ASPECTS OF THE UNCERTAINTY EVALUATION OF ULTRASONIC METERS IN THE PETROLEUM INDUSTRY

Ana Luísa A. S. Ferreira [1]

[1] Petrobras Transporte S.A., Rio de Janeiro, Brazil, anaferreira@petrobras.com.br

Abstract: This paper presents criteria for evaluating the uncertainty of a flow measurement system with ultrasonic meters used in the oil and gas industry. Features of construction of the meters, difficulties and possibilities in different applications are shown to identify parameters of influence. Measurement of liquids and natural gas is included.

Key words: flow measurement, ultrasonic meter, uncertainty.

1. INTRODUCTION

The ultrasonic flowmeter is robust, has no moving parts, operates with virtually all products in the petroleum industry, including oil, oil products and natural gas, and also operates with biofuels. There are meters available in the market for high flow rates, and wide ranges of pressure and temperature. Another feature that attracts the attention of the industry is that these meters produce excellent results when calibrated in the laboratory and therefore they achieve model approval for more stringent accuracy classes.

A few years ago, the ultrasonic meter was introduced to the industry as not requiring calibration and the importance of the upstream meter run was minimized. It is presently known that ultrasonic meters are sensitive to the installation and operating conditions, and the calibration of these meters at the operation is expensive.

Moreover, industry has these meters installed and must have information about their performance and the measurement uncertainty of the results.

2. DESCRIPTION

2.1. General considerations

The transit time ultrasonic flowmeter comprises one or more pairs of transducers. Each transducer sends and receives acoustic pulses in high frequency, transversally to the pipe. The pulse sent in the flow direction (in Fig. 1, from T1 to T2) takes less time than the pulse in the opposite direction (from T2 to T1). The difference between the propagation times will be proportional to the average velocity of the particles on the acoustic path. The ultrasonic meter with multiple paths is, in general, more accurate.

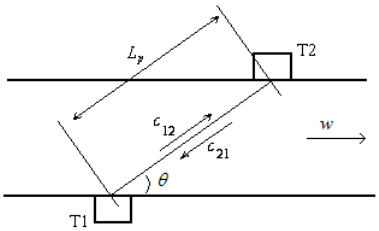

Figure 1: One path of a transit time ultrasonic meter.

The mean velocity in one path ($\overline{w}_T$) is not equal to the mean velocity in the cross-section ($\overline{w}$). Also, the average of all the paths of a meter will not be equal to $\overline{w}$. So, the meter has to be calibrated by the manufacturer.

The meters for natural gas custody transfer are calibrated in the laboratory with natural gas. For liquid custody transfer, the meter should be calibrated at the operation site. The meters used in operational control are not calibrated with the product, only with air (gas meters) and water (liquid meters).

The measurement systems include the flow computer that receives temperature and pressure data and chromatograph data for natural gas or density data for liquids. The results are volume or flow rate at base condition.

2.2. Uncertainty evaluation

The measurement uncertainty of the results sent to the process was calculated based on the equations configured in the flow computer that indicates the relation between volume and pressure, temperature and fluid properties.

The construction of the data-sheet for the uncertainty evaluation follows basically the GUIDE [1] and EA-4/02 [2] indications. The special step is to evaluate the uncertainty due to the differences between the operation and calibration.

Some aspects are discussed in different papers or standards, but they are not quantified.

3. RESULTS AND DISCUSSTION

The procedure presented by AGA 9 [3] for gas measurement indicates the uncertainty for the meter is

composed of the uncertainty in the calibration plus long term reproducibility in the field. Also there are the installation differences between the calibration and operation circuits.

API 5.8 [4] suggests prover volumes for the calibration of ultrasonic meters, larger than the volumes of the provers used to calibrate turbine meters. But the cost would increase. So, a master meter is used, sometimes with a mobile prover, but in other installations, the master meter should be calibrated in another site.

The measurement uncertainty calculation indicated by ISO 12765 [5] focus the meter. For the user it is easer to base the evaluation on meter calibrations.

Ultrasonic meters are very sensitive to the installation [6]. To evaluate de influence of steps (differences between the internal diameter of the ultrasonic meter and the internal diameter of the pipe upstream of the meter) an ultrasonic meter were calibrated in an installation with and without a −3.5% step. The differences between the calibration results were between 0.18% and 0.3% [7]. This information is a way to evaluate parameters of influence and its uncertainty.

In general, the meters of custody transfer measurement systems sent to a laboratory, are to be calibrated with the product it works with. But this does not happen with operational meters.

Zanker [8] indicates it is possible that a low-pressure nitrogen or air calibration might be more accurate than a high pressure natural gas calibration, but this debate has not yet finished.

The differences between the volumes indicated by two new measurement systems with new 3-path ultrasonic meters were around 6% [7], after all the verifications made by the manufacturer, and the expected uncertainty were 0.5%. The meter was calibrated with water and operates with oil products. In this case the uncertainty was really higher than the expected. But the process needs the information. These meters have to be compared by other volume measurements obtained by a dynamic measurement system or by a tank, factors may be used, but the uncertainty of the volumes indicated by these meters will continue high.

Calogirou et al. [9] developed a theoretical flow model to describe a fully developed velocity profile of a gas flow in pipe lines with wall roughness as parameter, and the results confirmed field data that ultrasonic meters are affected by wall roughness changes. Long term wall roughness and incrustation have to be considered.

The procedure used comprises historical data, calibration of all meter involved, calculation of a correction factor and the calculation of the uncertainty of the results sent to the process. Values are assigned to evaluate the uncertainty due to the experience and experiments carried out.

4. CONCLUSION

The recommendation is to calibrate the ultrasonic meters in the local of the operation.

The results of the uncertainty evaluation of a measurement system with ultrasonic meter may differ substantially from one facility to another and depending on the operating conditions, even using the same product. The omission or overvaluation of a factor completely changes the results. For a measurement operational system where the flow meter the uncertainties may be higher than 2%.

REFERENCES

[1] GUIDE: “Guide to the Expression of Uncertainty in Measurement”, 2008, International Organization for Standardization (Geneva, Switzerland).

[2] EA-4/02: “Expression of the Uncertainty of Measurement in Calibration”, 1999.

[3] API 5.8: “Metering: measurement of liquid hydrocarbons by ultrasonic flow meters using transit time technology”, American Petroleum Institute, Manual of Petroleum Measurement Standards, 2005.

[4] AGA 9: “Measurement of gas by multipath ultrasonic meters”. American Gas Association, 2007.

[5] ISO 12765: “Measurement of fluid flow in closed conduits: methods using transit-time ultrasonic flowmeters”. International Organization for Standardization, Technical Report, 1998.

[6] A.L.A.S. Ferreira, “Tecnologia Ultrassônica na Medição de Vazão em Escoamentos Incompressíveis”, D. Thesis, Pontifícia Universidade Católica, RJ, Brasil, 2010.

[7] A.L.A.S. Ferreira, “Effects of ultrasonic flowmeter internal diameter differences on the OSBRA pipeline measurement Results”, Proceedings of the 8th International Pipeline Conference, Calgary, Canada, 2010.

[8] K.J. Zanker, “The Transit Time Ultrasonic Multi-path Gas Meter”, North Sea Flow Measurement Workshop, 2003.

[9] A. Calogirou; J. Boekhoven; R.A.W.M. Henkes, “Effect of wall roughness changes on ultrasonic gas flowmeters”, Flow Measurement and Instrumentation, v.12, pp. 219-229, 2001.