Technique for on-site calibration of flow meters installed in mineral processing plants

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ABSTRACT

Significant plant maintenance expense is incurred when trying to obtain an accurate flow measurement with good repeatability and long-term stability, particularly when there is no installation location that meets the 'ideal' requirements. The use of an on-site flow meter calibration, when combined with the proper flow meter technology, can deliver this desired measurement quality at lower total cost.

Measurement quality is determined by the quality of the total measurement chain. A flow meter may be calibrated in idealized laboratory conditions, but effects from its on-site installation position and signal processing affect the final value reported to the control room. 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 and corrected for, allowing correction of the error components where they originate. Years of on-site calibration experience outside minerals processing have shown that by far the largest measurement errors originate not from the flow meters but from other parts of the measurement chain.

This paper presents the most widely applicable on-site calibration method, the radiotracer transit time method, which can account for errors in the measurement chain. The method is widely used in other industries but is not yet widely used in minerals processing. It is flexible in field conditions and provides traceable reference for turbulent flows of clean liquids or slurries. It has been thoroughly tested in over 10,000 accredited on-site calibrations by Indmeas of Finland, with accredited uncertainty as low as 0.5%. Examples are shown.

Maintaining an accurate flow reading over long time periods also requires a stable, reliable flow meter. The array-based non-invasive sonar flow meter is well suited for these challenging applications in minerals processing and solves many long-standing reliability and stability problems. An example is shown for a difficult slurry application.

INTRODUCTION

The need for measurement quality

Below, Figure 1 shows 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 application. The main flow to the plant had a measurement error of +30%. This measurement was directly controlling chemical dosage into the water, and due to the measurement error also the dosage and the costs for water treatment chemicals were 30% higher than necessary.

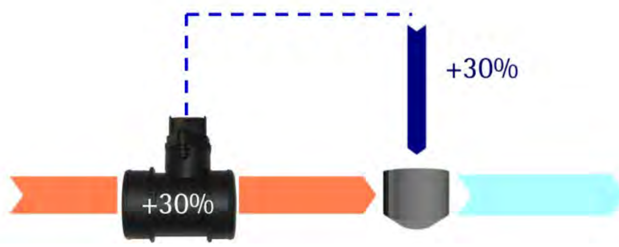

Figure 1 Chemical dosage was 30% too high due to measurement error in water flow measurement

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% of reading. 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 (Kuoppamäki, Baoyu, Lide, & Xiaona, 1996).

The overall measurement quality can often be roughly estimated from volume or mass balances. Figure 2 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.

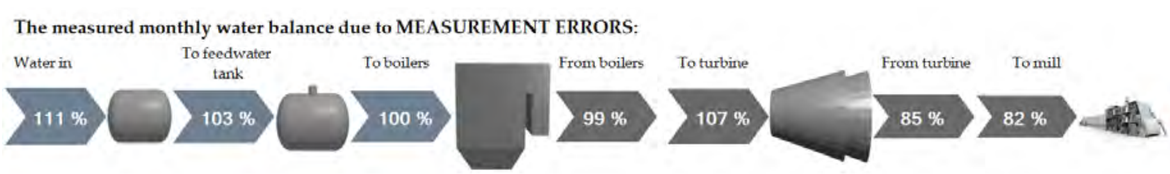

Figure 2 The monthly water balance of a power plant showing the effect of measurement errors.

Figure 2 represents a typical balance uncertainty situation in industry if no special measures have been undertaken to assure the measurement quality. The recirculations and accumulations are taken into consideration so that all balance points should add up to 100%.

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 the specifications. However, there are a vast number of things that can go wrong when a meter is installed on-site and put into service. Some of these sources are described in the Figure 3 below. Typically, the biggest measurement errors are not caused by the meter itself but arise from elsewhere in the measurement chain. The specifications needed by the meter are rarely met.

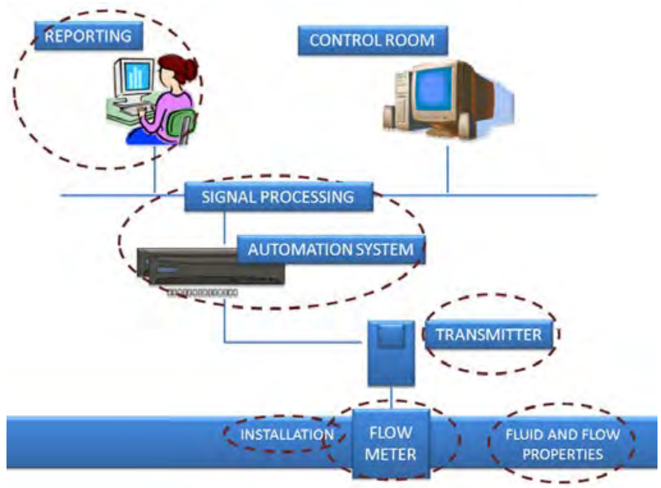

Figure 3 Largest sources of measurement error arrise from the measurement chain, often not the flow meter.

