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APPLICATIONS OF ULTRASONIC FLOW METERS IN THE PETROLEUM INDUSTRY

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With the recent advances in electronics, the ultrasonic flow measurement technology was the one with the greatest development, allowing a wider use of these flow meters in various applications in the petroleum industry.

The measurement of gas and oil at the inlet (import) and outlet (transfer) points, among other internal applications on an oil production platform, is essential for the volume balance and a good control of several properties of the fluid to be transferred.

A critical point in this balance is the calculation of the flared gas volume. Ultrasonic technology is able to do it, even considering critical flow rate conditions, big diameters, low pressures and huge turn-down, thus permitting a better process control.

Some types of multibeam ultrasonic flow meters for liquids present very low uncertainty, allowing their use as a reference (calibration) flow meter. Due to this feature, this type of meter presents great advantages in applications such as custody transfer, tanker offloading, transfer lines with high flow rates, etc.

It should be highlighted that the ultrasonic flow meters have no intrusive moving parts, therefore minimizing the head loss. This characteristic confers an additional benefit to the flow meter, so that it needs less frequent maintenance, if compared to the traditional mechanical flow meters, such as positive displacement and turbine flow meters.

The objective of this paper is to present some oil and gas applications of ultrasonic flow meters, which have generated advances in operational control, reliability in flow measurement, besides an updating of this new metrological scenario in Brazilian oil sector.

1 INTRODUCTION

Ultrasonic technology for measuring oil, gas or refined product flow rates has shown a great development in the petroleum industry lately. Some tests accomplished with petroleum operators and independent metrologic laboratories have proved this evolution, approving these meters even for custody transfer.

Some of the main advantages of the ultrasonic flow meters are their use in pipes with big diameters at a lower cost, with no need of protection filters and practically no additional head loss.

With the increment of the Brazilian oil production, through new projects, such as Marlim, Albacora, Barracuda and Roncador, there is a tendency of a growing use of sea terminals, via tanker systems of big flow rates and big size pipes, where this technology appears with vast advantages.

Considering the possible partnership of new petroleum operators for developing these fields and the possibility of a shared measurement, the search for a more advanced technology becomes necessary in order to minimize the uncertainty to meet the world's metrological requirements.

2 CLASSIFICATION OF ULTRASONIC METERS

The physical operational principle of the ultrasonic meters is based on the propagation of waves of ultrasound, emitted within frequencies of 150kHz to 3 MHz, through a fluid.

Generally, two basic principles determine the way a sonic propagation is sent and interpreted, characterizing the method of measuring by means of ultrasound. They are namely (a) the Doppler effect, and (b) the transit time effect.

The measurement principle called Doppler effect makes use of the continuous transmission of a single frequency rather than pulses. The sound beam is propagated into the flowing medium at some angle to the flow. Small inclusions of bubbles, solids, or eddies in the flowing medium reflect or scatter the sound back to a receiver. If there is any motion of these inclusions, there will be a shift in the frequency (Doppler shift) of the returned signal. Each particle or “scatterer” reflects sound while it is in the sonic field of the transmitter. The difference between the transmitted and the received frequencies is proportional to the motion or the scatterer (flow).

The principle called transit time consists of determining the time difference between the emitted and the received sonic signal. These flow meters transmit a pulse in a given direction and record the time of arrival of the pulse on the other end of the acoustic path. They then transmit a pulse in the opposite direction and record that time of arrival. The difference between the two time measurements provide information on the motion of the fluid in the flow path.

Ultrasonic flow meters may be manufactured in a spool, with one to five pairs of transducers, or they may be manufactered as a "clamp-on" meter. The diverse models encountered on the market present different characteristics and uncertainty inversely proportional to the number of pairs of transducers (for multibeam meters). The most commonly used principle in the petroleum industry is transit time, for it presents a much smaller uncertainty than the Doppler effect.

The current models of ultrasonic flow meters may be classified as follows:

Table 1. Classification of ultrasonic flow meters

Type	Class
Doppler	--
Transit time	• Intrusive (in a spool) ➢ 1 beam ➢ 2 beams ➢ 3 beams ➢ 4 beams ➢ 5 beams • non-intrusive ("clamp-on")

3 APPLICATIONS OF ULTRASONIC FLOW METERS FOR LIQUIDS

Several applications of the ultrasonic flow meter as a liquid flow meter is presented below.

3.1. Applications at MOT (Maasvlakte Oil Terminal)

MOT is located in Rottterdam, Holland, and defends a position of the biggest sea terminal in Europe, with a capacity of 8 320 000 m^3 (36 tanks of 120 000 m^3).

