Heartbeat Technology

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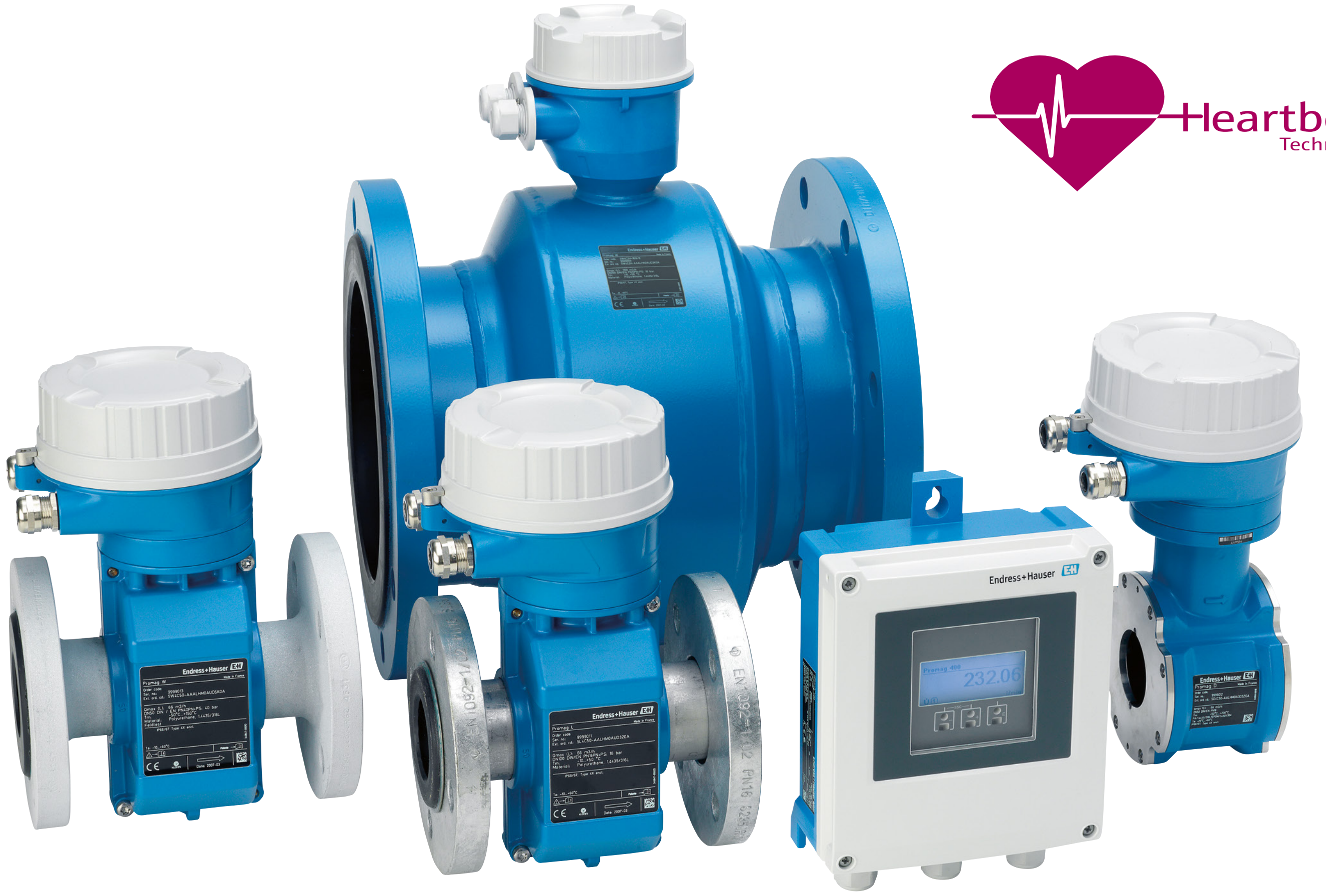


Endress+Hauser
People for Process Automation

Heartbeat Technology in Water Wastewater

Process reliability, consistent quality and accurate accounting for liquid flow and consumption are serious concerns for many industries, and the water/wastewater industry is no exception.

The water industry requires high levels of process reliability, consistent quality, reliable leak detection and accurate billing of water use. One of the important elements in meeting these goals is ensuring that flowmeters provide accurate data, which requires periodic flow calibration and verification of proper operation.

However the industry often uses large pipe sizes, and any needed recalibration of these flowmeters is proportionally more costly. In many cases any interruption of service or supply of water is not acceptable, making it difficult to remove the flowmeter from service for calibration.

