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Technique for improving water balance calculations by using field calibration of flow meters

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ABSTRACT

Measurement quality is determined by the quality of the total measurement chain. It includes, not only the meter itself and its behavior in idealized laboratory conditions, but also the measurement installation effects and the signal processing to the final value in water usage reporting. The large experimental data shows that by far the largest measurement uncertainties originates from these other parts of the measurement chain – not from the meter. The quality of the whole measurement chain can only be assured on-site when the meter is in operation at its true installation position. In an on-site calibration the error components caused by different parts of the flow measurement chain are identified. This allows for the correction of the error components in the position of the chain where they have been created.

The most widely applicable on-site calibration method at this moment is the radiotracer transit time method. The method is very flexible in field conditions. It can be applied to obtain the traceable reference value for turbulent pipe flows ranging from waste water and slurry to steam and flue gas. The method has been thoroughly tested in over 10,000 accredited on-site calibrations carried out by Indmeas. The best accredited uncertainty is 0.5% in the calibrations of Indmeas.

Maintaining an accurate flow reading over long time periods requires a stable and reliable flow meter. The array-based non-invasive sonar flow meter is well suited for many challenging water applications in mining, and solves many long-standing reliability problems. Examples of such applications are presented.

INTRODUCTION

The need for measurement quality

Below is a typical example demonstrating the expenses caused by a critical flow measurement error:

A flow measurement on-site calibration with tracer was carried out in a water treatment facility. The main flow into the facility had a measurement error of +30%.This measurement was directly controlling the chemical dosage into the water, and due to the measurement error also the dosage and the costs for water treatment chemicals was 30% higher than necessary.

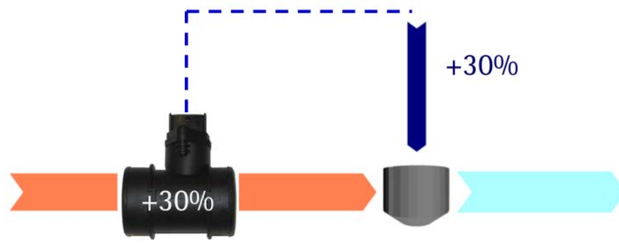

Figure 1 Chemical dosage was 30% too high due to measurement error in waste water flow measurement

On a more general level it can be stated that a prerequisite for modern process control is that the significant flows are accurately measured. Environmental assessing, process optimization, invoicing by measurements and balance calculations all impose specific demands on the quality of flow measurement.

The measurement quality on-site

To the end user of the flow meter the most important characteristic is the total flow measurement accuracy, which means the accuracy of the whole measurement chain. The measurement chain includes all the processing needed to form the final reported value.

The flow meters themselves used by the industry today represent very high quality. According to manufacturer's specifications the accuracy of flow meters is typically better than 1%. The meter itself however represents only a part of the total measurement chain. And as it turns out – the quality problems are most often elsewhere in the measurement chain than in the meter itself [1].

The overall measurement quality can often be roughly estimated from water balances. The figure below gives an example of an industrial water-steam balance. When losses, recirculation and accumulation are taken into account the comparable water balance should equal to 100% at each balance point. This is typically not the case. The real life example below shows the measured monthly values that range from 82%...111%. These differences are all due to measurement errors.

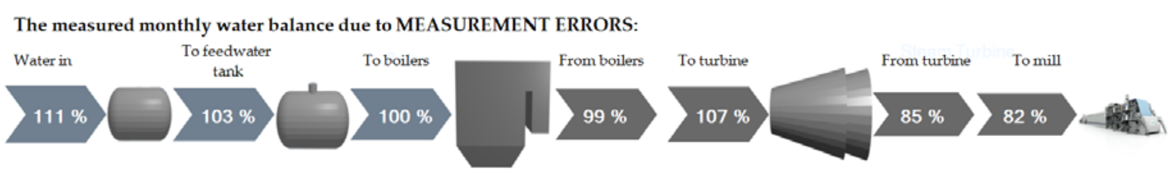

Figure 2 The monthly water balance of a power production showing the effect of measurement errors. The recirculations and accumulations are taken into consideration so that all balance points should add up to 100%.

Figure 2 represents a typical balance uncertainty situation in industry if no special measures has been undertaken to assure the measurement quality.

