Oil/water interface control for desalters

Profiling instrument provides vertical real-time phase density measurement in desalter vessels. Benefits include reduced process upsets from interface excursions, optimisation of crude blends, minimisation of chemical usage and reduction in chloride carry-through

Paul Hewitt
Tracerco

Within many refineries there is a growing tendency to process heavier crudes or blend these with lighter feedstocks. During crude oil refining, it is advantageous to optimise the blend to reduce overall feedstock costs, while at the same time ensuring the final mix can be adequately processed with minimal upset.

One fundamental need within a refinery process is the efficient separation of wastewater from crude feedstock using a desalter vessel after water washing the material to reduce chloride levels. In order to optimise this separation requirement, appropriate vessel and internals design must be used alongside reliable level and interface instrumentation.

When applied to the relatively “dirty” service experienced within a desalter, a number of existing level and interface control instruments have been found to demonstrate many shortcomings. Upon a request by a major oil refiner, the proprietary Tracerco Profiler instrument was redesigned. This instrument is commonly used in three-phase separation devices within the upstream oil and gas industry to withstand the elevated operating temperatures typically experienced in a desalter vessel.

Common instruments used in desalter vessels

There are many types of level and interface instruments available that have been used to measure critical levels within desalter vessels. The most common include displacement systems, differential pressure, capacitance probes, microwave, guided wave radar, ultrasonic, thermal conductivity and nuclear. Out of this list, only four have shown reasonable reliability for interface measurement. These include displacement, capacitance, guided wave radar and nuclear. However, there are distinct limitations for these instrument types when a rag layer/emulsion band occurs in the desalter. The principles of measurement of these instruments are examined in more detail, including:

- Capacitance probes
- Displacement interface gauges
- Nucleonic gauges
- Guided wave radar.

Capacitance probes

Capacitance probes operate by measuring the electrical characteristics of fluids that they contact. As an interface level rises on the probe, the measured capacitance changes as the probe goes from complete immersion in oil (0% on the interface level range) to complete immersion in water (100% on the interface level range). One problem with this method of measurement is that if the electrical characteristics of either fluid change significantly from the expected values, as will happen when different feedstocks are introduced to the vessel or when emulsions/rag layers are formed, the capacitance measured may change. This in turn can be interpreted incorrectly as a change in level to operators and inappropriate control actions taken. In addition, capacitance probes only measure a very small distance into a particular fluid. If the process material being measured is dirty and prone to surface coating, it can be rendered inoperable. As the capacitance measurement requires contact with the process fluid, any failure requires a shutdown for repair.

Therefore, this type of instrument is most suited to measurement within fluids that are relatively clean and not prone to solids deposition. It is also advantageous to have a well-defined step change in density. In practice, this is rarely the case in a desalter.

Displacement interface gauges

Displacement instruments have been the most commonly used instrument within desalters for interface-level control for many years. The instrument consists of a submerged body (displacer) suspended in the fluids, the weight of which is balanced by an upward force exerted on it by a particular density of fluid. As the level changes, the force increases or decreases, and this results in a vertical movement of the displacer, indicating a change in interface level.

The force exerted depends on the density of each fluid; therefore, if this characteristic changes significantly, the density change will be interpreted as a change in level. If the displacer is immersed in an emulsion, it will give an output corresponding to the elevation of a particular emulsion density, but will not allow the extremities of the interface emulsion layer to be determined.

Within desalters, an internal displacer is normally installed in the vessel using a stilling well. The stilling well provides protection for the suspended displacer tube and allows the measurement of “in vessel” conditions to be made, as opposed to an external bridle system, which may not necessarily mimic true fluid levels. The major drawback when using an internal displacer as opposed to a bridle-mounted displacer is maintenance. If a problem occurs with an internal stilling well instrument, the only way to get access is to shut down, depressurise the vessel and remove the instrument. Obviously, this is undesirable in a continuous refinery operation. One other common issue that has occurred in past
applications concerns the use of moving parts in dirty service conditions. At times, displacement systems have experienced solids build-up, resulting in them sticking at a specific point within their measurement range.

**Nucleonic instruments**

Nucleonic interface gauges use a radioactive source, which is mounted internally using a sealed 1in pipe that looks similar to a thermowell. The radioactive source is located at the end of the pipe inside the vessel. An external radiation detector is on the outside of the vessel close to the internal pipe. Figure 1 shows a typical arrangement.

When the radiation passes through the phase of lower density, the signal intensity at the external detector is high. When the denser phase increases in height, the radiation intensity at the detector is reduced. Through calibration of the system using the densities of both fluids involved, the interface position within the vessel can be measured and controlled.