Typical requirements are:

1. Flowmeters must be verified at regular intervals.
2. Verification must be performed by a qualified third party, with an accepted inspection method based on quality standards such as ISO 9001.
3. A test report must be provided for documented proof of verification.

Flowmeters may also periodically require actual recalibration, but the generally accepted method of full traceable flow calibration – using calibration rigs accredited to ISO 17025 – can be expensive and sometimes infeasible, mainly due to the labour and logistics involved in removing the flowmeter from the piping system.

It is important that flowmeters can be relied upon to continue to provide accurate data, and that intervention is kept to a minimum – which means that online verification can be a useful tool to ensure that process interruption does not occur unnecessarily.

Heartbeat Technology - Simply explained

Flow Verification & Monitoring with Heartbeat Technology

Self monitoring flowmeters - introducing Heartbeat Technology

Endress+Hauser flow meters have incorporated Heartbeat Technology since 2012 – a capability that provides a continuous health check of the flowmeter, ensuring key parameters are performing within specification at all times. This diagnostic capability is standard with all Heartbeat-enabled flow meters and has a total test coverage of up to 94%.

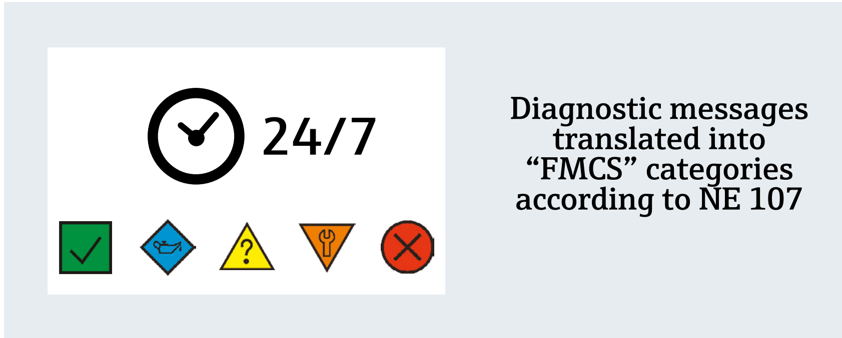
Heartbeat Technology also means that every flow meter may be verified and documented in-situ without any interruption of the process. A simple, predefined procedure guides the technician through the verification procedure and verification results are documented in a standardised and easily accessible form. Operators and technicians can obtain documented proof that diagnostic checks have been performed, supporting the documentation of proof testing in accordance with IEC 61511-1 for safety instrumented systems, and the SIL-certified Heartbeat-enabled flow meters have also been designed in accordance with IEC 61508.

Heartbeat Diagnostics

Heartbeat diagnostics constantly monitor the function of the internal components of the meter, so that any drift or malfunction can be detected and responded to. Users are warned of status via messages defined in accordance with NAMUR recommendation NE 107 and displayed on the device along with instructions on what actions need to be taken (see Figure 1). The diagnostics can also be sent to a higher-level control system.

Diagnostics also offer the ability to detect process-specific effects, via “out of specification” or “maintenance required” events, while the “function check” message is displayed if the measured value is temporarily invalid (i.e. frozen) due to on-going work on the device – such as when the device is performing a self-verification.

Continuous diagnostics means that the device is continuously tested for functional integrity during operation, allowing quick alerting and remedy in the case of a failure.



F	‘Failure’ An instrument failure has occured. The measured value is not valid any more.	
M	‘Maintenance required’ The measured value continues to be valid.	
C	‘Function check’ The instrument is in service mode (e.g. during simulation).	
S	‘Outside of specification’ The instrument is operated: ▪ Outside of its technical specifications (e.g. during start-up or cleaning). ▪ Outside of the parameterisation set by the user (e.g. flow outside of the parameterised span).	
OK	Measurement faultless.	

Figure 1: Instrument diagnostic status according to NAMUR NE 107

Heartbeat Verification

Flow meters commonly used in the water and wastewater industries, such as electromagnetic flow meters, do not have moving parts subject to wear, but they can have problems that cause them to drift from their original factory calibration. Such drifts can be caused by the effects of ageing or temperature on electronic components — or by corrosion, clogging and the buildup of residue in the flowmeter body over time.
The most accurate way of detecting and correcting such drift is via wet calibration, in which the flowmeter is removed from the process and taken to a lab or inserted in a calibration rig, so that the meter can be accurately compared with accepted standards and any deviations corrected. The obvious downside is the removal of the instrument from the process — necessarily involving a process interruption — and the risk of damage during transport, especially after recalibration. However, wet calibration is the only method in which there is direct inspection of the actual measurement parameter, such as the mass or volume flow.

