How flowmeters perform self-verification

Here's how modern flowmeters verify their own measurement performance

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Process manufacturing and other industrial facilities must often provide documented evidence of flowmeter performance to maintain compliance with various regulatory agencies, ensure product quality and optimize production. Today's smart instrumentation helps plants accomplish these tasks through built-in verification techniques traceable to known metrology standards.

In this article, we'll explain how self-verification works.

Regulatory Requirements

In the water and wastewater industry, typical flowmeter requirements are:

- Flowmeters have to be verified at regular intervals
- Verification has to be performed by a qualified third party and with an accepted inspection method based on quality regulations such as ISO 9001
- A test report needs to be provided for documented proof of verification

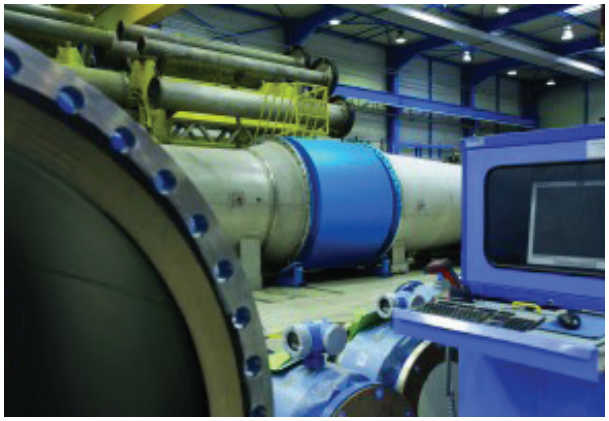

Figure 1: Removing a flowmeter for calibration and verification from a large line causes significant disruption and can be cost prohibitive

The water recovery industry often uses large pipe sizes, and recalibration of flowmeters used in these applications is very costly. In some cases a certified local reference standard, typically a mobile calibration rig accredited according to ISO 17025, is not available. And in many cases, any interruption of service or supply of water is not acceptable, making it very difficult to remove the flowmeter from service for calibration (Figure 1). These applications are well suited for self-verification because it minimizes the need to take flowmeters out of service.

In the pharmaceutical industry, Quality Risk Management has become a mandatory regulatory requirement for drug manufacturers. The Food and Drug Administration (FDA) and the European Medicines Agency (EMA) publish guidelines and requirements for process instrumentation which customers and vendors are expected to follow. Guidelines such as "Process Validation: General

Principles and Practices" by the FDA and Annex 15 issued by the EMA offer input to help drug manufacturers manage instrumentation correctly.

The chemical industry has requirements for proof testing per IEC 61508 and IEC 61511, while the oil & gas industry must adhere to contractual agreements between buyer and seller, and comply with government agency mandates. For example, a company pulling oil from a well under an agreement with the Bureau of Land Management or the property owner may have to prove flowmeters at a determined frequency.

Calibration versus Verification

Modern flowmeters operating based on a Coriolis, electromagnetic, ultrasonic, vortex or thermal measuring principle do not have moving parts subject to wear. But they can have problems requiring recalibration including failure of an internal part or degradation due temperature effects on electronics—or corrosion, clogging or coating buildups in the flowmeter body.

Legal requirements are commonly fulfilled with wet calibrations, where a flowmeter is removed from the process (Figure 2), taken to a flow lab or calibration rig, and tested by a formal comparison to a standard directly or indirectly related to national standards. Detected deviations between the displayed value and the reference value can be corrected after the calibration by adjusting the calibration factor. A calibration protocol is issued to document the findings, and is put on record for possible audits.

The downside of wet calibration is the instrument typically must be removed from the process. After calibration, the instrument is then sent back to the facility to be reinstalled. Damages during transport or handling can sometimes stay undetected, and lead to a situation where a recently calibrated instrument is not performing per specifications.

Figure 2: Flowmeters typically have to be removed from the process for calibration in a lab. On-board verification can determine when a flowmeter actually needs calibration

An alternative way to fulfill legal requirements is on-board verification of the flowmeter. The flowmeter's transmitter electronics run an on-board diagnostics program, where all relevant components of the instrument are checked to confirm and document the instrument is still in calibration and none of the meter components have drifted outside original tolerances.

Verification of a flowmeter equipped with built-in capabilities can be performed without removing the instrument from the process. It may not even be required to interrupt the process as the verification tests can all be performed in the background.

Several flowmeter manufacturers offer self-verification, and all work differently. In this article, we'll use Heartbeat Technology from Endress+Hauser as an example.