This terminal receives crude oil from the operators Shell, British Petroleum, Exxon, Total, P8 and Pakhoed, exporting it to some refineries.

In this application, the ultrasonic flow meter is used for:

- Balance;
- Identification of fluid change (oil and water), from each specific sonic speed;
- Control of loading and offloading of tankers.

During the offloading operation of tankers, not only the product flow rate but also the total volume are continuously measured and the sonic speed is monitored. The total volume measured

is compared with the value informed by the tanker and with the level readings of the terminal tank.

The measurement of the sonic speed, using the ultrasonic flow meter, permits the identification of different products. In this application, the precocious detection of water helps prevent non-programmed emergency stops of the refinery.

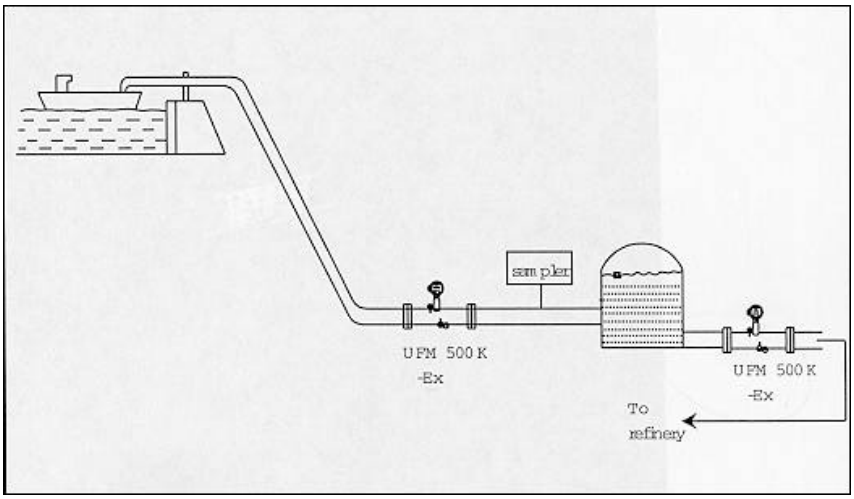

Figure 1. Oil Unloading at MOT

3.2. Application at Nerefco (Netherlands Refining Company)

Nerefco is a joint venture of the British Petroleum group (65%) and Texaco (35% share), established in 1989. It is located in Rotterdam, Holland. It has two production sites (Pernis and Europoort) and one distribution site (Botlek). The complex located in Europoort owns dozens of tanks, with a total capacity of 3.5 million m^3 for stocking oil and end products. It has 8 jetties for loading products for sea transport. Supertankers up to 256000 tons may unload crude oil to Europoort.

The complex located in Pernis has 80 tanks, with a total capacity of 800 000 m^3 of crude oil and end products. Most of the products is transported in barges from 4 jetties.

In this application, the ultrasonic flow meter is used for:

- Measuring LPG;
- Measuring naphta;
- Measuring gasoline;
- Measuring kerosene;
- Measuring diesel;
- Measuring fuel oil.

Botlek site is basically used as a stocking and loading center of gasoil and fuel oil. These products come from the Europoort site, via pipelines.

3.3. Application at Saga

Saga is the third biggest operator in North Sea, settled in Stavanger, Norway.

In this application, the ultrasonic meter is used for continuous custody transfer, traceable by NPD (Norwegian Petroleum Directory). This maritime unit processes 18 000 m^3/d of oil to Statoil and 12 000 m^3/d to Gulfaks. The oil comes from two different fields (different customers), in independent separation trains, and is exported to two other different operators (Statfjord and Gulfaks).

With great experience in offloading, Saga has been replacing turbine flow meters by high accuracy ultrasonic meters (0.15% uncertainty), due to the high reliability of this equipment, as well as low maintenance cost and less calibration frequency.

Presently, it is necessary to calibrate the export flow meters each 4 days, due to the strict calibration control demanded by NPD. Nevertheless, Saga has been logging the calibration history of the ultrasonic meters in order to prove that they do not fail the calibration, thus eliminating the need of a prover.

3.4. Applications at Dow Chemicals

This plant is located in Terneuzen, Holland.

Dow Chemicals operates with high accuracy ultrasonic meters, in place of mass flow meters, for custody transfer of cumene (liquid product) in offloading. This replacement resulted in a significant economy, thus allowing only one flow meter to do all the job, instead of three mass flow meters, besides the reduction of head loss and the installation simplification.

Besides this application (offloading), Dow Chemicals uses clamp-on ultrasonic meters for leak detection.