Next to calibration, in-situ verification of the flowmeter — while it doesn't involve direct comparison of the actual liquid flow — provides an accurate way to assess the drift in accuracy of the meter over time. With no moving parts to wear, often the main cause of inaccuracy in modern flowmeter technologies is electronics drift. Verification has commonly been carried out using an external verification tool, the verification tool being connected to the flowmeter via a test interface. A functional test is carried out by simulating calibrated reference signals and observing the system response. Performing this kind of verification however involves opening the flowmeter to access the electronics and the meter cannot be used for measurement and control of the process for the duration of the test, so some process downtime also occurs — although not for as long as removing the flowmeter for calibration. The verification tool itself is also subject to the need for periodically undergoing traceable calibration. Verification in this way also requires specific flowmeter knowledge, which is why external verification is usually implemented as part of a service contract.

Onboard self-verification

An alternative way to fulfill verification requirements is via an onboard verification technology built into the flowmeter itself. The transmitter electronics perform internal diagnostics in which internal components of the meter are verified against redundant in-built references and previous calibration data to detect whether they have drifted outside of acceptable tolerances.

It may seem counter-intuitive to suggest that a calibrated meter can verify its own operation, as there is not an external independent reference.
The following sections will explain why internal verification is indeed possible (and reliable) using Endress+Hauser's Heartbeat Technology.

How self-verification works

Modern flowmeters provide secondary (internal) variables other than the primary measurand (flow). These secondary variables provide information on the internal operation of the flowmeter and can be used to detect if the meter's operation deviates from its previously calibrated condition.

During verification, the secondary parameters are compared against reference values based on stored calibration data and a traceable and redundant reference contained in the verification system of the device.

The International Bureau of Weights and Measures (BIPM) 1 defines the term traceability as 'the property of a measurement result to be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty.' Figure 2 shows an example of a traceability chain for a flowmeter.

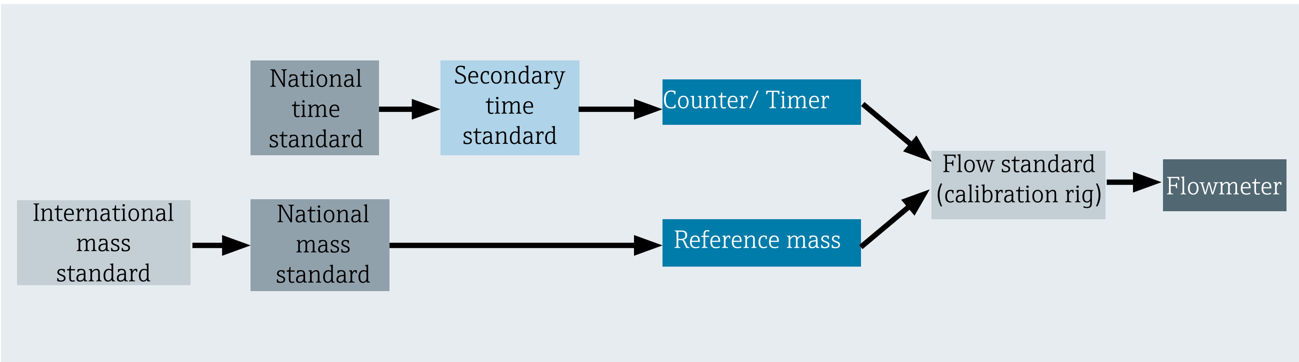


Figure 2: Example of a traceability chain for a flow meter

Heartbeat Technology
Flowmeter verification made easy

Heartbeat Technology Whitepaper

There are two types of measurement result we are interested in:

1. **Measurand:** The process variable to be measured (e.g. volume flow)
2. **Auxiliary Variable:** Internal signals coming from either the flow meter's sensor, or other elements of the flowmeter transmitter such as its ADC, signal processor, amplifier etc., commonly in the form of a voltage, current, time reference, frequency or pulse.

Internal verification involves assessing those auxiliary variables (AVs) that can significantly impact the measurand. These values are compared against reference values with a manufacturer-established error tolerance. Depending on the type of flowmeter, the significant AVs may be different. In the case of electromagnetic flowmeters use a voltage reference, since the primary initial measurement is a voltage induced by the measured fluid passing through a magnetic field.