The measurement quality assurance

In order to achieve reasonable uncertainty for flow measurements some form of quality assurance is needed. The traditional approach is to send the critical flow meters for laboratory calibration and then try to control the measurement conditions on site to match those of specifications. However there are a vast number of things that can go wrong when a meter is installed on site and taken into use, some of these sources are described in the figure 3 below. The specifications needed by the meter are rarely met.

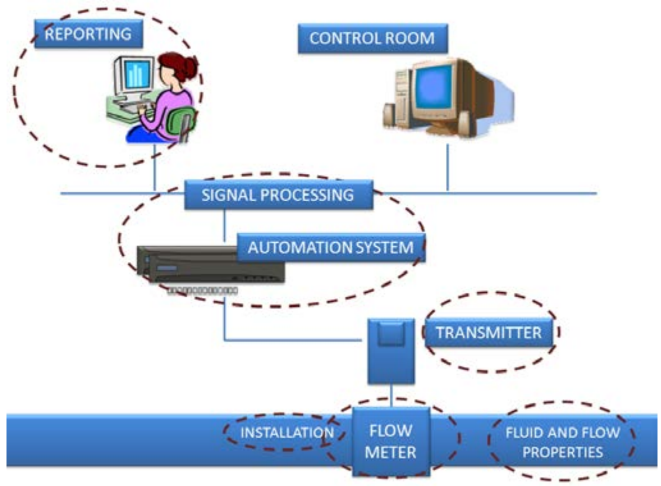

Figure 3 Typically the biggest measurement errors are not caused by the meter itself, but arise from elsewhere in the measurement chain.

The only way to control the operation of the total measurement chain is to control the measurement by using on-site calibration.

METHODOLOGY

Field Calibration and Verification Methods in general

Piston provers provide the most accurate but also the most expensive field calibration method for liquid flows. They are based on the principle of measuring the time required to collect a known volume of liquid into a piston cylinder. The calibration uncertainty is of the order of 0.2 % but disadvantages include not only high costs but also laborious implementation, because the flow needs to be directed through a separate prover cylinder. Provers are mainly used within the petrochemical industry, especially off-shore platforms [2].

A comparison against tank level or the weighing of liquids using a tank truck and truck scale measurements is a commonly used method to verify the flow measurement. This however is always difficult and often impossible to arrange, particularly with larger flows.

There are also two tracer methods available for flow calibration: the dilution method and the transit time method [3]. In general these have the advantage that no changes for process pipelines or operations are required.

In the dilution method tracer is injected continuously into a flow and its diluted concentration is determined. The flow is then calculated from the dilution ratio. The tracer can be short half-life radioactive isotope or some easily detectable chemical such as lithium or rhodamine. These techniques have higher uncertainties than other calibration or verification techniques, but are usually well suited for open channel flow measurements.

At the moment the other tracer method – the radiotracer transit time method - seems to provide the most effective and flexible field calibration method for industry. It suits both for liquid and for gas flows, has a very large flow region and reaches a small uncertainty without disturbing the process.

