Lydia Miller, Emerson Automation Solutions, USA, explores how guided wave radar instruments can help a refinery make accurate level measurements in a corrosive environment.

PROVIDING A GUIDE

The alkylation process has long been an important technique for refiners to create economical gasoline blending components capable of raising the octane rating. There are two main process approaches that are distinguished from one another by their catalyst, either sulfuric acid or hydrofluoric acid (HF). Both approaches take lighter components – primarily isobutane and olefins (various low-molecular-weight alkenes) – and, using one of the acids as a catalyst, convert them to alkylate, which can be added to gasoline.

This octane booster can be used year-round as it does not cause vapour pressure problems that are common to alternative additives. Both processes were developed during World War II to help increase the supply of high-octane aviation fuel available to allied air forces, and both have been in use ever since. This article will concentrate on the HF alkylation unit design since it presents the more serious corrosion challenge.

An HF alkylation unit is fairly complex (Figure 1), but the process does not require particularly high temperatures nor high pressures. It does, however, use HF, which is both highly toxic and corrosive. As a result, safety mechanisms are critical, and the construction materials throughout the unit must be carefully selected, applied and maintained. HF is unforgiving and will find its way through any poorly executed weld or inferior seal material, with potentially serious results in terms of leaks and possible safety incidents.

A HF alkylation unit produces three main product streams:

- Alkylate.
- Butane, which is also used as a gasoline blending component.
- Propane.

The first two product streams come out of the main fractionator and are sent on for additional refinement. The propane is part of a mixed stream coming out of the acid settler, also containing unrecovered HF and unreacted isobutane. This stream is sent to a de-propanising stage, which is effectively a large trayed distillation column, where propane is separated from the liquid and sent on for purification. The liquid stream is recycled back to the original reactor and mixed with fresh feedstocks. The highest possible degree of separation is desirable because when the propane is sold as a product it must not have HF residues, and returning propane to the reactor reduces its efficiency.

The de-propanising tower

A typical de-propanising tower is approximately 200 ft tall and has around 80 trays. There is a tray about two-thirds of the way up the tower that is much deeper than the others and is used as the liquid collection point, or draw tray. Some of the liquid is returned to the tower as reflux, while the balance is recycled back to the reactor. The liquid level in the draw tray must be monitored and controlled since it is the determining factor for how the liquid is sent back. This seemingly simple measurement can cause many difficulties and challenges for a variety of reasons.

The connection to the draw tray extends out through the wall of the tower to an externally-mounted bridle. A bridle in this application needs to be designed to avoid trapping any corrosive liquid when the tower is drained (Figure 2). All the pipe, fittings and components are commonly made from Alloy 400, which is one of the few materials able to withstand the corrosiveness of HF on a continuous basis.

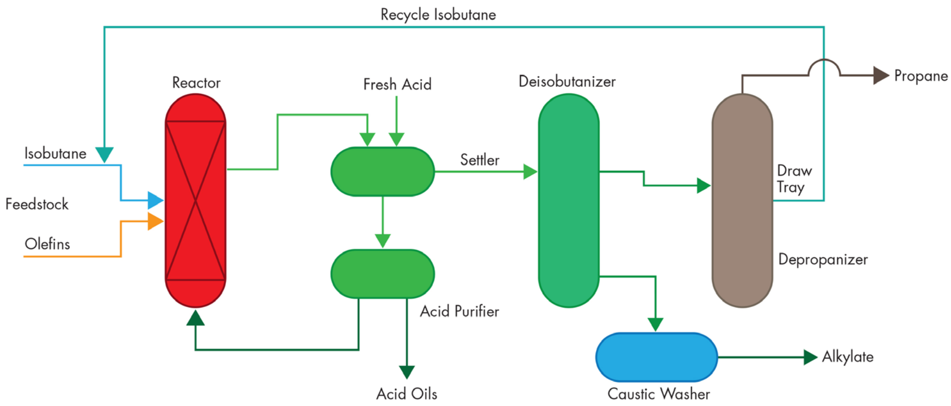

Figure 1. The de-propanising tower is effectively a trayed distillation column. The draw tray sends the purified liquid back to the reactor.

Figure 2. The bridle for the draw tray is typically designed to drain fully so it does not retain HF residues when the unit is drained.

The challenge for designers comes when trying to find a good measurement technology for this application.