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 (Kuoppamäki, 2003).

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 (International Organisation for Standardisation, 1977). 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, depicted in Figure 4. It is suitable for both liquid and gas flows, covers a very large range of flow speeds, and reaches a small uncertainty without disturbing the process.

Field calibration with the radiotracer transit time method

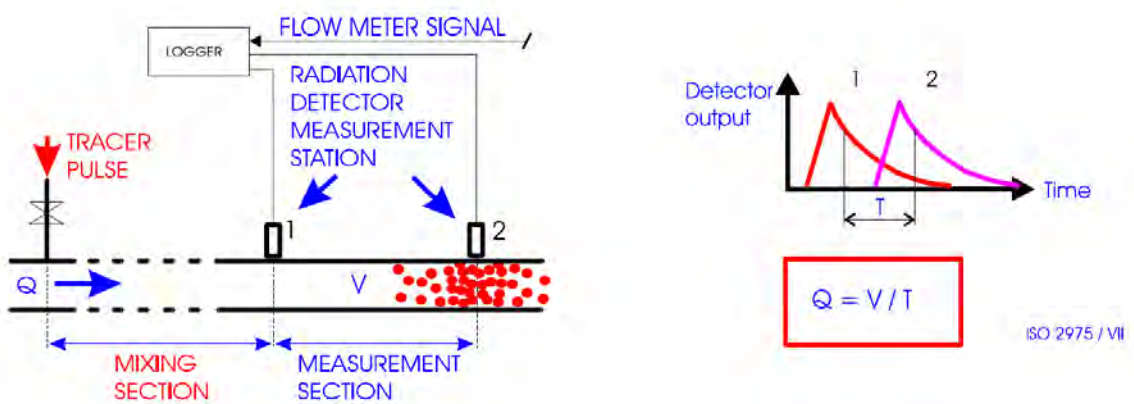

Figure 4 The tracer transit time method

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 entire 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 Q is obtained from the following simple formula:

$$Q = \frac{V}{T} = \frac{\pi L D_{in}^2}{4T} \qquad (1)$$

Where:
V = inner volume of the pipe between the detectors
T = time the tracer pulse spends between the detectors
D_{in} = inner diameter of the pipe
L = distance between the detectors

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 the process industry has been well demonstrated by Indmeas, who has used the method for accredited on-site calibrations for over 17 years. The accredited flow regime is 0.5 – 5,000 l/s for liquid and 5 – 5,000,000 l/s for gas flows. The best accredited calibration uncertainty has been 0.5% for both liquid and gas flows. Figure 5 shows an on-site calibration underway.

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

RESULTS AND DISCUSSION

Calibration example 1: Water system balance

A water system of a mineral processing plant was evaluated and a balance difference of close to 30% was identified. The total measurement was calibrated and a large error was detected that was caused mainly by a human error in installation and tuning. Figure 6 below illustrates the example.

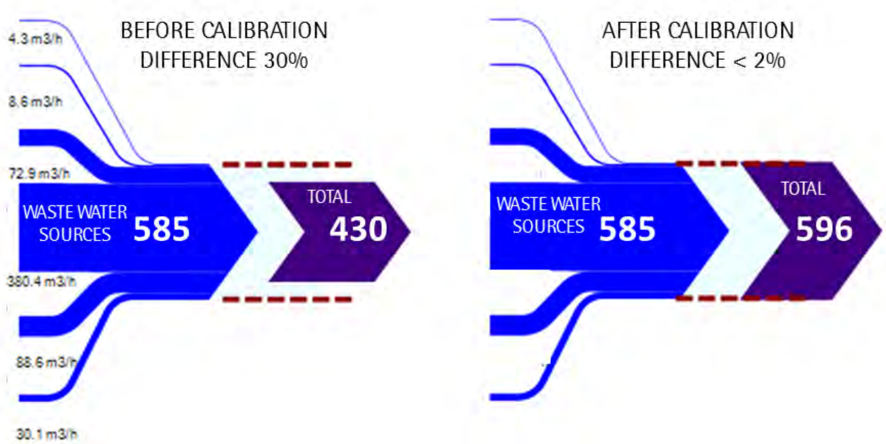

Figure 6 Water balance before and after calibration of the total meter.

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 nuclear tracer. A very large error was detected and the reason was obvious (see Figure 7). The installation of the orifice plate was very unsatisfactory. 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 ruined the possibility of proper meter function.

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, an interesting statistic has appeared. 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 human error. An example of this is shown below in Figure 8 where an old correction coefficient of 1.1 with unknown origin had been left by mistake in the signal calculation block in the automation system. This automatically created a +10% error in the measurement chain.