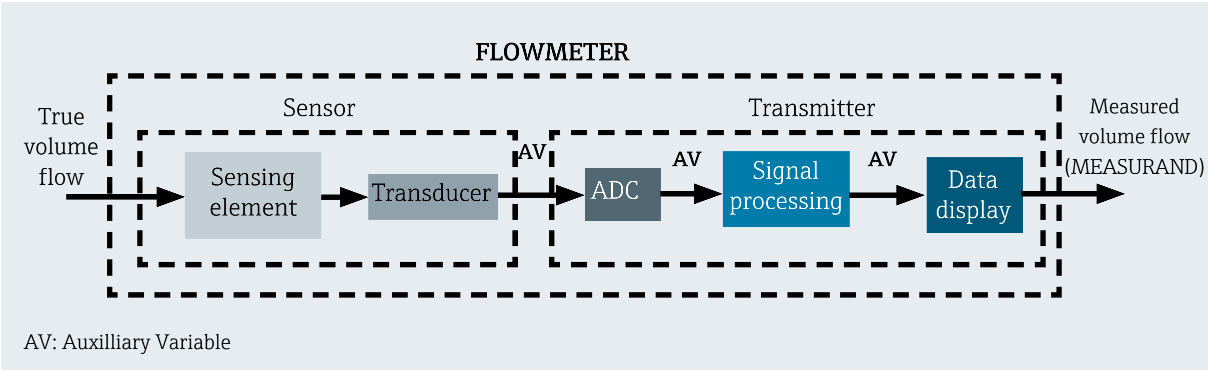


Figure 3: Basic components of a flowmeter, showing potential auxiliary variables

Initial values

The reference values for the AVs are stored in the instrument's non-volatile read-only memory as well as in the device's electronic documentation. This documentation – the Common Equipment Record (CER) – is stored by Endress+Hauser for all devices it manufactures, and can be accessed by customers via an online web portal. Thus a record of the condition of the device when it is new is stored and will remain valid for the flow meter's entire lifecycle.

Reference redundancy

For internal verification to be reliable, the internal references need to remain stable and not drift for the life of the device. If such a drift should occur, it needs to be detected immediately.

The risk of drift is minimised by:

1. utilising only the best, most stable and long-lasting components for the reference circuitry
2. providing redundancy through the use of two high quality references.

The two internal references are continuously cross checked to see if they drift out of tolerance, and if they drift relative to each other. It is highly unlikely that both references will drift in exactly the same way. Endress+Hauser have calculated that on an installed base of 100,000 Promass flow meters, both references drifting in the same way is expected to occur only once in 148 years.

Sensor verification

Verifying internal secondary variables verifies the internal processing functionality of the instrument transmitter, but is also necessary to be sure that the sensor itself is functioning correctly. Heartbeat verification is also capable of carrying out a sensor inspection on demand.

In the case of an electromagnetic meter, for example, various aspects of the electromagnetic coils are tested (see the example for the Proline Promag 400 flow meter on page 11).

Test coverage

Modern flowmeters and other instruments can be designed to have a self-diagnostic coverage of 94% or better, according to the definition found in the IEC 61508 standard for functional safety.

The total test coverage is defined as:

$$TTC = \frac{\lambda_{TOT} - \lambda_{du}}{\lambda_{TOT}}$$

where:
λ_{du} = dangerous undetected failures

λ_{TOT} = all theoretical failures

In the case of a flowmeter, the 'dangerous' failures are those that, should they occur, cause an error in the primary measurand.

The typically achievable TTC for an external calibration with an ISO 17025-compliant calibration rig is 98%. In comparison, the internal Heartbeat verification function for Proline flow meters can achieve greater than 94% TTC, without removing the instrument from the process.

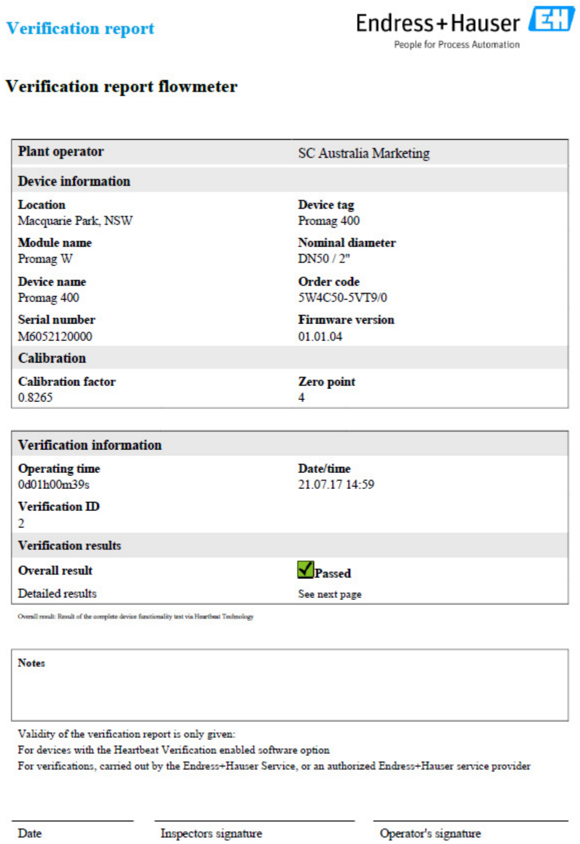
Traceability

Heartbeat verification constitutes an unbroken chain of traceability, while ever the internal references remain within tolerance – which is expected for the entire device lifecycle – because they have been initially calibrated at an accredited calibration facility. The calibration at Endress+Hauser's calibration facilities can be directly traced back to international standards.