Field calibration with the radiotracer transit time method

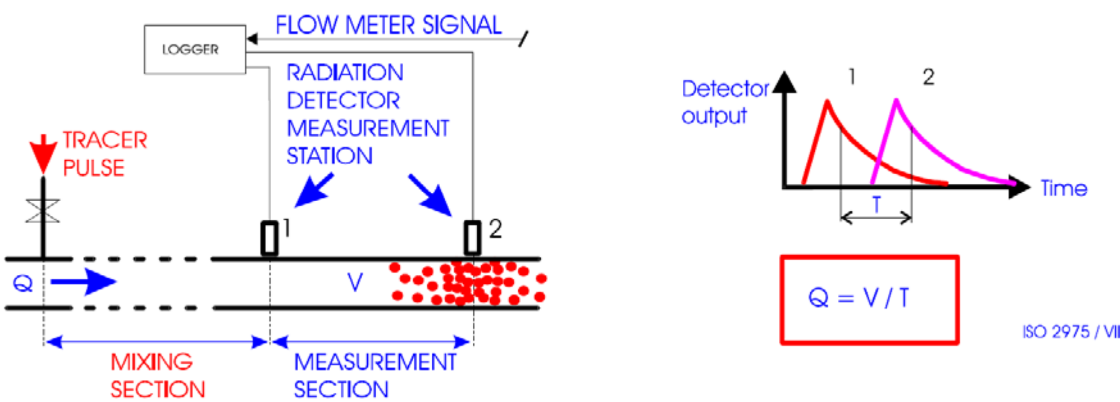

Figure 4 The tracer transit time method

A small amount of radioactive liquid or gas tracer, depending on the fluid type in question, is injected into the flow. Downstream where the tracer pulse has mixed over the flow cross section its velocity is measured on a straight pipe section by using two radiation detectors mounted on the pipe. The gamma radiation emitted by the tracer penetrates the pipe wall and is detected by the detector. When the tracer pulse passes the first detector the tracer concentration response is registered. A similar measurement result is registered when the pulse passes the second one. The flow reference value Qref is obtained from the following simple formula:

Figure 5 On-site flow calibration on a natural gas line

The high applicability of the radiotracer transit time method in on-site calibrations in process industry has been well demonstrated by Indmeas who has used the method for accredited on-site calibrations already over 17 years. The accredited flow regime is 0.5 – 5000 l/s for liquid and 5 – 5000 000 l/s for gas flows. The best accredited calibration uncertainty has been 0.5 % for both liquid and gas flows.

Since the company started in 1986 Indmeas has carried out about ten thousand field calibrations for the process and energy industry of Finland and Sweden. This figure is large even in global terms.

RESULTS AND DISCUSSION

Calibration example 1: Waste water balance

A waste water system of a mineral processing plant was evaluated and a balance difference of close to 30 % was noticed in the water balance. The total measurement was calibrated and a large error was detected that was caused mainly by a human error in installation tuning.

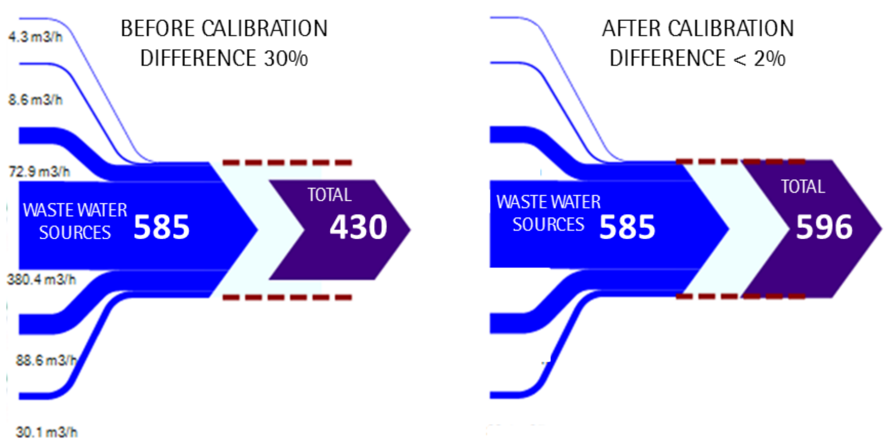

Figure 6 Waste water balance before and after calibration of the total meter.

When the error in tuning and the remaining fault was corrected the balance difference was reduced to less than 2%.

Calibration example 2: Steam flow measurement installation

A steam line flow measurement to a paper mill was calibrated with gaseous tracer. A very large error was detected and the reason was obvious (see Fig. 7). The installation of the orifice plate had gone terribly wrong. Because the impulse-lines needed to measure the pressure difference could not fit between the wall and the steam line, the maintenance department had quickly welded four 90 degree angels just before and after the orifice plate. This of course ruined the possibility of the meter to function properly.

Figure 7 An example of an installation gone wrong.

Calibration example 3: Problem in the automation signal calculation block

Of the thousands of calibrations carried out during the past 10 years a quite interesting statistics has showed up. One-in-five of the measurements had an error of more than 2% in the signal processing chain. That means an error in either A/D transformation, scaling or density compensation. These errors are nearly always due to a human error. An example of this is shown below where an old correction coefficient of 1.1 with unknown origin had been left by mistake to the signal calculation block in the automation system. This automatically caused the measurement an extra error component of +10% in the measurement chain.

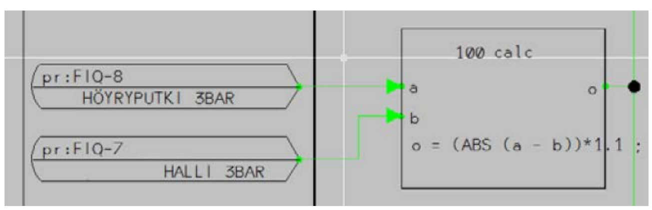

Figure 8 An old correction factor (1.1) had been left by mistake to the signal calculation block in the automation system.

