White Paper

Gain Measurement Confidence with Smart Meter Verification for Magnetic Flow Meters

EMERSON™

In This White Paper

Magnetic flow meters are often the best solution to measure flows of slurries, sludges, and all manner of conductive liquids. New technologies allow these meters to be functionally checked without process interruption.

In 1831, Michael Faraday noticed a voltage was created when a conductor moved through a magnetic field. This discovery ultimately spawned a host of revolutionary advancements, including electric motors, generators, and surprisingly, a flow meter called the magnetic flow meter.

A magnetic flow meter provides several advantages over many flow measurement alternatives, and it has certainly taken its place as one of the more common flow metering techniques, but a leading challenge for magnetic flow meters is the lack of an easy calibration method. Magnetic flow meters generate a simple voltage, but that voltage is dependent on the pulsing and timing of a magnetic field, which is not as easily reproduced. As a result, magnetic flow meters are often proven by either pulling them for testing or by running the same flow through a second check meter, with both methods expensive, and either or both methods not possible in some applications.

This paper explains how magnetic flow meters work, and it describes a new method of in-situ flow meter performance verification that has recently become available, which solves the calibration problem.

Magnetic Flow Meters Explained

While experimenting with magnets and coils of wire in the early 1830s, Michael Faraday discovered he could create a voltage by moving a magnet through a conductive coil of wire (Figure 1). Further experiments by Faraday and others would prove that the opposite was also true, so when a conductor was moved through a fixed magnet field, this would also generate a voltage.

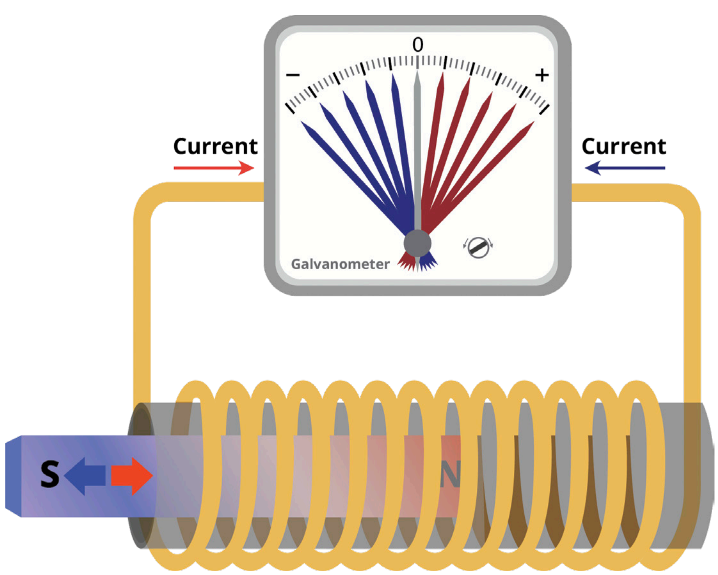
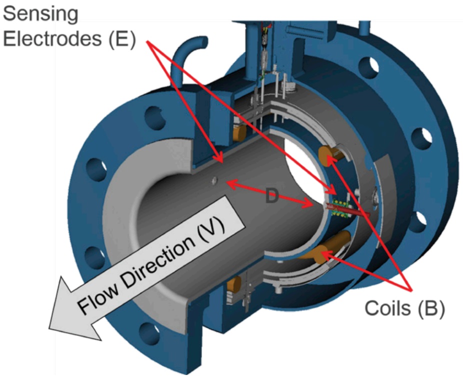


Figure 1. Faraday's experiments in 1831 showed that moving a magnetic through a conductive coil of wire generated a voltage across the wires.

Faraday's Law



$$E = k*B*D*V$$

E= Induced Voltage (Linear with Velocity)
k= Proportionality Constant
B= Magnetic Field Strength (Coil Inductance)
D=Distance Between Electrodes
V=Velocity Field of Process Fluid

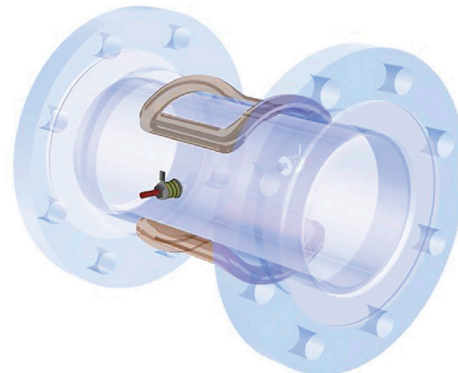


Figure 2. Based on Faraday's discovery, a magnetic flow meter measures the velocity of a conductive liquid as it moves between fixed magnetic coils in a lined pipe. The voltage across the electrodes is directly proportional to fluid velocity.

Further testing showed the magnitude of voltage varied with the strength of the magnetic field, the speed of conductor/magnet movement, and the distance between the magnet and the conductor. Eventually Faraday's law would be leveraged to create motors and generators, and it would spawn a wide range of related discoveries.