How Self-Verification Works

Modern flowmeters incorporate self-testing developed as an integral part of the device from the beginning. For example, Heartbeat Technology was developed when Endress+Hauser's new generation of Proline flowmeters were first designed. This concept embeds diagnostics in all flowmeter technologies that operate 24/7. In addition, the entire signal chain from sensor to output can be checked using the flowmeter's self-testing, traceable verification.

Verification in flowmeters equipped with Heartbeat Technology is based on continuous monitoring of all relevant internal parameters, and mechanical, electromechanical and electronic components.

Typically, a failure mode, effects and diagnostic analysis is used during the flowmeter's design phase to identify critical components in the signal chain, starting at the process-wetted parts and followed by the electro-mechanical components, amplifier board, main electronic module and outputs. A proper margin of safety is then assigned to every critical path or component.

These tests include digital signal processing and continuous loop checks with the help of internal reference components. In the case of a Coriolis flowmeter—and other time-based measuring principles like vortex or ultrasonic—there is a frequency reference oscillator used for analyzing the frequency of the measuring tubes. For electromagnetic flowmeters, this is a reference voltage, since the measured value is determined by comparing the voltage on the electrodes to the reference voltage.

The primary reference is monitored by a second redundant reference system to guarantee it does not change during the device lifecycle. The two reference signals from the primary and secondary reference are compared against each other. A drift or deviation of the two systems from each other is immediately detected and reported by the device diagnostics.

For an internal component to be used as a diagnostic reference, it has to fulfill special requirements such as factory traceability and exceptional long-term stability. For the most critical circuits, independent and redundant components are implemented, greatly reducing the possibility of undetected drift. Today, it is possible to design instruments with a self-diagnostics coverage of 94% or higher (in accordance with IEC 61508), and correspondingly low rates of dangerous undetected failures.

Heartbeat Technology continuously monitors the entire signal chain for deviations within a very tight band. The failure threshold is defined by the specified accuracy of the flowmeter. If the diagnostics detect an error, Heartbeat Technology sends an alarm message that conforms to NAMUR recommendation NE 107 (Figure 3). The alarm is displayed on the flowmeter's front panel and can be sent as a message over the interface to the automation system. The message also includes troubleshooting tips and remedial instructions.

Status signal	Color	Symbol
Normal; valid output signal		
Maintenance required; still valid output signal		
Out of specification; signal out of the specified range		
Function check; temporary non-valid output signal		
Failure; non-valid output signal		

Figure 3: Diagnostic messages sent by Heartbeat Technology conform to NAMUR recommendation NE 107

Verification Functions

Diagnostics to detect problems are performed continuously, but a verification is done on command from the automation system or at the instrument itself. In most cases, diagnostics continuously perform all of the same checks in the background as the verification performs on-demand. The verification, then, is simply a snapshot in time. Verification allows documented evidence to be generated from the device and saved for record keeping purposes.

During flowmeter verification, the current conditions of secondary parameters are compared with their reference values, thereby determining the device status. Heartbeat Technology produces a "pass" or a "fail" statement based on the tests, which is performed by traceable and redundant internal references. The individual tests and results are automatically recorded in the flowmeter, and can be used to produce a verification report.

For Coriolis devices, Heartbeat Technology tests electrodynamic excitation, electrodynamic sensors, temperature sensors, connectors, cables and the measuring tube (Figure 4).

