Paper 2

Guidelines for efficient improvement of accuracy in oil and gas flow measurements

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Abstract

The process industry has plenty of flow measurement positions for natural gas and oil. Through these positions gas and oil are delivered into inner consumption positions. This in turn requires good measurement accuracy.
Indmeas has developed a calibration method based on a radiotracer transit time measurement. Our method can be flexibly used for field calibrations of flow meters in industry without disturbing the production process. In a field calibration the total flow measurement chain is calibrated and the total measurement error can often be split into components caused by different parts of the flow measurement chain. Indmeas has had accreditation for these field calibrations since 1994.
Experiences from natural gas and oil flow calibrations show that the largest measurement uncertainty originates from factors outside the flow meter itself. These factors and hence also the related significant errors tend to be constant and can be removed by the first field calibration. Recalibrations are needed thereafter to control the potential slow drift in the measurement chain.
Field calibrations have proved to be an effective means of improving and maintaining the total measurement accuracy in natural gas and oil measurements. The long-term stability of the mechanical meters normally used for natural gas and oil is fairly good as there is an allowance for long calibration intervals.

1. Introduction

The process industry uses large amounts of natural gas and oil. The distribution of these fluids inside industrial plants is measured by using flow meters. A good measurement accuracy is needed in these measurements because the industry wants to optimise and control the energy efficiency of different processes and to deliver accurately the costs between the users of the plant. The importance of measurement accuracy assurance has especially during recent years markedly increased due to the general adoption of the ISO 9000 quality standards, the outsourcing of energy production and energy efficiency audits.

The possibility to calibrate flow meters in calibration laboratories has existed for a long time. The process industry, however, has not used them to any significant extent. One practical reason behind this is the fact that on the one hand the short process stops do not allow for meters to be sent to flow laboratories and on the other industry`s reluctance to double metering. The most important reason, however, is probably the fact that laboratory calibrations do not meet the ultimate needs of the industry. Instead of relying on checking meter behaviour in ideal laboratory conditions the process industry wants to assure the total flow measurement accuracy of the measurement positions.

2. The total measurement accuracy

The total accuracy of a flow measurement means the accuracy of the final flow value, ie. the accuracy of the whole flow measurement chain. In the process industry the final flow value is often the digital value in the automation system used for process control, process reports, calculation of energy and material balances etc. For the process industry flow measurement accuracy is a meaningful concept only if it means the total accuracy.

The flow measurement chain is presented in Fig. 1 in a general form.

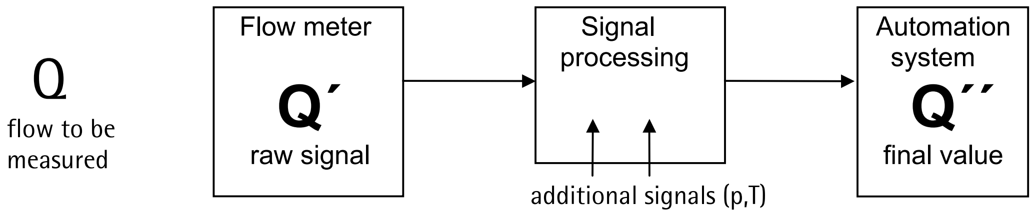

Figure 1 The flow measurement chain

The total measurement uncertainty e_{tot} of the whole measurement chain is expressed as:

$$e_{tot} = \sqrt{e_1^2 + e_2^2 + e_3^2 + \ldots + e_n^2}$$

The uncertainty components e_i refer to the following sources of uncertainty:

e_1 = the meter in ideal measurement conditions
e_2 = installation tolerances (mechanical)
e_3 = installation inaccuracies (electronic)
e_4 = the fluid properties
e_5 = a non-ideal flow profile
e_6 = instability of the meter electronics
e_7 = changes in the contact between the fluid and the sensor
e_8 = compensation (measurements and algoritm)
e_9 = measurement signal transport and processing
e_{10} = tolerances of the automation system components
etc.

The list above shows that there are plenty of uncertainty components present in a flow measurement. The components are independent of each other and summed in squares. It means that the largest terms dominate and the small terms can be ignored. Due to the large number of uncertainty components the realistic target level for the total measurement accuracy is much lower that that in the ideal measurement conditions of a flow laboratory.

e_1, the measurement uncertainty in ideal laboratory conditions is in most cases the only reasonably well known uncertainty component. The observations on the total measurement accuracy [1], [2], [3] indicate that e_1 is almost always a negligible component in the total uncertainty budget.

In order to achieve and maintain total measurement accuracy in industrial flow measurements the whole measurement chain has to be calibrated. This is possible by using field calibrations.

