Ultrasonic Flow Meter Proves its Worth on Vacuum Tower Bottoms

Rainer Wetzel, Sales Director, FLEXIM GmbH Wolfener Str. 36, 12681 Berlin, Tel: 0049-172 3299004 Email: rwetzel@flexim.com

Process conditions at the bottom of vacuum distillation towers make flow measurement challenging. In this case study, a clamp-on ultrasonic flow meter proves more reliable than the traditional orifice plate.

Operating at temperatures of around 350°C, the bottom of a vacuum distillation tower is no place for delicate instrumentation. To measure the flowrate of vacuum residue or bitumen, refiners therefore traditionally rely on differential-pressure (DP) devices such as orifice plates or venturis. These are simple, robust, and economical in line sizes above 200 mm.

Unfortunately, simplicity and robustness do not always imply accuracy or reliability. The biggest problem with all DP devices is the need for a pair of impulse lines connecting the sensor to the DP transmitter. Impulse lines often become plugged with particles of solid material such as coke, or bubbles of gas. In bitumen service, blockages are most commonly due to frozen product – a particular problem in cold climates, despite trace heating.

Faced with unreliable orifice plates, one refiner sought a better way to measure the flow of bitumen leaving a vacuum tower on its way to a delayed coker. In this case the product starts life as crude bitumen which is diluted with lighter hydrocarbons to create a synthetic crude. The lessons learned, however, apply equally well to refined bitumen produced in the vacuum distillation of conventional crude.

Versatile Technology

The refining company decided to try a clamp-on ultrasonic flow meter as a way to make flow measurement more reliable. The main rationale for the experiment was that because ultrasonic flow meters are non-invasive and do not require impulse lines, they cannot become clogged or blocked. Other important features of this flow measurement principle are that it is independent of system pressure, works with practically any fluid, and remains accurate over a wide turndown range (see boxes).

The company first carried out several tests with a portable ultrasonic flow meter, allowing it to select the best transducer type and positions for the job in hand. Once the engineers were confident that the new technology would perform well, they installed a permanent clamp-on ultrasonic flow meter on the 400 mm pipework connected to the bottom of the vacuum tower.

The complete system comprised two sets of FLEXIM Type G low-frequency ultrasonic transducers with high-temperature mountings, and a Fluxus® ADM 7407 transmitter with two input channels . The transmitter communicates with the refinery's distributed control system (DCS), making it easy to compare the readings from the ultrasonic flow meter with those of the flow transmitters linked to the three original orifice plates (Figure 1).

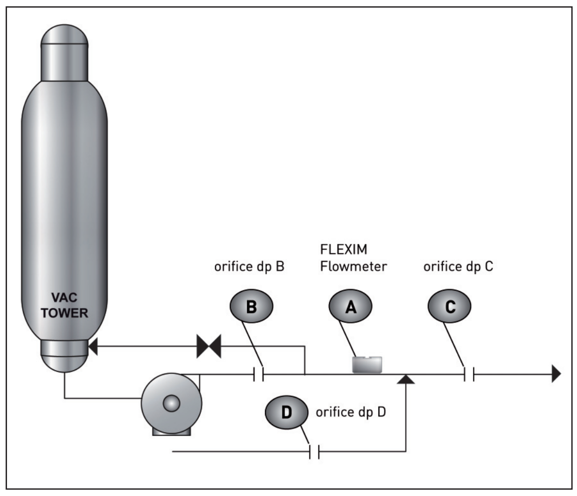


Figure 1: The FLEXIM ultrasonic flow meter (A) in position on the 400 mm discharge line from the bottom of the vacuum tower. B, C and D are the original orifice plates with flow transmitters

Sound Performance

The trial took place from December 2008 to April 2009.

Figure 2, which represents a period of 24 hours, shows that the FLEXIM flow meter (A, red line) provided reliable and consistent readings, albeit with short-term spikes caused by the presence of gas bubbles. Orifice plate B (green), in contrast, was noisy and unreliable due to problems with freezing of the impulse lines. Ignoring noise, the readings from the ultrasonic flow meter agreed well with those from orifice plate B.

The flowrate as calculated by subtracting the reading of orifice plate D (light blue) from that of orifice plate C (dark blue) (Figure 1) was consistently higher by around 10% (44 bbl/h) than that measured by the FLEXIM flowmeter and orifice plate B. The accuracy of the FLEXIM flow meter under ideal conditions is ±1.6% of reading; the trial did not attempt to establish its accuracy under real plant conditions, but this is likely to be considerably better than that of an orifice plate and DP transmitter.

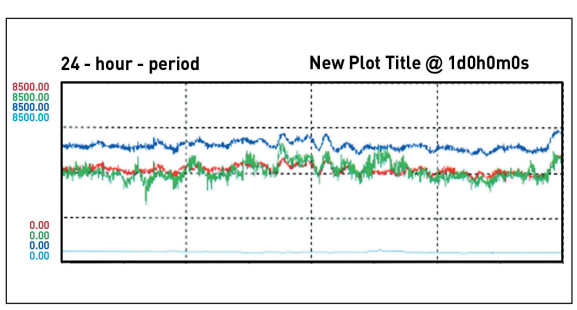


Figure 2: The FLEXIM flow meter (red line) agrees well with orifice plate B (green), but is much more reliable. Flowrate trends shown by orifice plates C (dark blue) minus D (light blue) show a consistent discrepancy of around 10%

Figure 3 shows the same comparison over the first month of the trial. The reading from the ultrasonic flow meter shows spikes, occasionally very large, due to gas bubbles – but it is clearly more reliable and stable than the measurements from orifice plates B and C.