For many plants, a nuclear level device is the technology of choice since it can function without creating a penetration in the bridle. These instruments generally work, but are not very accurate when the liquid density changes, which is common in this application. This affects its ability to deliver consistent readings. Additionally, de-propaniser towers are typically inspected regularly with X-rays. Unfortunately, the X-rays interfere with nuclear level measurement devices, so readings are unavailable during inspections.

Without an accurate and reliable level measurement at the draw tray, it can be difficult to optimise the process.

Critical process parameters

The HF alkylation process needs precise regulation to perform properly. The ratios of feedstocks and acid are critical for maximum efficiency, and to avoid reactions creating undesirable polymers. If acid strength is not high enough, it loses the ability to act as a catalyst. This allows polymer production to increase, which further reduces acid strength in a condition called 'acid runaway'. If this downward spiral of acid loss takes hold, the unit must be taken offline, inspected and the acid completely replaced.

For an HF alkylation unit, effective and efficient operation means the maximum volume of alkylates is being produced with the lowest amount of contaminating polymers and maximum HF acid recovery. Achieving this condition requires careful control of the isobutane to olefin ratio (I/O ratio) and acid strength. Maintaining the correct I/O ratio depends on having precise control of the return flow from the draw tray, which means having a reliable and precise level measurement.

An outage of the HF alkylation unit caused by acid runaway incurs the cost of replacing the acid, performing the inspection, and the lost production for the unit – plus the costs of other blending agents used in place of the alkylate to maintain gasoline production during the outage. All of these costs mount up quickly and can move well into the millions of dollars in a very short time.

Exploring different level technologies

In one US refinery, the instrumentation engineering team was trying to find an alternative to the existing nuclear level instrument. After some research, the team settled on guided-wave radar (GWR). This technology (see 'Understanding GWR technology' sidebar on p. 46) offered some interesting benefits for this application:

- GWR works well in bridle installations, although the bridle for this unit would have to be modified to allow mounting the transmitter and penetration of the probe. At the same time, the nuclear level instrument could be left in place and remain fully operational as the radar would not interfere with those readings.
- GWR is not affected by changes in density.
- GWR is precise through a variety of operation conditions.
- GWR is unaffected by X-rays.
- A unit can be made in appropriate alloys, able to withstand the corrosive conditions.

The main drawback was a concern that the dielectric constant (DK) of the liquid would be too low, resulting in

Understanding GWR technology

Over the last decade and more, radar level instruments have become increasingly popular as effective top-down measuring methods for liquids and solids in tanks and vessels. Many radar methods use time-of-flight to calculate distance based on the time required for a microwave pulse to be sent to the liquid or solid surface and reflected back to the instrument.

Non-contacting designs simply send the microwave pulse into the open head space of a tank or vessel and listen for its return. These designs offer many advantages as they do not come into contact with the process medium.

GWR also uses a microwave pulse, but sends it down a probe made of a metal rod or cable, which serves as a wave-guide. The pulse does not spread and is not reflected by other equipment inside the vessel. And since the pulse follows the wave guide, it can even be used for interface measurements of non-mixing liquids such as oil and water.

GWR is particularly useful in problem applications where turbulence and foam make reflected readings difficult to quantify. Radars are unaffected by changing density and many other unpredictable application characteristics.

erratic or unreliable reflections. Ultimately, the decision was to proceed with the belief the DK would be high enough.

Modifications were made to the bridle during a brief shutdown, and Emerson's Rosemount 5301 GWR level transmitter with a 7 ft long probe was installed. The wetted parts of this unit were made from Alloy 400 to survive the environment.

Performance in a difficult environment

The initial performance was promising and proved the DK was not a factor. However, after approximately six months in service, the GWR began behaving erratically. The fear was the corrosive product may have made it past the standard O-rings into the probe seals and could be affecting the microwave path.

The company provided a new unit, this time with DuPont Kalrez O-rings. Once reinstalled, everything returned to normal, at least for a while. After a year, the same problem emerged. It became clear that a more comprehensive solution would be needed.

Working with engineers in Sweden, the decision was made to try a completely different seal system that had no O-rings. The new system used alumina ceramic as the primary seal material, with PTFE sleeves and graphite gaskets. The new design also included a secondary seal to ensure a gas-tight connection and avoid any escape of HF.

This new assembly was installed more than two years ago and has presented no sign of issues. Since then the alkylation unit has been stable, maintaining production with high-quality alkylate products, in large part due to the reliable and accurate level measurement delivered by the GWR instrument.