3. Field calibrations based on radiotracer techniques

Indmeas has developed the radiotracer transit time method [4] to serve as a generally and flexibly applicable field calibration method for pipe flow measurements for both liquids and gases. A small amount of radiotracer liquid is injected as a pulse through a connection into the pipe flow. After a mixing distance the velocity of the tracer pulse is measured on a suitable straight pipe section by using two sets of gamma radiation detectors mounted on the pipe. The reference value for volume flow is obtained by multiplying the measured average velocity by the inner pipe cross section. The reference is compared with the simultaneous flow value given by the flow measurement to be calibrated. The tracer injection is repeated several times on the same flow level and the calibration result is obtained as the mean value from the repetitions. If the process allows, the flow level is changed and new calibration points are measured in order to cover the nominal part of the measurement range.

For liquid flows the radiotracer used is the short living Ba-137m (half life 2.5 minutes) eluted on site from a Cs–137/Ba-137m radioisotope generator. For gas flows ethylbromide gas containing 82-Br-radioisotope (half life 36 hours) is used as the tracer. In gas measurements gas pressure and gas temperature are also measured in order to be able to give the calibration result in mass or normalised volume flow units.

The transit time field calibrations of Indmeas have been accredited for nearly a decade. The best accredited calibration accuracy is at the present time 0.8 % for liquids and 1.0 % for gases. Indmeas carries out some 500 field calibrations, more than 90 % of them within long-term quality maintenance agreements for the process industry annually.

4. Experiences on the accuracy improvement of natural gas measurements

The natural gas flow meters involved have mainly been turbine meters with good accuracy characteristics specified by their manufacturers. Fig. 2 shows the distribution of total errors observed in the first time calibrations of natural gas flow measurement positions. The distribution represents the accuracy reached by the industry through installing and maintaining the meters according to normal industrial standards. The width of the distribution proves that dominant errors originate from the measurement chain outside the flow meter. In practice the only means to identify and correct these errors is to field calibrate the flow measurement position.

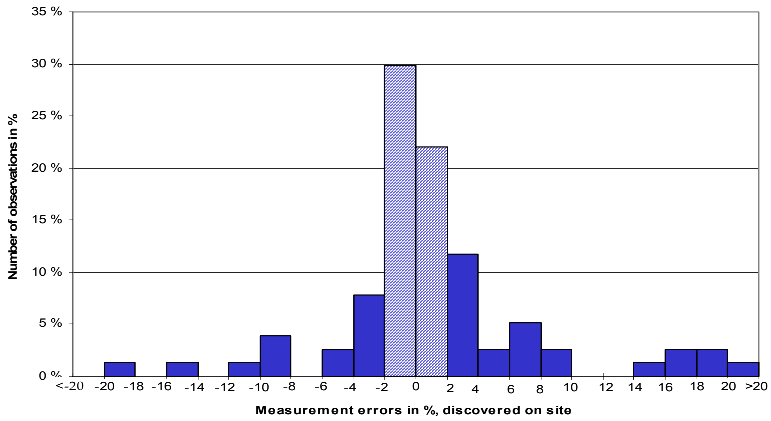

Fig. 2. Total measurement errors in natural gas flow measurements observed in first time field calibrations. Number of observations is 77.

With a field calibration it is possible to split the observed total measurement error into five components:

- the flow meter and its installation position
- temperature measurement
- pressure measurement
- calculation of normalized flow
- other uncertainties in the measurement chain

In the natural gas flow measurements of Fig. 2 the flow meter and its installation position caused half of the statistical total measurement uncertainty. The uncertainty due to temperature and pressure measurements was negligible. The statistical uncertainty component due to normalized flow calculation was significant because some larger calculation errors were discovered. Only a couple reasonable errors were found in the remaining measurement chain.

The stability of natural gas flow measurements can be estimated by using the distribution of Fig. 3.

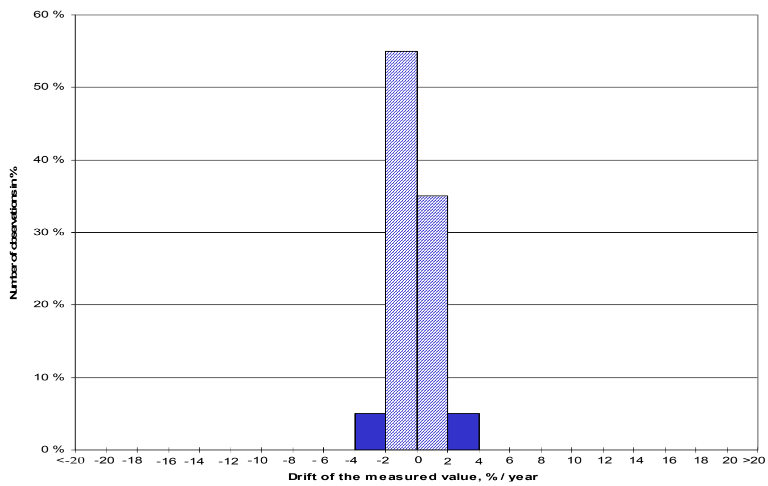

Fig. 3. Instability in natural gas flow measurements observed as the change of the total error / year. The number of observations is 20.