Verification reporting

The diagnostics capability integrated into a self-verifying flowmeter constantly delivers information about the device status, and can notify of events such as a verification failure. During verification, the device also stores the information necessary for documenting the verification, and can be downloaded from the instrument via its various interfaces. Such documentation is in the form of a printable verification report in keeping with the requirements of ISO 9001, as confirmed by the TÜV test institute.

Due to the seamless integration of modern instruments with control networks via digital fieldbus technologies or industrial Ethernet, verification reports can be collected from instruments remotely without staff having to travel to the site of the instrument.



Verification report

Endress+Hauser
People for Process Automation

Verification report flowmeter

Plant operator	SC Australia Marketing
Device information	
Location Macquarie Park, NSW	**Device tag** Promag 400
Module name Promag W	**Nominal diameter** DN50 / 2"
Device name Promag 400	**Order code** 5W4C50-5VT9/0
Serial number M6052120000	**Firmware version** 01.01.04
Calibration	
Calibration factor 0.8265	**Zero point** 4

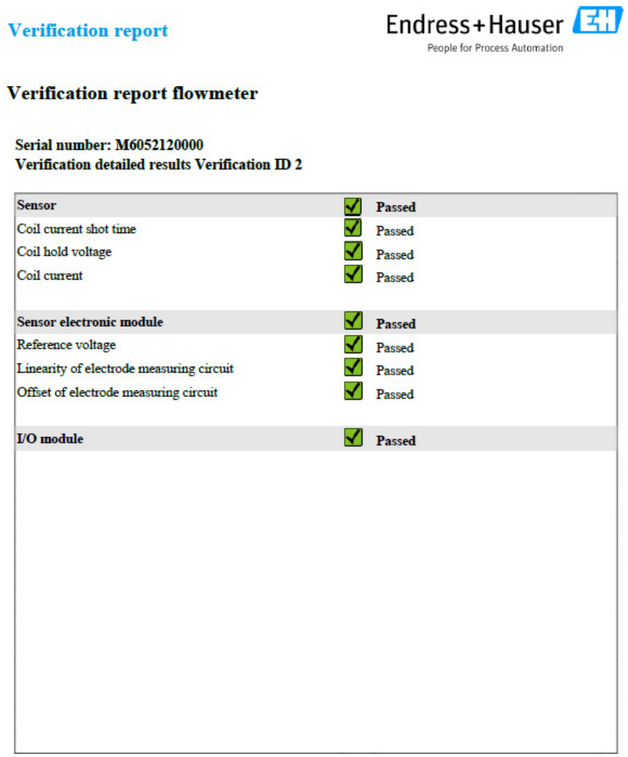
Verification information	
Operating time 0d01h00m39s	**Date/time** 21.07.17 14:59
Verification ID 2	
Verification results	
Overall result	Passed
Detailed results	See next page

Overall result: Result of the complete device functionality test via Heartbeat Technology

Notes

Validity of the verification report is only given:
For devices with the Heartbeat Verification enabled software option
For verifications, carried out by the Endress+Hauser Service, or an authorized Endress+Hauser service provider