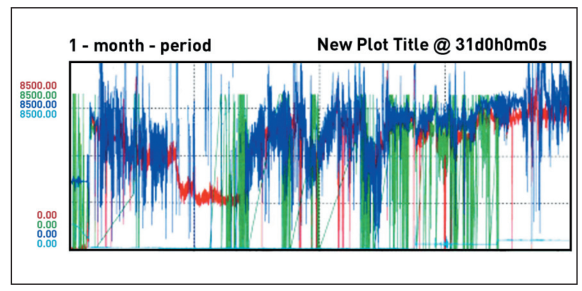


Figure 3: Over one month of challenging conditions, the reading from the FLEXIM flow meter (red) is much more stable than that of orifice plates B and C (green and blue, respectively)

Figure 4 shows the results for another one-month period, this time between 15 March and 15 April. By the beginning of April ambient temperatures are above freezing, and the stability of the readings from orifice plates B and C improves accordingly. Regardless of temperature, however, the FLEXIM flow meter is more stable than either of the two main orifice plates.

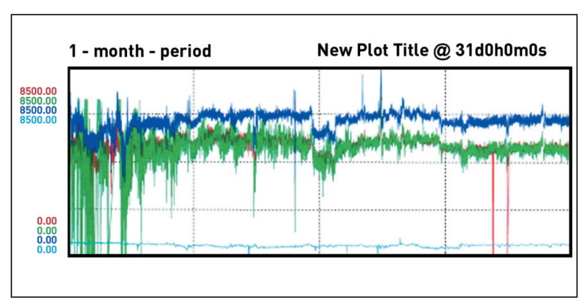


Figure 4: As ambient temperatures climb above freezing, the orifice plates become more reliable, though still not as reliable as the FLEXIM flow meter

Permanent Placement

By the end of the trial the refiner was sufficiently impressed with the ultrasonic flow meter to make it a permanent installation, further increasing measurement reliability and reducing maintenance costs.

The company concluded that for bitumen and high-temperature service the FLEXIM clamp-on ultrasonic flow meter is more reliable than an orifice plate with a DP transmitter. This is true at all times, but especially during freezing weather, when impulse lines are especially likely to block.

The fact that it can be installed without shutting down process makes the ultrasonic flow meter ideal for retrofitting to existing plants.

The Author:

Rainer Wetzel is Sales Director at FLEXIM GmbH and has over 20 years of process instrumentation experience, especially in the field of flow measurement. Since several years Mr. Wetzel analyses oil & gas processes for possible FLEXIM operations.

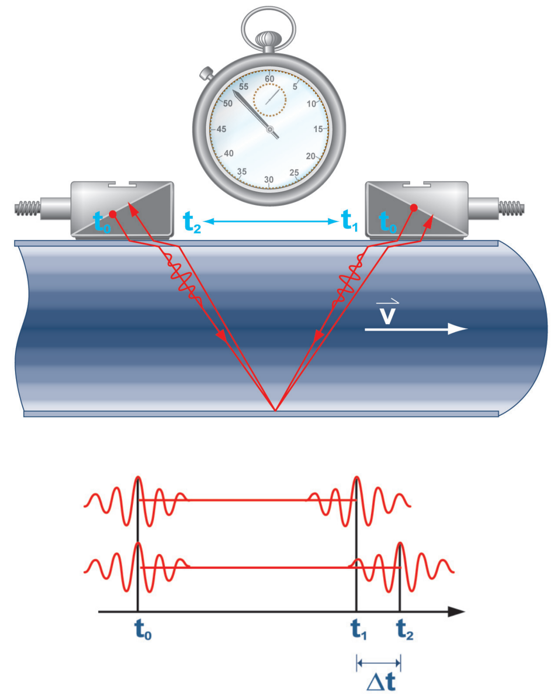
How ultrasonic flow meters work

Ultrasonic flow meters use beams of high-frequency sound to measure the velocity of moving fluids. They come in two kinds: Doppler and transit-time.

Doppler flow meters measure the frequency shift that occurs when ultrasound is reflected by bubbles or particles in the moving fluid – the same principle as a radar speed gun.

Transit-time (time-of-flight) flowmeters like the FLEXIM design rely on the fact that the apparent velocity of ultrasound waves through the fluid depends on whether they are travelling with or against the direction of flow. The ultrasound transmitter and receiver can be mounted on opposite sides of the pipe, or on the same side; in the second case they are arranged so that the ultrasound reflects off the far wall of the pipe. Alternate ultrasound pulses travel in opposite directions: once with the flow and once against it.

Since the velocity of sound in the process fluid is known, the difference in transit time (ΔT) in the two flow directions gives the average flow velocity across the pipe. When the pipe diameter is known, it also gives the volumetric flowrate.



Ultrasound Advantages

The ability of ultrasound to travel through pipe walls and other solid materials allows the ultrasonic transducers to be attached to the outside of the pipe.

This brings some significant advantages:

- The flow meter can be installed without shutting down the process.
- Installation is quick and simple, with no need for drilling, cutting or welding, no reduction in the integrity of the pipework, and no need for impulse lines or trace heating.
- The inside surface of the pipe remains smooth, with nothing to cause blockages or increase pressure drop.
- With no direct contact between the transducers and the process fluid, erosion and corrosion are avoided, and maintenance needs reduced.
- Corrosive fluids, high temperatures and high pressures can all be handled safely. Special mounting brackets allow FLEXIM transducers to work reliably at process temperatures up to 400°C.
- With no moving parts, the transducers are highly reliable.
- Multi-beam technology, with two input channels and two sets of transducers, increases accuracy by averaging flow velocity in two directions across the pipe.