It is impossible to manage what cannot be measured, and across hydrocarbon processing, managing levels is critical. From monitoring inventories and supply chains to preventing overfills, detecting leaks and avoiding dry-runs that damage pumps, accurate level measurement is essential to safety, efficiency and reliability.

Most obviously, level measurement is key to the monitoring and control of terminals. It is ubiquitous across tank farms, offsites, storage areas, and loading and unloading sites. In many of these cases, measurement is critical but not complex, and operators can choose from a wide range of available technologies, each of which has its own strengths and weaknesses.

Even in these circumstances, challenges can arise. Tanks and tank farms may be in extreme or widely varying climates, resulting in changing or challenging ambient temperatures. For example, measured liquids may be sticky and coating, with heavy fractions and impurities at the bottom of the tank, and the properties of the liquids in some tanks may vary by batch or product specification.

Such cases make consistent and reliable measurement more difficult to achieve. More widely, though, level measurements are required not just for the main, large storage tanks for crude
or gasoline. Accurate measures are critical at almost every stage of hydrocarbon processing.

Measurements are crucial across crude processing: at the well stream separator, for crude storage, dewatering, dehydration, desalting and degassing, as well as during chemical injection and vapour recovery. They are also essential during refining: for input storage, at the preflash, flare knockout and compressor drums, and at the distillation column, reflux accumulator, separators and so on.

In many of these applications, measurements are not taking place in large tanks with relatively static product. It is smaller tanks where crude or product is being heated, put under pressure, moved, mixed, blended and having chemicals added. Hydrocarbon production is a dynamic, turbulent process with foaming, condensation, expansion and constant changes in the liquids’ properties.

Accurate level measurements are just as crucial in these applications, but in many cases significantly more challenging to achieve.

**Crude processing applications**

Right at the outset, initial separation of gas, crude oil and water, conditions are turbulent:

- The headspace of a separator contains pressurised, wet gas with the possibility of condensation.
- The liquid surface in high pressure separators may be bubbling and foaming.
- A degree of emulsion is present in both high pressure and low pressure separators.
- Residue and contamination gathers on the bottom of a separator, leading to build-up and fouling.

Many of these issues are present across other processes. The need to provide accurate measurements despite foaming and fouling is, to a greater or lesser extent, present across crude storage, chemical injection, dehydration and degassing, for example. Interface measurement is particularly key, not just during separation, but also across many of these same processes.

Meanwhile, at the vapour recovery stage, operators need accurate measurement of liquefied hydrocarbon vapours in a flash drum or output tank. The challenges are again significant:

- The low dielectric constant of liquefied hydrocarbons results in a small reflection signal for measurement technologies relying on one.
- Small tank dimensions require measurement close to the top and bottom of the tank.
- There are cold temperatures and the presence of vapours above the surface of the measured liquid.

There are countless other examples. Each stage of the process has its own issues.

**Refining measurement**

The challenges during refining are no less significant. Smooth operation of the preflash drum, for example, is critical for efficient performance of the main distillation unit, and continuous operation means long periods between maintenance during which operators need reliable measurements. These measures must account for densities of the measured liquids that change at startup – creating difficulties for measurements based on pressure or displacement – and foaming, again, on the surface of the liquid.

Meanwhile, in the distillation columns, level measurement at the bottom of a distillation tower controls the ‘bottoms’ product, which is hot, and can contain impurities and be sticky (coating), while lighter products in the upper part of the column have low dielectric constant. The fluid can also be volatile and may be at bubble point, giving noisy measurements with some level technologies.

And so it goes on. Changes in temperature, pressure, density, dielectric constant or the measured material abound throughout the process. Agitation, foaming, corrosive properties, dust and construction of the tank should also be factored in when choosing a measurement technology.
The choice of technology

To some extent, the choice of technology has already narrowed. The drive towards automation and uninterrupted production, as well as safety, has moved many away from manual and mechanical level measurement. Electronic methods, with no moving parts and built-in diagnostics, also offer lower lifecycle costs.

However, a range of options remain, including bubbler, hydrostatic and differential-pressure instruments. But these are all sensitive to changes in the density of the measured product, while capacitance level measurement can, in some applications, be affected by changes in the dielectric constant of the measured product.

Ultrasonic measurement is perhaps a stronger contender. Nevertheless, it requires a path for the ultrasonic signal clear of obstacles and foams, dust or heavy vapours, as well as an application falling within a limited operating pressure and temperature range.