Date | Inspectors signature | Operator's signature



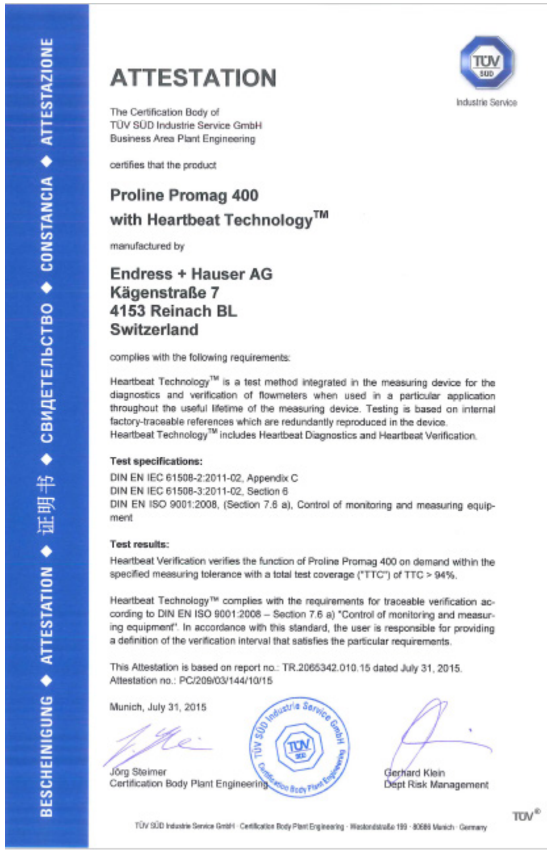
Verification report

Endress+Hauser
People for Process Automation

Verification report flowmeter

Serial number: M6052120000
Verification detailed results Verification ID 2

Sensor	**Passed**
Coil current shot time	Passed
Coil hold voltage	Passed
Coil current	Passed
Sensor electronic module	**Passed**
Reference voltage	Passed
Linearity of electrode measuring circuit	Passed
Offset of electrode measuring circuit	Passed
I/O module	**Passed**



BESCHEINIGUNG ◆ ATTESTATION ◆ 证明书 ◆ СВИДЕТЕЛЬСТВО ◆ CONSTANCIA ◆ ATTESTAZIONE

TÜV SÜD Industrie Service

ATTESTATION

The Certification Body of
TÜV SÜD Industrie Service GmbH
Business Area Plant Engineering

certifies that the product

Proline Promag 400
with Heartbeat Technology™

manufactured by

Endress + Hauser AG
Kägenstraße 7
4153 Reinach BL
Switzerland

complies with the following requirements:

Heartbeat Technology™ is a test method integrated in the measuring device for the diagnostics and verification of flowmeters when used in a particular application throughout the useful lifetime of the measuring device. Testing is based on internal factory-traceable references which are redundantly reproduced in the device.
Heartbeat Technology™ includes Heartbeat Diagnostics and Heartbeat Verification.

Test specifications:
DIN EN IEC 61508-2:2011-02, Appendix C
DIN EN IEC 61508-3:2011-02, Section 6
DIN EN ISO 9001:2008, (Section 7.6 a), Control of monitoring and measuring equipment

Test results:
Heartbeat Verification verifies the function of Proline Promag 400 on demand within the specified measuring tolerance with a total test coverage ("TTC") of TTC > 94%.

Heartbeat Technology™ complies with the requirements for traceable verification according to DIN EN ISO 9001:2008 – Section 7.6 a) "Control of monitoring and measuring equipment". In accordance with this standard, the user is responsible for providing a definition of the verification interval that satisfies the particular requirements.

This Attestation is based on report no.: TR.2065342.010.15 dated July 31, 2015.
Attestation no.: PC/209/03/144/10/15

Munich, July 31, 2015

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Dept Risk Management

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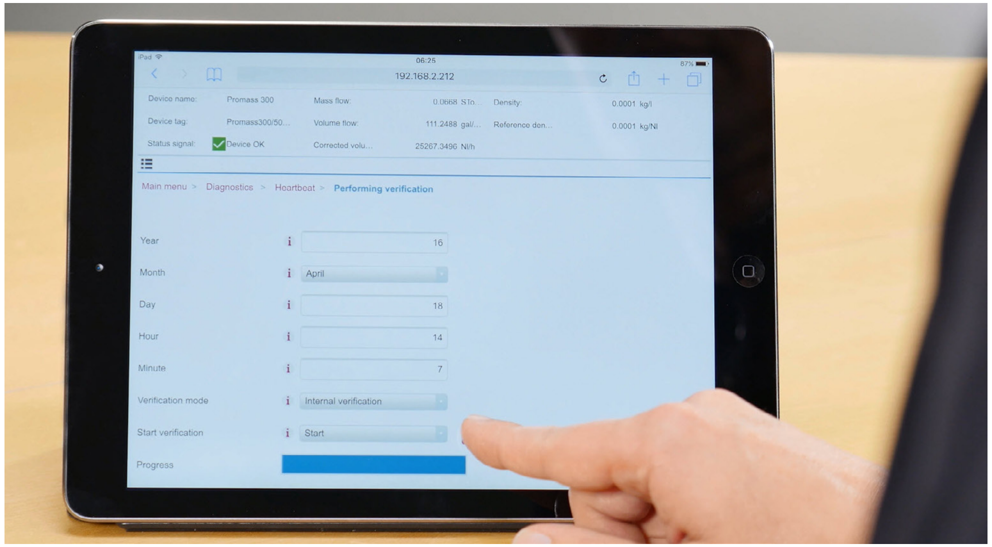
TÜV®

Calibration-Traceability- Accrediation

Heartbeat ease-of-use

Heartbeat verification can be easily performed without the need to call out an in-house or Endress+Hauser specialist to a remote site — with all the costs that such callouts incur — and requires no specialist verification tools.

