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KEY PARAMETERS OF SELECTION AND CALCULATION OF MEASUREMENT UNCERTAINTY OF CORIOLIS FLOW-METER

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ABSTRACT
A continual development of science, engineering and technology resulted in usage of reliable, durable instruments and devices which maintenance costs are reduced to minimum during their life-time. Nowadays, usage of flow-meter based on the Coriolis force on measuring places is increasing. An everyday flow measurement is known problem of calculation between mass and volumetric flow and it is stressed in fiscal measurement especially in the oil industry. To get accurate mass units from volumetric, beside volumetric meter, it is necessary to include additional measurement apparatus for measurement of temperature, pressure, density and other variables. All mentioned parameters in continual flow process makes calculation harder and in many cases makes uncertainty higher. In this paper, important parameters for proper design and selection of a certain flow meters will be presented. Also, basics of measurement uncertainty will be presented under conditions of relatively low measurement passes as well as basic information about appearing of Coriolis force and Coriolis mass flow meter.
Keywords: Flow measurement, Coriolis mass flowmeter, Measurement uncertainty.

1. INTRODUCTION
Flowmeters are commonly validated by comparing the indicated flow measurement to a reference flow measurement [1]. These instruments are also commonly verified by tracking a secondary variable that is highly correlated to the flow measurement. Coriolis meters have historically used secondary variables to verify performance, e.g. drive gain. Unfortunately drive gain is only loosely correlated with the flow measurement. A method of verification using a known density fluid has been used successfully, but this approach is prone to user error. In response to customer demand for an easy to use meter verification methodology for Coriolis flowmeters, Micro Motion has developed Structural Integrity Meter Verification that uses the onboard electronics to verify the integrity of the flow tube as well as the electromechanical components, the transmitter electronics, and the transmitter software [1, 2]. In situ testing means checking and verification of meteorological features (meaning accuracy, repeatability and stability) flowmeters in real work condition. It means, already installed flowmeter will be verified with working fluid and under working exploitation condition (flow, pressure, working and ambient temperature etc). In situ verification proves the meter in its operating location and therefore indicates the meter's installed performance. There are a different methods of in situ verification and this paper is based on verification of Krohne mass flow meter verified by Compact Prover as a Master meter approved by National Measurement Institution as a working measure etalon [2, 3].

2. CORRIOLIS FLOWMETERS AND SOURCES FOR UNCERTAINTY

Aside from measuring highly accurate mass fluid flowrates, the Coriolis technique offers numerous other advantages. The Coriolis metering principle is independent of the fluid's density, temperature and conductivity, making it very flexible to use. It's also independent of the flow velocity profiles. So, it does not require upstream and downstream straight runs of piping. As a bonus, the flowmeter provides a measurement of fluid density within the tubes. It also includes a temperature sensor to compensate for dimensional and elasticity changes of the tubes with fluid temperature. Lastly, these flowmeters can measure nearly zero flow, where other measurement methods don't work or result in significant measurement errors [4, 5]. Inertial force is a pseudo force (fictitious force), which occurs as a result of the complex motion of particle and is called the Coriolis force. It depends on the value of the transmission movement and the relative movement and it is vertical to the plane on which vectors lie. Typical Coriolis meter, shown in Figure 1, consists of one or two parallel tubes through which the measured fluid flows, impuls generator (electromagnetic exciter) which excites tubes to vibrate and two motion sensors (pickoff displacement) which measure the relative velocity between pairs of tubes at two points equidistant from the center-symmetrical [3,6].

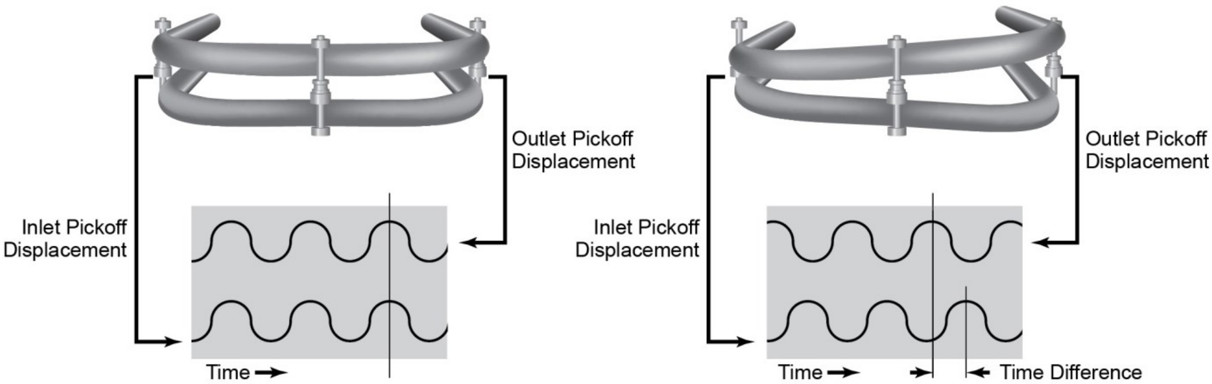

Figure 1. Basic elements of Coriolis flowmeter.