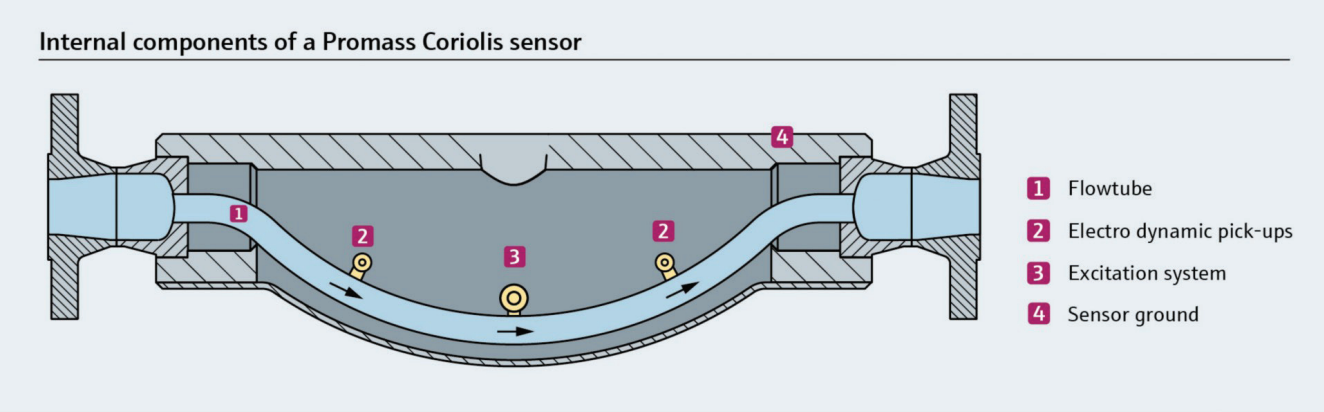

Figure 4: Verification tests on an Endess+Hauser Promass Coriolis flowmeter

Heartbeat Technology verifies the excitation system and the coil current for electromagnetic flowmeters, and checks the electrical and mechanical integrity of the transducer and the temperature sensors (as applicable). This enables systematic failures, caused by factors such as fluid properties or process operating conditions, to be detected.

A traceable and redundant reference, contained in the verification system of the device, is used to ensure the reliability of the results. In the case of an Endress+Hauser Proline electromagnetic flowmeter, this is a voltage reference, which provides a second, independent reference value.

Integrated self-monitoring can replace external test equipment only if it is based on factory traceable and redundant references, as with the Proline flowmeters. The reliability and independence of the testing method is ensured by traceable calibration of the references at the factory, and by the constant monitoring of the flowmeter's long-term stability during the lifecycle of the product.

Heartbeat Technology fully complies with the requirements for traceable verification according to DIN EN ISO 9001:2008, Section 7.6 a, "Control of monitoring and measuring equipment." Performing regular Heartbeat Verification on a flowmeter can extend calibration cycles by a factor of 10 or higher without jeopardizing the quality or the regulatory compliance. In some cases it may even be possible to replace wet calibrations completely with Heartbeat Verification.

The verification procedure for Endress+Hauser flowmeters can take anywhere from a few seconds to about ten minutes depending on the flowmeter type. The process can be done locally (Figure 5). Alternatively, if the flowmeter has a permanent Ethernet or other digital bus connection to the plant network, the procedure can be performed remotely from a PC located in the maintenance department or the plant's control room.

Figure 5: For field verification, a technician connects a smart device to the flowmeter's web server via an optional WLAN connection, up to 15 feet in proximity. The same procedure can be performed via laptop PC and Ethernet connection. The flowmeter does not have to be removed for this procedure

Upon completion of a verification, Heartbeat Technology generates a report that summarizes the results. The report can be shown to an inspector in case of an audit.

Condition Monitoring

Flowmeter faults during operation that go undetected by diagnostics can result in an unexpected plant shutdown, product loss or a reduction in product quality. This is particularly true in applications where process-related faults during operation are to be expected due to demanding operating conditions such as multiphase media, buildup, corrosion or abrasion. Condition monitoring recognizes if the measuring performance or the integrity of the flowmeter are impaired.

The monitoring values described above are transmitted to an external condition monitoring system, such as Endress+Hauser's PC-based FieldCare software. FieldCare can be used to recognize trends in the secondary measured values and to evaluate relationships among individual parameters. Condition monitoring reduces the risks of an unexpected failure. Condition monitoring also makes it possible to display temporary, process-specific faults that neither calibration nor verification can detect, since the latter only takes a snapshot of the device status, as opposed to continuous condition monitoring.

Summary

Built-in flowmeter verification can be initiated locally or remotely from the automation system, even during operation. Because the procedure is simple and non-invasive, the meter can be verified on a regular basis (e.g. daily or quarterly), drastically reducing the risk of degradation in meter performance between wet calibrations. In batch applications, a system check can be initiated from the automation system prior to starting the batch to ensure all flowmeters work properly, greatly reducing the risk for product loss due to instrument failures.

About the Author

Nathan Hedrick has more than seven years of experience consulting on process automation. He graduated from Rose-Hulman in 2009 with a Bachelor's degree in Chemical Engineering. He began his career with Endress+Hauser in 2009 as a Technical Support Engineer. In 2014, Nathan became the Technical Support Team Manager for Flow where he was responsible for managing the technical support team covering the flow product line. He has been in the position of Flow Product Marketing Manager since 2015.

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