During verification, normal process measurement will be suspended for a few seconds, and the flow meter will set its fieldbus/network status to indicate that verification is occurring, and hold the previous measured value.



Local verification

A simple verification can be performed locally without reporting via the instrument's push button interface.

Endress+Hauser flow meters with Heartbeat Technology come equipped with an on-board Webserver and offer a standard RJ45 Ethernet port as a service interface, so that a standard laptop can be connected. Without the need for special software tools, the internal web server can be accessed using any web browser, and the verification performed with the click of a button. An ISO 9001-complaint report can be downloaded directly as a PDF.

Remote verification

In many sites, the flow meter will be connected to an industrial Ethernet network, or if not, a gateway device can be connected locally, allowing access via a VPN over public 3G/4G networks.

In either case, it is then a simple matter to access the internal web server remotely and perform the verification and access reports.

Heartbeat Verification
Demonstration via web server

Condition monitoring and condition-based maintenance

External verification or calibration have traditionally been the only way to check that a process instrument is still operating within specification, or to determine whether process conditions are causing flaws in the output of the instrument. As effective as they may be, they are however only snapshots of the instrument at a specific time, and are unable to provide continuous status or predict in advance the potential of a failure or out-of-specification condition.

The internal verification process and the availability of secondary variables mean that reliability data can be logged regularly to a condition monitoring system or external maintenance service. Permanent monitoring and external trend analysis enables optimised condition-based maintenance, allowing instrument service (or the need for re-calibration) to be predicted and planned in advance.

A flowmeter that offers continuous diagnostics and that can verify its function and accuracy can provide this information to a condition monitoring system, enabling all the verification and sensor test variables to be trended to predict such events as the future need for instrument recalibration, or the potential failure or degradation of the instruments' sensing elements.

For example, Figure 4 illustrates how failure can be averted by monitoring parameters that relate to the build-up formation inside the sensor tube. Once a device reaches its wear limit, it will fail and the process will have to be halted or run without sight.

Since Condition-Based Monitoring systems and asset management systems are vendor and site-specific in their design and implementation, Endress+Hauser can provide specialised consulting services to assist in configuring these systems to monitor Heartbeat variables from its instruments if required.

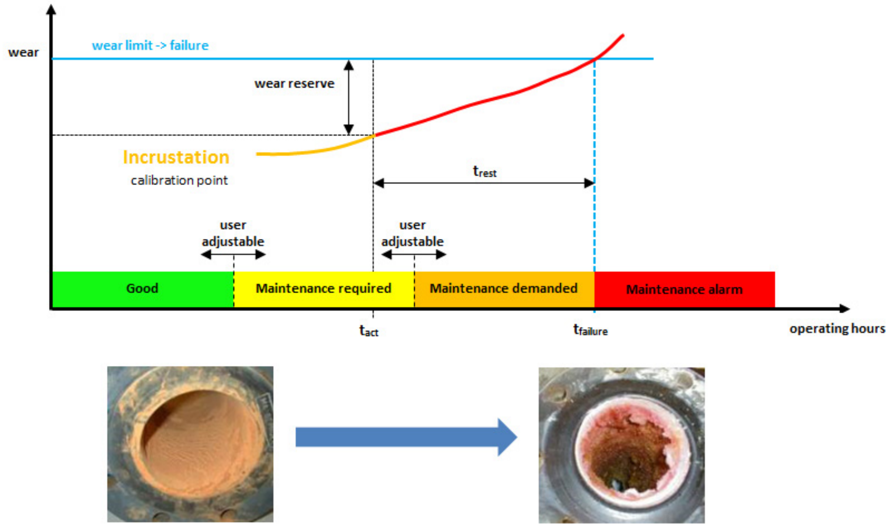


Figure4: Failure can be prevented by using the wear reserve for device maintenance before a failure can occur

Example: Proline Promag 400 Electromagnetic Flowmeter

In the case of the Promag 400 flowmeter, Heartbeat Technology is embedded in the design of the flowmeter electronics, covering the entire signal chain from the sensor to the outputs.

With this meter, the sensor functionality is tested continuously:

- Coil current shot time: The ratio of time interval during which the coil current rises to its maximum level, versus the time period during which it falls to its minimum level. If the ratio is not within an expected range, interference from an external field is the likely cause.
- Coil hold voltage: The ratio of positive versus negative hold voltage to hold the magnetic field. Out-of-specification results can also indicate external interference.
- Coil current: The ratio of current flowing into the coils versus the current exiting the coils. If the deviation too great, there may be a grounding problem.