In fact, the checklist of requirements for a measurement technology that is suitable across hydrocarbon processes is significant, and includes the following:

- Maintenance-free level measurement.
- Ability to cope with a wide range of pressures and temperatures.
- Insensitive to changes in density or dielectric constant.
- Immunity to heavy vapours, dust or foaming.
- Accurate, even with turbulent surfaces of the measured product.

Unlike mechanical or other electronic methods, guided wave radar (GWR) can meet these demands.

A good aim

GWR instruments send electromagnetic pulses to the product and use the time of travel of the reflected signal to calculate the level in the tank. The signal travels along a waveguide that can be made of a stiff metallic rod, flexible wire or a coaxial construction (Figure 1).

Compared to ultrasonic meters or even non-contact radar (another alternative), the measurement signal for the GWR is concentrated around the waveguide (or inside it in the case of a coaxial waveguide). This narrow signal propagation path (Figure 2) minimises the potential impact of stray signals caused by construction elements or obstacles in the tank. The waveguide can be mounted on an angle or even formed to follow the contours of an irregularly shaped tank.

The electromagnetic pulses used by the GWR and waveguide also give it much greater immunity to the influence of the mechanical properties of the atmosphere in the tank (vapours, dust, changes in temperature and pressure, or foaming). These can particularly affect technologies relying on mechanical wages, such as ultrasonic measurement. It also copes well with changes in the specific gravity. Meanwhile, when measuring interfaces (such as oil on water), the waveguide allows the measuring signal to penetrate the upper product and provide measurement of the lower product.

Finally, with no need for an antenna, GWR is simple to install. The waveguide fits easily through narrow mounting holes or nozzles.

Theory and practice

Despite the inherent advantages of GWR, its performance is heavily dependent on the ability to discern the correct signal (reflection) from interference. Thin interfaces, probe ends, in-tank obstacles, build-up, and other issues can all still cause challenges.

Usually this distinction between the reflection from the surface and other factors is done through a simple...
peak-finding algorithm, which attempts to separate the strongest signal from the (hopefully weaker) interference. This is not always entirely possible in more challenging applications, however.

To address this, Honeywell has developed a unique algorithm that compares the signal with an internal model of the expected reflection (stored in the instrument). This model can be adjusted with parameters such as gain, width and attenuation, and is based on the type of liquid, process connection, probe and tank properties, combined with the company’s internal experience gathered through experimentation and laboratory work.

By overlaying the actual echo curve of the signal captured by the GWR on the model (Figure 3), the true signal reflected from the liquid surface (and therefore the level) can be distinguished from echoes caused by obstacles near the probe or secondary reflections originating from multiple reflections of the radar signal in the tank. The correlation method also allows users to filter out and selectively follow small reflections from the surface of liquids with small dielectric constants (including liquefied gases, such as LPG and other light hydrocarbons).

**Fine tuning**

To set the model, the sensor is pre-programmed with default values for parameters determined by the dielectric constants of the liquids being measured. These can be easily adjusted at any stage.

Where the attenuation of the material measured changes during the process in the tank, Honeywell’s GWR uses an auto-amplitude tracking feature. This supplements the pulse model determined by the user-defined parameters with historic measurement data. In these cases, once the sensor has locked onto the correct level, it will track the level signal, even when the amplitude of it changes.

This feature enables the instrument to track signals with amplitudes up to 35% different to those expected from the pre-programed parameters. Thus, it can adapt to changes resulting from varying conditions in the tank, whether due to temperature, vapour density, turbulence or build-up of films on the probe.

**Conclusion**

The choice of level measurement method in hydrocarbon processing is critical because the applications are both varied and demanding. There are few viable alternatives that can meet the requirements of the many challenging applications across the process.

GWR can meet most, if not all, of the requirements. It has strong immunity to the common foaming, fouling, build-up, turbulence, temperature, pressure, and tank characteristic issues – and many other challenges to accurate level measurement. It is a measurement principal with many significant inherent advantages.

In practice, however, some applications can challenge even GWR to deliver consistently reliable measurements. For this reason, the choice of not just the measurement method, but the precise technology employed is also critical. The level algorithm used in Honeywell’s Smartline transmitter builds on the inherent advantages of GWR with a unique model-based comparison for more accurate level measurements – whatever challenges the dynamic, turbulent, complex processes involved present.