However, the instrument essentially measures the elevation of fluid having a density that is the average density of the upper and lower phases. It therefore provides an accurate indication of the elevation of both a clean interface and the midpoint of a diffuse emulsion band, but it does not provide information about the depth of an emulsion layer.

**Guided wave radar**

Guided wave radar works in much the same way as conventional radar. An electromagnetic energy signal is transmitted from an antenna. When it reaches a definitive interface point, some of this energy is reflected back. Time domain reflectometry measures the transit time to this point and back, allowing calculation of the interface position. The system utilises a guide that is in contact with the liquids. This is used to transmit the electromagnetic radiation pulses to reduce signal degradation through the liquid. The technology relies upon back-reflection of the signal from the interface position.
Unless there is a clearly defined interface, there will be no point at which this will occur. Unlike displacement, capacitance and nuclear instruments, which will measure an approximate or average interface position when a rag layer is present, the signal from guided wave radar technology may continue to the bottom of the vessel and no interface measurement will be observed.

Density profiling technology
Density profiling technology can define all fluids inside a separation vessel to a greater degree than conventional instruments. It measures the density and extent of different phases within a vessel. It maps different densities of materials such as gases, liquids and interface spans between phases. These materials can be separated into different user variable-density bands or phases. The interface of the various phases can then be calculated with respect to the vessel height.

In place of traditional single-point measurements for interface and bulk level, an operator can measure the position of each phase in real-time and determine the quality of each interface. This level of measurement gives the operator confidence to increase fluid throughput and minimise the use of various separation-enhancement chemicals. The information provided can also be used to automatically control interface levels in a DCS system and influence the injection of effect chemicals.

A density profiler is housed in dip-pipes (sealed pockets similar to thermostwells) installed within the vessel through a single flange, as shown in Figure 2.

A narrow dip-pipe holds an array of Americium-241 sources, Americium-241 being a low-energy gamma emitter commonly used in domestic smoke detectors. The other dip-pipes hold radiation detectors made up of a vertical array of up to 150 Geiger Muller (GM) tubes, each one 28mm in height. Each tube is matched to the radiation source on the same plane, as shown in Figure 3. On the screen, the fluid density at each 28mm channel is depicted.

Principle of operation
Radioactive level measurement methods are normally based on the absorption of radiation. The absorption principle utilises the reduction in radiation passing through the process material with increasing density. The difference in absorption for radiation passing through oil, water and solids is sufficiently large to detect interface levels. Ion tubes (eg, GM tubes) detect the radiation passing through the process material. An ion tube is a gas ionisation detector. An electric field is applied between two electrodes in a gas (eg, argon) filled tube. Radiation produces an ionisation process in the gas and, because of the electric field, the free electrons and positive ions produce an electric current or a voltage pulse frequency that is proportional to the amount of incident radiation.

A scintillation detector can also measure absorbed radiation. A scintillation detector emits light pulses when subjected to ionising radiation, and the light pulses produced can then be detected by a photomultiplier.

The absorption principle was chosen for the density profiler together with GM tubes for the measuring device, as they offer greater reliability than photomultipliers and are more stable under temperature fluctuations. GM tubes are smaller in size, more rugged and less expensive than scintillation detectors.

Titanium and Americium
Titanium was chosen for the dip-pipes, as due to its density it is relatively transparent to the low-energy 60KeV radiation emitted from Americium-241 sources. If steel dip-pipes were used, the radiation employed would require a higher energy, such as a Cs-137 source with a 660KeV gamma energy. This high-energy radiation is less sensitive to density changes. This would make it necessary to employ a much larger source-to-detector separation, in the region of 500mm, between the dip-pipes (ie, more than one vessel nozzle would be required). In addition, because the radiation from Cs-137 is difficult to shield, the beam from each source would appear as a patch of significant size at the detector assembly. This makes it difficult for a Cs-137 device to provide the same vertical resolution (28mm between discrete density measurements) that is normally obtained from an Am-241-based profiler.

It is the use of low-density, high-strength titanium for the dip-pipes that makes it possible to use low-energy
Amercium-241 sources in the profiler. An Amercium-241 profiler requires only a small source/detector separation. This means that only one vessel nozzle needs to be utilised. Moreover, because Am-241 is easy to shield, it allows for excellent vertical resolution and hence provides a highly accurate density profile.