The transmitter electronics tests include:

- Reference voltage: To detect potential drift, the two independent reference voltages are continuously tested against one another.
- Linearity and offset of electrode measuring circuit: On demand, during verification, this test simulates several front-end voltage signals and compares the measured results to fixed nominal values.
- Current output: On demand, during verification, the current output undergoes a loopback test, with a tolerance of 100 µA + 1% of given value.

The total test coverage for this meter is currently 94%.

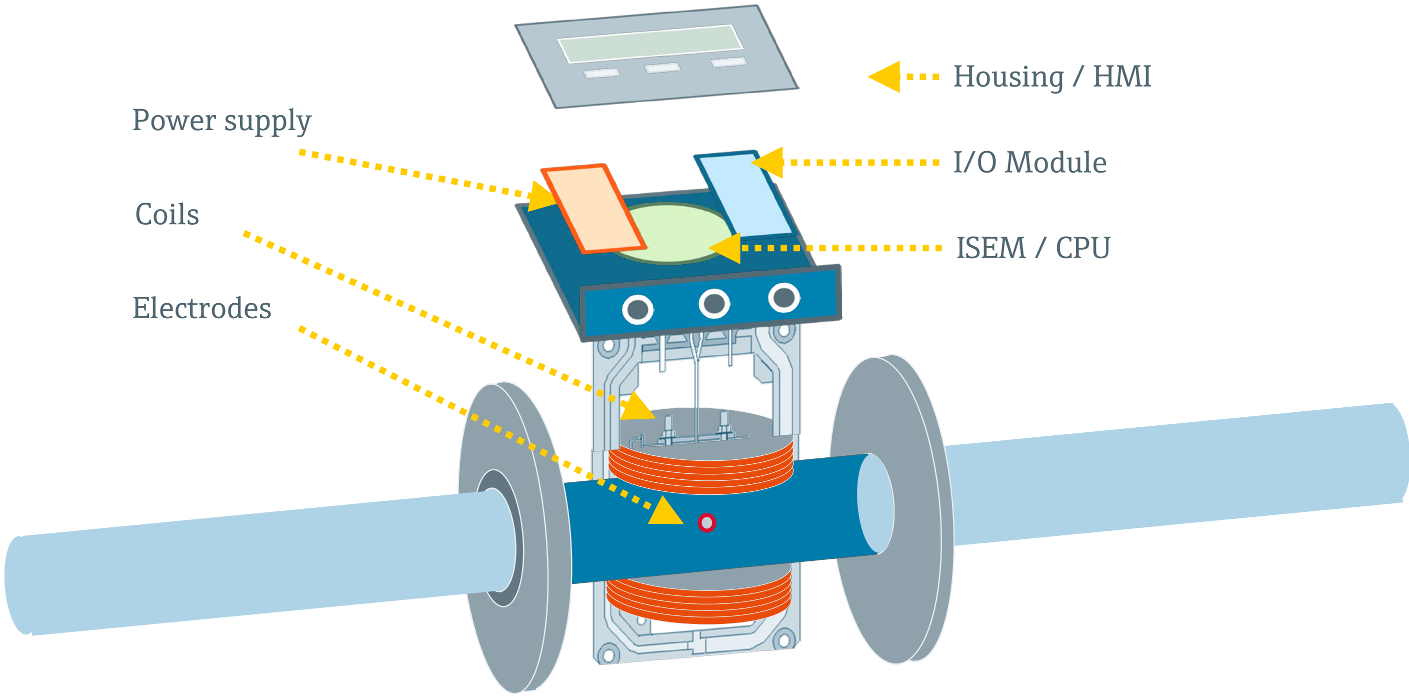


Figure5: The components of an electromagnetic flowmeter

Conclusion

Maintaining the accuracy of flow meters is critical in all industries, and is especially true of the water and wastewater industries, where flow meters may be located in remote locations, making calibration and verification particularly costly.

Endress+Hauser's Heartbeat Technology, available across its entire flow meter range, enables easy and reliable flow meter verification without the need to call out specialist technicians with expensive verification tools (which also require calibration). Ethernet and VPN access allow standardised verification reports to be obtained remotely as required with access via a standard web browser.

All diagnostic and verification capabilities offered by Heartbeat Technology offer at least 94% total test coverage and are traceable back to the devices' initial, TÜV-accredited and ISO-certified calibration, while providing flow measurement confidence and reduced maintenance costs.

References

1. International Bureau of Weights and Measures, http://www.bipm.org