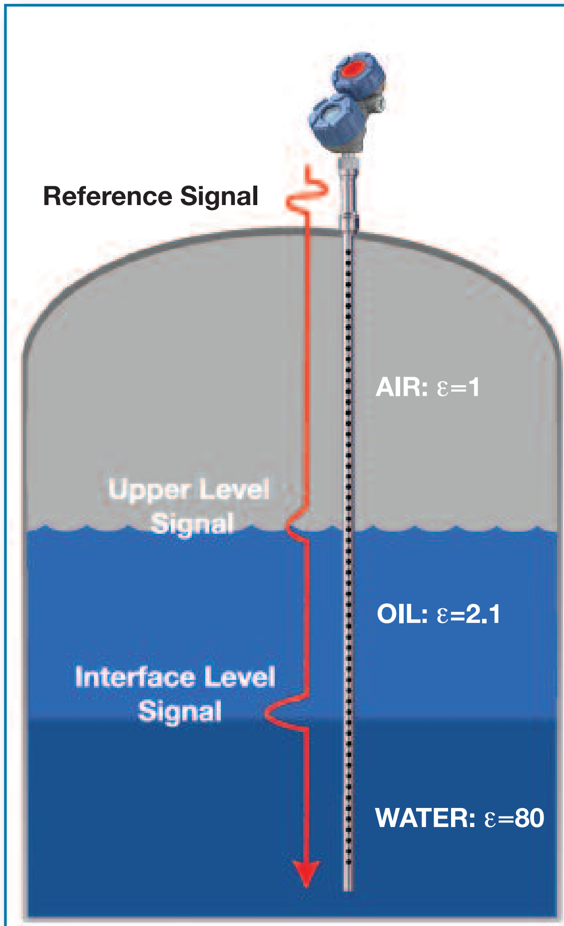

Figure 2: *GWR – Technology*

GWR operates similarly. The GWR probe has characteristic impedance when in air, which has a dielectric constant of 1. As the signal travels down the probe, a reflection occurs at the point where air meets the fluid. This reflection is a result of the impedance change due to the fact that a fluid has a higher dielectric constant than the air. (The more conductive the process medium, the larger the amplitude of the reflected signal.) High speed electronics are used to measure the transit time to the liquid and to calculate the corresponding liquid level.

The GWR probe affords a highly efficient path so that degradation of the signal is minimized. Thus, extremely low dielectric materials like butane and propane can be effectively measured. Further, because there is very little signal loss down the probe, turbulence and foams have minimal effect on the measurement. GWR can handle varying specific gravity because true level is being detected. Since media (dielectric constant) changes affect only the amplitude of the signal, not its position in time, GWR is an excellent choice for mixing vessels.

GWR signal propagation is largely unaffected by vapor space gas composition, temperature, or pressure. GWR transmitters can operate in a vacuum, need no calibration, and can be used in interface applications where water may reside below a hydrocarbon. Confining the wave to follow the probe or cable eliminates proximity issues—such as false echoes that often occur from tank walls and structures.

Guided Wave Radar vs.
Differential Pressure Transmitters for Liquid Level Measurement

GWR is particularly suitable for a very broad range of level measurement applications including:

- Liquids, slurries and solids
- Hydrocarbons to water-based media (dielectric 1.4 - 100)
- Mixing vessels
- Most process or storage vessels up to 75 feet
- Bridles and bypass chambers
- Hygienic probe offering for the food and beverage industry
- Virtually all level measurement and control applications

There are very few fluid level measurement applications that GWR cannot handle. The most important decision is choosing the correct probe for the given application. Coaxial probes are the most efficient configuration, capable of handling very light hydrocarbons such as butane and propane. Twin rod and single rod probes are designed for more viscous applications. Regardless of the probe type, GWR simply eliminates many of the variables that can adversely affect other level measurement technologies.

Guided Wave Radar overcomes many of the weaknesses of older level measuring systems. Being immune to changes in specific gravity, for example, GWR outperforms DP transmitters. Since it has no moving parts, it also eliminates the issue of mechanical parts requiring maintenance or losing tolerance.

Typically installed vertically, GWR probes can also be installed horizontally with the waveguide being angled or bent up to 90°. It is a very versatile technology that only requires an area in the vessel providing mechanical clearance for the probe.

Being a microprocessor-based instrument, GWR also offers the advantage of offering comprehensive diagnostics. Most GWR transmitters perform a series of internal self tests that offer the ability to alarm users when faults are detected. Most GWR suppliers offer their transmitters with HART®, FOUNDATION fieldbus™, and PROFIBUS® digital outputs which also increase the level of diagnostic capability. The advanced diagnostic capabilities offered by electronic transmitters can be utilized for proactive maintenance.

Additional advantages come in the way of using GWR on safety-related applications. GWR level transmitters can have third party Safety Integrity Level (SIL) evaluation (FMEDA) performed on them, which may make them suitable for SIL 1 or SIL 2 applications.

Guided Wave Radar vs.
Differential Pressure Transmitters for Liquid Level Measurement

- Inferred level measurement is based on hydrostatic head pressure.
- Inexpensive to purchase but, typically, costly to install.
- Changes in specific gravity or vapor pressure will cause inaccurate level measurement.
- Calibration and re-calibration can be difficult.
- Condensation in remote capillary tubing will cause measurement error.
- Viscous and dirty media require diaphragm seals.
- Not suitable for mounting to an external chamber or cage.
- Side mounting near tank base increases number of possible leak points.