During the flow duration, movement of pipes caused by Coriolis forces, Figure 2, shall result in excitation and shift output sensors which, in contrast to no flow condition, are not in phase with each other. The change in the mass flow will proportionally increase or decrease such shift in stages. Changes in the properties of fluids usually affect the flexibility / elasticity of the oscillating measuring tube.

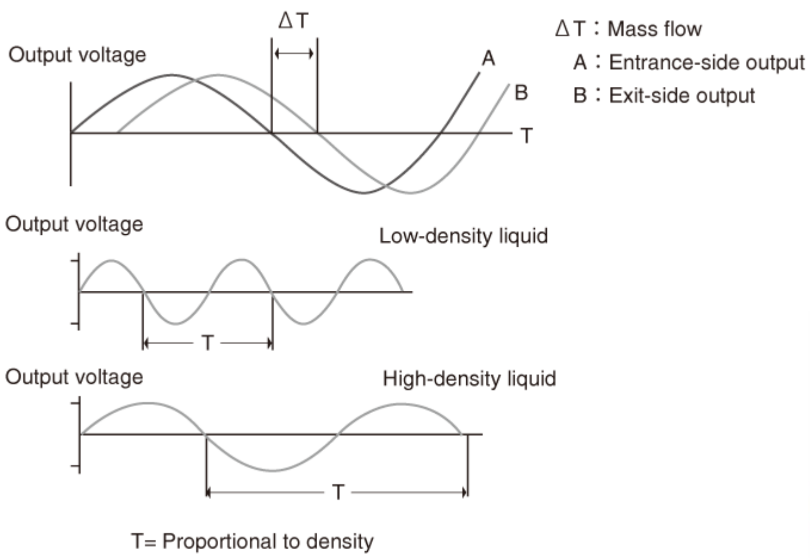

Figure 2. Excitation and shift output sensors

3. ANALYSIS OF RESULTS OF IN SITU TESTING

One fairly common mistake is to accept a volumetric calibration when the flow meter is used for measuring mass flow. The correlation between a volumetric flow and a mass flow is density. If the lab measures volumetric flow rate and does not have a density measurement, then there is no traceability in the mass flow rate and the calibration has no value for a Coriolis meter used for mass transfer. The temperature and the pressure have the most significant effect on the mass flow measurement. The additional factors that may affect the performances criteria can be: the influence of stability of zero meters, gas trapped in the media, external vibration, erosive media properties, coats of paint or dirt inside the measuring tube and the like. The experiments were done in the Refinery Pančevo, where a new system for transferring LPG are designed, and consists of eight measurement points. Upon the meter is calibrated in the factory, installed in the skid, and then the skid is installed in the system, it is done in situ testing. Test phase, in other words, proving is possible in case when a higher class meter or “Master meter" is connected to the space provided for it. Figure 3 shows two schemes: normal measuring mode and proving mode [3]. First one is without connection to the Master meter and the second one is presenting proving mode with schematic flow path through Master meter. When proving, differences can be occurred in the course of converting volume to mass, especially when the Master and main meter are different type of measuring principles (volume or mass flow).