It presents the observed changes per year of the total flow measurement error in measurement positions. Fig. 3 effectively describes the observed long term instability of the flow measurements. The instability detected was mainly caused by the flow meters. Figs.1 and 2 confirm the fact that as long as a measurement chain remains unchanged the large error components also remain unchanged and can be corrected according to the first field calibration result. Recalibrations are thereafter needed just to control the slow drift taking place in measurement chains. The calibration interval for each measurement position is adjusted according to observed stability and according to the target level of measurement accuracy. According to Fig. 3 relative long calibration intervals can be allowed on the average in natural gas flow measurements.

5. Experiences on oil measurements

Most of the field calibrated oil flow measurements have been fuel oil measurements in boilers. The meters have been mostly mechanical meters of different types. There are also a few orifice measurements from oil refineries.

Fig. 4 gives the distribution of total measurement errors observed in first time calibrations. As in the case of natural gas total measurement errors encountered in first time calibrations are large, much larger than what would be expected from meter specifications.

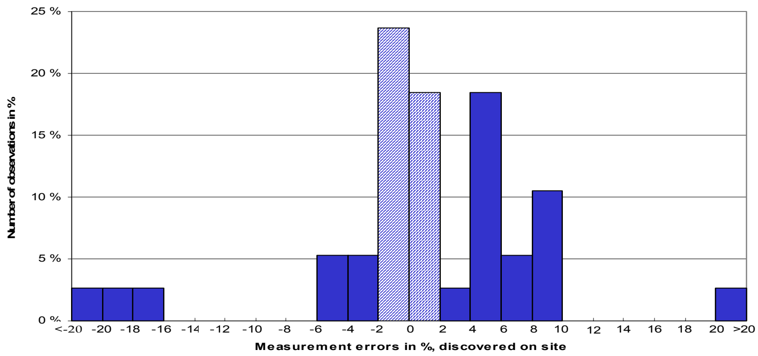

Fig. 4. Total measurement errors in oil flow measurements observed in first time field calibrations. Number of observations is 34.

For oil measurements sufficient recalibration data for evaluation of the common measurement stability is not available. Fig. 5 presents an example of a long calibration history of a single flow measurement for liquefied gas.

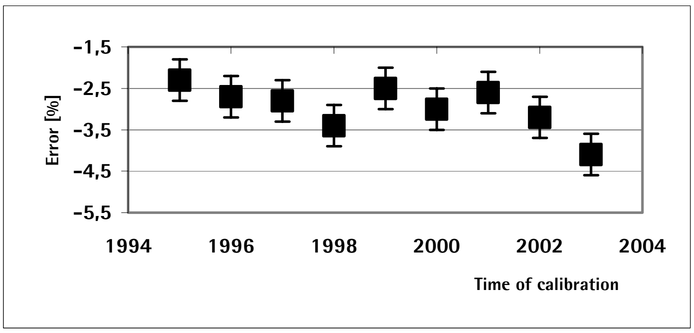

Fig. 5. Calibration history of a liquid gas flow measurement. The uncertainty bars represent the repeatability of the calibration.

Fig. 5 presents an example of a long calibration history of a single flow measurement for liquefied gas. The flow meter is a mechanical meter. The measurement has been fairly stable. After the first field calibration the accuracy in charging liquefied gas deliveries remained effectively as good as the accuracy of the field calibration.

6. Discussion

It may seem at first glance that Indmeas´ best accredited accuracy, 0.8 % for liquids and 1.0 % for gases, is insufficient for the calibration of high quality flow meters with specified accuracies of the order of 0.1 …0.5 %. In field calibrations, however, the object is not to check the flow meter manufacturer specifications but to calibrate the whole flow measurement chain with significantly larger inherent measurement uncertainty.

Our experience shows that by using field calibrations the total measurement accuracy of gas and oil flow measurements can be effectively improved and maintained. This is also clearly the case for other fluids like district heating water, waste water and steam.

References

[1] R. Kuoppamäki, Quality Maintenance of Flow Measurements in Industry, *Flomeko`2000, The International Conference on Flow Measurement*, June 4 – 8, 2000, Salvador Brazil

[2] R. Kuoppamäki, A Quality System for Flow Measurements in Industry, Z. Baoyu, H. Lide, Z. Xiaona (ed.), *Proceedings of the 8th International Conference on Flow Measurement* (Beijing, October 20-24, 1996), Beijing, China, 1996, p.579-584.

[3] P. Ravila, The Improvement of the Total Measurement Accuracy of Large District Heating Flow Meters, *7th International Symposium on District Heating and Cooling*, 20 May 1999, Lund, Sweden

[4] ISO 2975/VII - 1977 (E), ISO 4053/IV - 1978 (E)