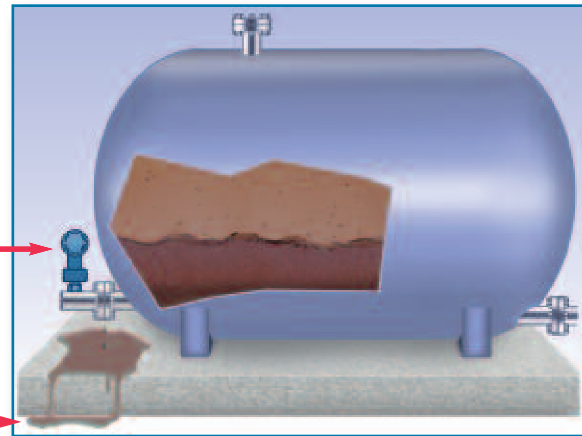

***Figure 3**: D P Transmitter*

- GWR measurement is direct; actual product level is measured.
- GWR is competitively priced and inexpensive to install.
- GWR is not affected by changes in specific gravity or vapor pressure.
- No calibration is required; GWR only requires simple configuration.
- No capillary tubing is needed to balance pressurized vessel.
- GWR is designed to mount on a vessel or in a chamber.
- Leakage hazard is minimized since GWR is top-mounted.
- Various GWR probes are available to match a media's specific characteristics.

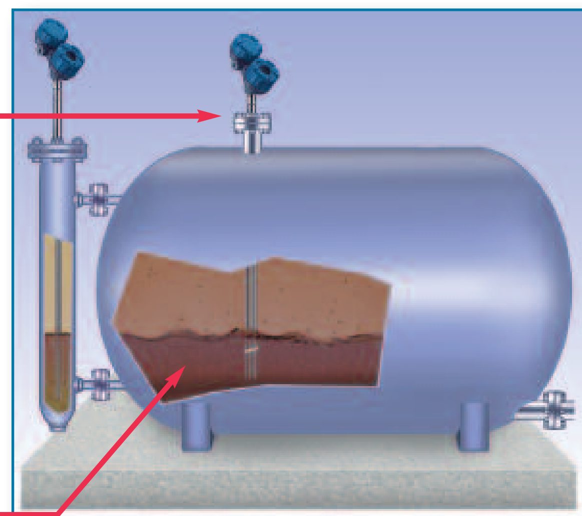

***Figure 4**: Guided Wave Radar*

The Future

Although Guided Wave Radar is a relatively young technology and just starting to make an impact in the process industries, tens of thousands of units have been sold to major companies, worldwide. GWR transmitters continue to sell at a faster rate than any other leading level measurement technology.

Which of these two diverse level measurement technologies will have market dominance in the years to come? Will DP transmitters keep their reign, or will Guided Wave Radar continue to gradually steal away market share? Time will tell, but as our industrial world advances toward more sophisticated technologies and diagnostics, it is inevitable that level measurement will go the same course.

Comparison Points:
DP Transmitters vs. Guided Wave Radar Transmitters

The following is a comparison of some critical features between Differential Pressure and Guided Wave Radar:

DP Transmitters	Guided Wave Radar Transmitters
Liquid Level Measurement	
DP transmitters infer level measurement from hydrostatic head pressure.	The Guided Wave Radar probe is in direct contact with the media and measures actual product level.
Calibration	
Calibration and re-calibration are necessary for DP technology. The process can be time consuming and expensive.	GWR requires no calibration—only simple configuration. This configuration can be accomplished with the transmitter disconnected from the probe and can be done in the instrument shop.
Process Changes	
DP transmitters are affected by liquid density or vapor density variations. Measurement performance can also degrade due to condensation forming in DP cells' remote capillary tubing.	GWR is not affected by changes in specific gravity, dielectric constant, temperature, or pressure. Coating buildup has minimal effect on measurement accuracy. It contains no moving parts and has a robust pressure boundary.
Temperature Range	
DP transmitters have a standard temperature range of +250° F (+120° C), but may be increased to +650° F (+345° C).	GWR withstands temperatures to +800° F (+427° C), and cryogenic temperatures to -320° F (-195° C).
Pressure Range	
DP transmitters maintain a wide pressure range to 7000 psi (470 bar).	GWR withstands pressures from full vacuum to 6250 psi (345 bar).
Material Compatibility	
Both DP transmitter and GWR transmitter process seals are subject to material compatibility.	
Accuracy	
DP transmitters have an accuracy of ± 0.25% of span; ± 0.10% optional.	GWR can obtain accuracies up ± 0.1" (3 mm).
Mounting	
Mounting for DP transmitters is limited. Side mounting of a DP cell near a tank base offers a source for leakage.	GWR mounting is versatile, designed to mount directly onto a vessel or in a side-mounted chamber.
Cost	
Although DP transistors have a low initial equipment cost, additional costs for installation and maintenance are quite high.	GWR complete units (transmitter and probe) are priced around $2,000. Cost of maintenance is low.

For more information on Magnetrol Eclipse® Guided Wave Radar, please contact:

Kathleen Cacciato, Marketing Communications Manager
Magnetrol International
5300 Belmont Road, Downers Grove, Illinois 60515-4499
Phone: 800-624-8765 • Fax: 630-969-9489
email: kcacciato@magnetrol.com • www.magnetrol.com.

Magnetrol®

5300 Belmont Road • Downers Grove, Illinois 60515-4499 • 630-969-4000 • Fax 630-969-9489 • www.magnetrol.com
145 Jardin Drive, Units 1 & 2 • Concord, Ontario Canada L4K 1X7 • 905-738-9600 • Fax 905-738-1306
Heikensstraat 6 • B 9240 Zele, Belgium • 052 45.11.11 • Fax 052 45.09.93
Regent Business Ctr., Jubilee Rd. • Burgess Hill, Sussex RH15 9TL U.K. • 01444-871313 • Fax 01444-871317