The material between the two dip-pipes will attenuate the radiation, so the intensity of radiation seen by a GM tube is related to the density of the intervening material. Each sensor produces a train of voltage pulses as its output signal. The rate at which these pulses are produced is directly proportional to the intensity of the radiation incident on the sensor, which is determined by the density of the process fluid at the sensor elevation.

Pulses from the GM tubes are counted in the signal processor unit mounted above the dip-pipe assembly. The count period is user selectable so that the random nature of the radiation pulses can be smoothed out.

These counts are transmitted for analysis via a fibre-optic link and an RS232 converter to a PLC that collects the information and calculates the density of the material for each individual GM tube. Thus, a density profile of the vessel can be achieved. Density bands are allocated for each of the different phases; the top level of these phases can then be calculated with respect to vessel or instrument height. These heights and phase-band thicknesses can then be used to control the process. Instrument setup is shown in Figure 4.

**Profiler application in desalters**

As previously mentioned, the Tracerco Profiler has been widely used in many upstream oil and gas separation applications over the past few years. However, it had never been used within a desalter due to temperature limitations. Typical desalter temperatures are above the allowable intrinsically safe certification temperature of 125°C.

In 2004, a major refiner approached Tracerco to determine if a profiling unit could be modified to operate at temperatures up to 250°C. The solution was to use the existing profiler design that had been well proven in the field at lower temperatures, with the addition of a cooling jacket around the detector tube. The cooling fluid is designed to flow at about 3–5 gallons per minute (gpm) through an annular space between concentric pipes. The inner pipe contains the detector array. The coolant is then piped through a separate ½in titanium up-pipe to an outlet at the top of the Profiler.

A closed loop cooling system was used, providing continuous coolant to the Profiler. The coolant system was tested with a range of flow rates and found to be very efficient.

The unit was commissioned in the first-stage desalter vessel in spring 2005 as a part of a crude unit turnaround (Figure 5). The installation required an 8in nozzle to be fitted to the vessel at an appropriate position. The system was designed to allow measurement within the water phase up through the interface and into the lower grid of the desalter vessel.

The use of the Profiler started in spring 2005. After a short time, the operations group began to utilise the device as the primary interface-level indicator. A typical instrument output from the desalter is shown in Figure 6. By mid-year 2005, using real-time data from the Profiler, the operations team was confident enough to raise the oil/water interface higher in the vessel, very close to the lower electrostatic grid. Once this was achieved, it was quickly observed that a much smaller rag layer was present with clean outlet water and no process upsets. Once the electrostatic grids were able to perform efficiently, the Profiler was used to carry out a series of optimisation tests that resulted in:

— Operator confidence to run the interface level at or within the lower electrostatic grid, thus optimising separation of difficult blends
— Increased upstream desalter mixing to enhance the removal of chloride carry-over to downstream vessels, thus reducing corrosion and fouling issues. This has reduced the carry-over of chloride levels from 3–4 ppm to 1–2 ppm
— Increased blending ratios of lower-quality crudes with enhanced margin of refined products
— Optimisation of emulsion, water clarifier, neutraliser and asphaltene stabiliser-reducing chemical use within the desalting process, leading to considerable cost savings
— The elimination of process upsets resulting from water carry-over or oil carry-under from the desalter vessel.

**Benefits**

The conventional Profiler system has been redesigned for use within high-temperature desalter systems. Over the last two years of operational life, it has allowed the accurate measurement of phases, including oil, emulsion (rag), water and solids/sludge in real-time. The cooling system associated with the system has also proven itself to be robust and efficient at maintaining detector temperatures at appropriate levels with minimal maintenance requirements.

The experience gained from use of the instrument has resulted in a number of benefits, including the elimination of unplanned desalter shutdowns, reduced chemical usage, increased fluid throughput and the ability to handle more challenging blended crudes.

Due to the success of the Tracerco Profiler in the first-stage vessel, a second instrument has recently been installed in the second-stage vessel in order to fully optimise desalting operations in the facility.

The Tracerco Profiler (TRACERCO Profiler) is a mark of Tracerco.

**References**

1 Lees R P, Charlton J S, Synetix — dialog alliance — the future of three phase separation control, presented at the SPE Asia Pacific Oil and Gas Conference and Exhibition, Melbourne, Australia, 8–10 October 2002, SPE 77891.

Paul Hewitt is president for Tracerco Americas in Pasadena, Texas, USA, where he manages the Tracerco business covering Canada, USA, Mexico, The Caribbean and South America. Hewitt graduated in 1989 with a degree in chemistry, together with a diploma in industrial studies from Loughborough University, UK.

Email: paul.hewitt@tracerco.com