Figure 2. Camp-on ultrasonic meter used for leak detection

The error detected in cumene custody transfer, at 0.7 cSt viscosity, 170°C, 7 bar, in a 10-inch pipe, was between -0.10% and 0.04%, according to Figure 3.

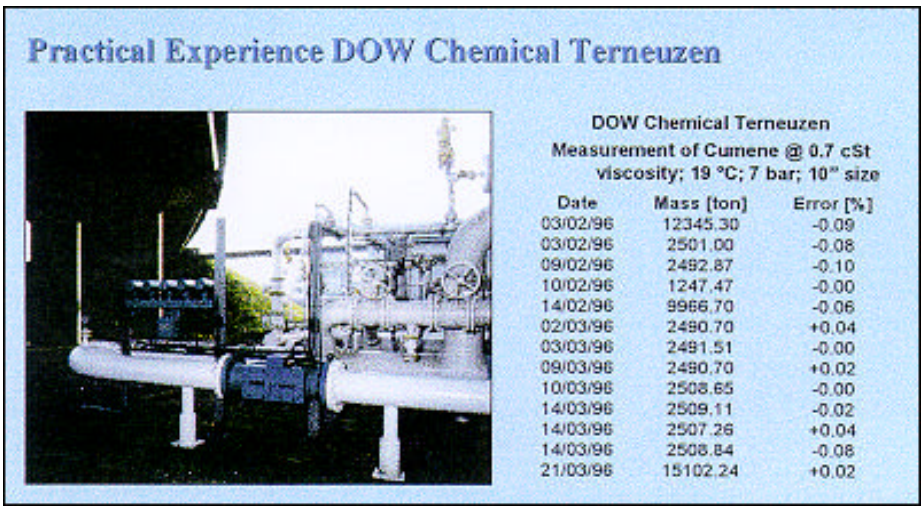

Figure 3. Custody transfer of cumene, at Dow Chemicals.

3.5. Applications at Shell

With the new technology of ultrasonic measurement, Shell's tendency, within the petrochemical domain, is to substitute the ultrasonic flow meters for mass flow meters, in pipes with sizes bigger than 4 inches, besides using only ultrasonic flow meters in new projects.

Considering the use of ultrasonic meters for liquids, a comparative test was accomplished with a turbine meter, a prover and a high accuracy ultrasonic meter (a 5-beam flow meter), all in series, for measuring diesel, gasoline and naphta. The results showed that the prover could not reach the low uncertainty and the high range of the ultrasonic meter. A repeatability problem with the prover was also identified.

Other advantages of the ultrasonic meter tested by Shell are:

- Viscosity independence of the fluid;
- No need of frequent calibration;
- Direct measurement of basic quantities (time and distance).

Proving these qualities, through history logging, NMI recognized the use of the ultrasonic flow meter tested for custody transfer in offloading for Shell.

Besides the application of this meter for liquid, Shell also uses it in boiling vessel control systems, for dosing the fuel gas.

4. APPLICATIONS OF ULTRASONIC METERS FOR GAS

The ultrasonic measurement of gas offers a great performance for the measuring system and a better control of the process.

This type of flow meter has presented a great development lately. The following advantages may be highlighted:

- High turndown;
- Negligible head loss;
- Less operational cost;
- Higher operational safety;
- Real-time measurement;
- Bidiretional measurement;
- Installation and withdrawal of the transducers in operation.

Recently AGA (American Gas Association) published AGA 9 Report, recommending this technology for custody transfer.

Figure 4. Application of ultrasonic meter for gas in custody transfer

Besides measuring gas in high pressure pipes, it is possible to use ultrasonic flow meters in special applications, such as for flared gas. In this case, a higher turndown is needed (sometimes 2000:1), as well as very low pressures and a varied gas composition.

The measurement of flared (burnt) gas has a fundamental importance for the volume balance of the gas in a unit (for instance, a platform).

Figure 5. Application of ultrasonic flow meter for flared gas

5. CONCLUSION

Ultrasonic flowrate meters have presented a great technological evolution in the last decades. This evolution has enabled their use in diverse applications, including oil flow measurement in daily production points, but also in critical situations, such as loading and offloading of tankers, FPSOs, etc., where big sizes, high flow rates and other characteristics such as identification of fluid change are found.

As to the use of ultrasonic flow meters for gas, the recent edition of an AGA report should be highlighted, for it standardizes this technology, and its special application such as measurement of flared gas, where very special conditions are demanded, such as very low pressures, high turndown and transducer withdrawal with no need to stop the flow.

One must bear in mind that there are a lot of different models of ultrasonic meters, with different uncertainties and diverse applications. It is necessary to know well the process characteristics, so that the flow meter may be adequately specified.