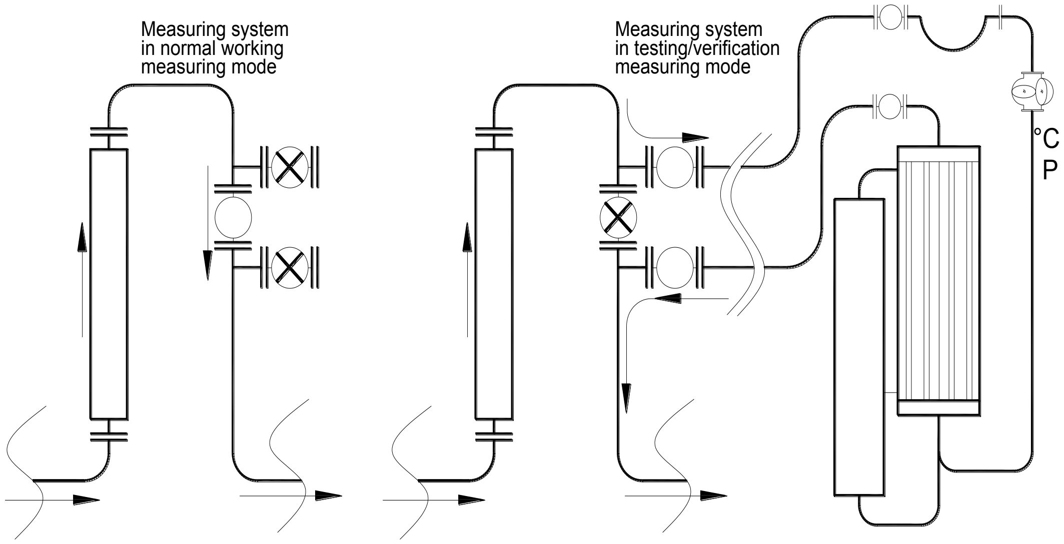

Figure 3.Normal and Proving measuring mode

In order to calculate the mass in a proper manner, it is required to know the density of the fluid. In any case, any prover, even of minimum configuration, has both measurement of pressure and temperature. By knowledge about fluid and its basic characteristics, with influence of pressure and temperature, coefficients that give density are obtained, and after that meter factors criteria is calculated. After that, the coefficients C_{tsp} and C_{psp} are calculated, the factors that depend on the prover material, impact of pressure and temperature, and have an impact on all measurement results. Individual meter factor is then calculated for each passage according to the equation, [3, 5]:

$$MF_m = \frac{BVP \cdot C_{tsp} \cdot C_{psp} \cdot \rho_p}{\dfrac{Meter\ factor}{K - Faktor}} \tag{1}$$

Measurement uncertainty *E* when proving is calculated according to the equation [3,4]:

$$E = \sqrt{\left(E_{calref}\right)^2 + \left(E_{prover\ cal}\right)^2 + \left(E_{prover\ res}\right)^2 + \left(E_{counter\ res}\right)^2 + \left(E_{density}\right)^2 + \left(E_{steel}\right)^2} \tag{2}$$

In addition to the value of the relative error of measurement it is required to get uncertainty of the mean C if the number of measurements n is less than 25. Uncertainty C therefore depends on t factor (variable of Student's distribution) and on the number of repeated measurements n, [3]:

$$C_{(P=0,95)} = \pm t \sqrt{\frac{1}{n(n-1)} \sum_{i=1}^{n} (x_i - \bar{x})^2} \qquad (3)$$

where x_i is measured value and $\bar{x}$ the arithmetic mean.

The relative measurement errors, according to the calibration certificates, for the number 3 measuring spot, after typical flow rates are presented in Figure 3. Green triangles indicate the maximum deviation of the factors scales between passages in one set, and the maximum allowed of 0,05%. Scale factor values are shown in the blue rhombus.

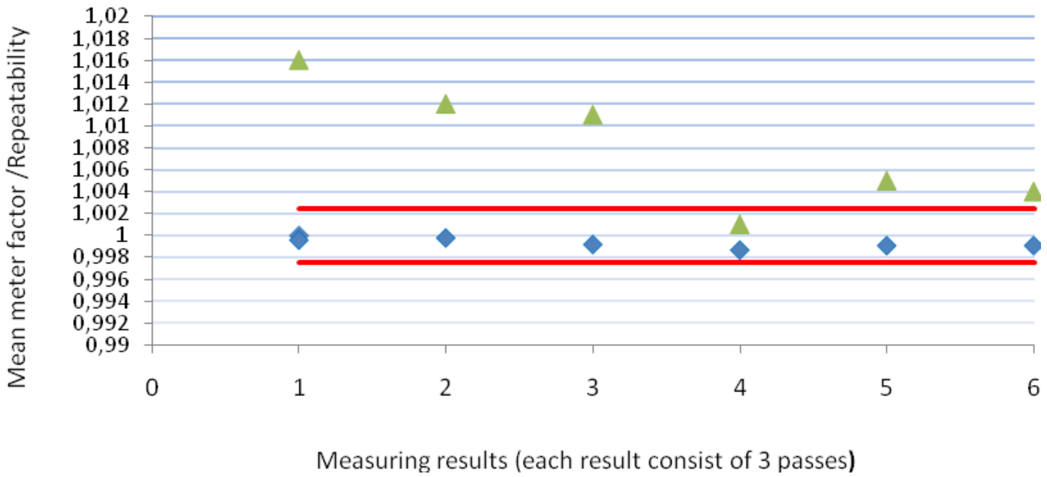

Figure 4. Scale factor / repeatability related to the measurement result.

Based on 15 measurement results, each of them having 3-passes metering piston, satisfactory results that are later taken into account when calculating the uncertainty of measurement scales were got. Measurement results with uncertainty are calculated as: 133,5032 kg ±0,0969 kg.

4. CONCLUSION

To approve using flowmeter in certain measuring system, in situ testing is most accepted method in today praxis. The most important factors on measurement error, such as changes in temperature and pressure are listed here. Also, within the measured media a mix of gas and liquid phase may be occurred, which can lead to inaccurate measurements. In addition to these effects, different vibrations may be a common cause of uncertainty measurements. Together with other influences, some inaccurate measures during the measuring can be occurred, and the main goal is to identify the same and to find solutions for their reduction and elimination. The Basic equation for uncertainty calculation is based on Emerson company approach. Experimentally obtained results confirmed producer's references that the accuracy is lower than ±0,1% of measured value, as well as requirement of OIML standard with its requirements better than ±0,2%.

5. REFERENCES

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