Calibration example 4: A contact problem with temperature signal

Sometimes the measurement trends can reveal the quality problem. This was the case with an energy flow calibration where the temperature measurement used for the density compensation for flow was operating normally during calibration itself. However when we controlled the monthly aggregate values for the measurement chain calibration, it was easy to notice that there was a serious problem with the temperature measurement signal. Due to a bad electrical contact the measurement value was jumping from minimum value of 200 to maximum of 450 sometimes however showing the correct values even weeks in a row.

Figure 9 The temperature signal used for density compensation of the flow meter was not operating properly.

Quality assurance between calibrations

As the calibration example 4 and figure 9 showed, on-site calibrations alone are not able to guarantee the measurement quality. They are a critical part of the quality assurance program, but stability between calibrations must be followed by other means. The modern automation systems equipped with history databases provide a useful solution to this. It is possible to build a measurement fault detection system, based on water balances and stability controls which alarms in case of significant inconsistencies. This cooperation with measurement fault detection and on-site calibrations enables condition based maintenance work for instrumentation which in systems of hundreds of measurements means significant savings as well as better measurement quality.

Selecting appropriate flow meter technology for typical mining applications

One key to an accurate and reliable flow measurement is selecting the best available flow meter technology for the application. In the arid regions of South America, the increasing scarcity of water has substantially increased the need for accurate, reliable water measurements in mining. This need is being driven by water use restrictions imposed by the government, and the desire of mining companies to operate in a sustainable manner as good corporate citizens. Thus, the mining companies must demonstrate to both the communities and the government that they are operating within their agreed-upon consumption limits, which may even be reduced in the future.

Installing flow meters on water lines involves many challenges. Critical lines are costly to shut down because that will interrupt plant operation. Installation of invasive meters in old piping carries a risk of pipe cracking that will require costly repair. Installing a large, heavy invasive electromagnetic flow meter is logistically difficult and carries safety risks to personnel. The build-up of scale on the pipe inner wall, which is very common in these regions, causes eventual measurement deterioration and the need for maintenance for both invasive electromagnetic and non-invasive ultrasonic meters.

The non-invasive array-based sonar flow meter solves these problems. It requires no breach of the pipe, is light weight, is easily and rapidly installed, is unaffected by internal scale, works on pipe of virtually any material, both lined and un-lined, and is maintenance free.

A typical application is the recent installation of a 30″ sonar meter for a large mining customer in northern Argentina. The 12 year old steel line carried fresh water from deep wells, and the government required a flow measurement. The existing electromagnetic flow meter had been operating erratically due to failure of an electrode seal that allowed water to leak into the electronics. Stopping the line for meter repair or replacement would require stopping the concentrator plant and a costly loss of production. Although a partial repair to the electromagnetic flow meter during scheduled concentrator shutdown did return it to operation, the customer lost confidence in its reliability and decided to switch to sonar technology.

Another typical application is the installation of two 48″ sonar meters for a large mining customer in northern Chile. The existing lines carried recovered water from the tailings pond. A flow measurement was required by the government and by the mine for operational control. There were no existing flow meters on the lines. However, severe electrode scaling with existing flow meters on other lines was known to be a severe problem. Also, very large electromagnetic flow meters for 48″ line size are difficult to install due to size and weight, and are high priced. These factors caused the company to select sonar technology during a redesign for plant expansion.

CONCLUSION

Results from the on-site calibrations carried out show that, on the average, the accuracy of the industrial flow measurements is far from the flow meter specifications. The uncertainties are in the order of ten times that of meter specifications. The meters themselves are seldom at fault, but flow measurements even by top quality meters are influenced by the conditions affecting the installation positions, as well as problems with signal processing.

The quality maintenance system based on on-site flow calibrations has proved to be an effective means to improve the accuracy of the flow measurements in process industry. A realistic target level for assured accuracy is around 1 – 2 % depending on the application. This normally well matches or even exceeds the requirements of the authorities. Selecting an appropriate flow meter technology, such as a non-invasive array-based sonar meter, is a significant contributor to an accurate and reliable measurement in certain applications.

ACKNOWLEDGEMENTS

NOMENCLATURE

REFERENCES

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