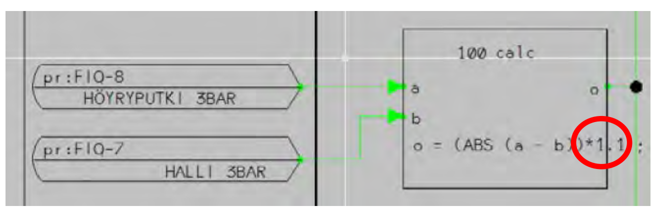

Figure 8 Old correction factor (1.1) was mistakenly left in signal calculation block in automation system.

Calibration example 4: Magnetite slurry with flow meter in non-ideal location

A sonar array-based flow meter was installed on a magnetite slurry line in the only location available, which was a short distance after the pump discharge. This slurry is very difficult to measure with some flow meter technologies due to its strong magnetic characteristics that cause errors in electromagnetic flow meters and its corrosive properties, which can affect any invasive flow meter technology. So a sonar array-based non-invasive flow meter was chosen. In 2009, an on-site calibration at a low flow velocity showed an error of -21% with +/-6.0% uncertainty (95% confidence), which was believed to be due to a non-homogenous slurry condition. A calibration at a higher velocity showed an acceptable error of -1.5% with +/-2.8% uncertainty because the slurry was believed to be homogenous (see Figure 9). The calibration corrections were then entered into the plant Distributed Control System. A recalibration with these new corrections was then performed at the low velocity, and the error was found to be +3.2% with an uncertainty of +/-3.8%, which the customer deemed acceptable. Three years later in 2012, another on-site calibration was performed at two flow velocities slightly different than the originals due to plant conditions at the time. The errors were found to be -0.8% with +/-2.5% uncertainty at the low velocity, and -1.5% with +/-5.5% uncertainty at the higher velocity. Thus, it is shown that at a non-ideal installation location with difficult-to-measure slurry, an accurate flow measurement with long-term reliability can be obtained by using a robust and drift-free flow meter technology, such as the sonar array-based flow meter, combined with an on-site calibration.

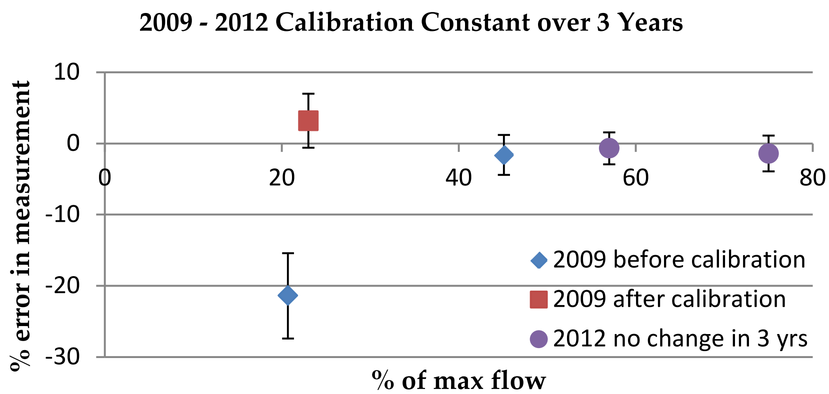

Figure 9 On-site calibration verifies stable measurement by sonar meter over 3 years

Quality assurance between calibrations

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 flow volume balances and stability controls, which alarms in case of significant inconsistencies. This combination of measurement fault detection and on-site calibrations enables condition-based maintenance scheduling 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 achieving accurate flow measurements with long-term reliability is selecting the best available flow meter technology for the application. For example, 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 such 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 damage that will require costly repair. Installing a large, heavy invasive electromagnetic flow meter is logistically difficult and carries safety risks to personnel. And 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 to the concentrator plant, 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 to the concentrator plant. A flow measurement was required by the government regulation 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

It has been shown that on-site calibration of flow meters has been developed to a highly commercial level, enabling accurate field calibrations with results traceable to a calibration laboratory. This tool, when combined with a robust and inherently drift-free and maintenance-free flow meter, such as sonar array-based technology, leads to more accurate flow measurements and mass balance results. This combination enables an effective, efficient Quality Assurance procedure that improves the reliability of the flow instrumentation, reduces the total cost of related maintenance activities, and thus improves plant operation and lowers operating costs.

Results from the on-site calibrations using the radiotracer transit time method show that on 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.

A quality assurance system based on on-site flow calibrations has proved to be an effective means to improve the accuracy of flow measurements in process industries. Based on experience from over 10,000 on-site calibrations, a realistic target level for assured accuracy is around 1 – 2% depending on the application. This normally meets or even exceeds the requirements of the regulatory authorities and/or operational control. It was shown that selecting the appropriate flow meter technology, such as a non-invasive array-based sonar meter, is a significant contributor to accurate and reliable measurement in certain applications.

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