Perhaps not so obvious is the fact that Faraday's experiments also created a means to measure liquid flow in a pipe, for example a conductive liquid moving through a lined pipe (Figure 2). In this case the conductive liquid acts as the conductor moving through the fixed magnetic field crossing the pipe, creating a voltage across the electrodes. As the liquid velocity increases, the generated voltage rises. Note that the pipe must be lined with a nonconductive material to keep it from shorting the generated voltage signal to ground.

Magnetic Flow Meter Applications

Magnetic flow meters (Figure 3) have certain advantages over other flow meter technologies. An abbreviated list of benefits includes:

- Magnetic flow meters are full bore meters and create essentially no pressure drop.
- Magnetic flow meters can read flow in either direction.
- Magnetic flow meters provide turndown ratios of 100:1 or better.
- Magnetic flow meters can operate in a wide range of pressures, temperatures, and even vaccum.
- Magnetic flow meters offer a variety of liner materials that are largely impervious to degradation or damage from most fluids. The electrodes are typically very small — so even if an exotic material like platinum, nickel alloys, or tantalum is required — they are relatively inexpensive. This makes magnetic flow meters an excellent choice for measuring flow of slurries and/or corrosive liquids.
- Magnetic flow meters are available in sizes up to 48" or more.
- Magnetic flow meters require modest meter runs of five pipe diameters upstream and two downstream.
- Magnetic flow meters are often more cost-effective than other flow measurement technologies, especially when full lifecycle costs are taken into account.

Figure 3. Magnetic flow meters (Rosemount™ 8705 Flanged Magnetic Flow Meter Sensor with Integral Rosemount 8732E Transmitter) are an excellent choice for measuring flows of slurries, corrosive liquids, and any conductive liquid.

Magnetic flow meters do have limitations that are important to be aware of in certain applications, including:

- The fluid must be a conductive liquid, generally 5 microsiemens/cm or higher.
- The meter cannot measure vapors or gases.
- Magnetic flow meters only work in pipes with full or nearly full flows.
- Magnetic flow meters can be installed in lined (non-conductive) pipes, though they usually require grounding rings for these applications
- Magnetic flow meters are volumetric flow meters, and they cannot measure density or mass flow.

Magnetic flow meters are an excellent choice for slurry applications, including the very abrasive slurries found in mining applications. In addition to their standard offerings, which typically work well in these types of applications, Emerson offers magnetic flow meters for very demanding slurry applications, such as long fibers in pulp stock flows in pulp and paper applications, or sand and rocks in mining applications. These meters have an increased coil drive current and therefore a stronger magnetic field, providing increased induced voltage created when the conductive fluid passes through the magnetic field, which improves the signal-to-noise ratio. They also provide users with the capability to change operating frequencies and signal processing methods, both useful because slurries tend to create a lot of process noise, and some frequencies work better than others.

Magnetic flow meters are also very common in water/wastewater applications and in corrosive service. They work well and generally have a long service life, except in very aggressive slurry applications, which can damage the liner. However, carefully selected meter designs and liner materials can provide extended life even in these difficult environments.

When magnetic flow meters do fail, the typical failure modes are somewhat limited. The meter may cease to operate correctly for any of these reasons:

- A less than full pipe will result in a low reading or no reading at all.
- A pipe filled with a mix of gas and liquid can result in overreporting the liquid volume flow rate because the meter assumes the pipe is full of liquid.
- The electrodes can become coated with a non-conductive material, which blocks them from reading the voltage signal or reduces the voltage, resulting in a lower than actual reading.
- Conductive coatings can allow stray voltage signals to get picked up by the electrodes, causing false flow readings.
- Coatings of any type can reduce the effective inside diameter of the pipe and lead to higher flow readings than actual values.

As a result, magnetic flow meters should be checked and have their performance verified on a routine basis. This is particularly true for mission critical flow meters that must operate reliably and accurately to ensure smooth plant operations.

Magnetic Flow Meter Performance Verification

The pulsed nature of the magnetic field and resulting voltage creates a complicated signal that is not easily duplicated. As a result, calibration and testing of a magnetic flow meter is not straightforward. Typically, the only testing options include removing the meter from the line for flow testing or diverting the same flow through a check meter if the piping allows this configuration. Unfortunately, neither method is easily accomplished, so many magnetic flow meters get checked infrequently, if at all. Fortunately, Smart Meter Verification verifies that the magnetic flow meter is within calibration without needing to remove the meter.

Smart Meter Verification provides a review of the transmitter and sensor's critical parameters, including coil inductance, coil resistance, electrode resistance, sensor voltage conversion, and 4–20 mA output, as a means to document verification of calibration.

Baseline values for each of these measurements are recorded during initial commissioning and stored in the meter’s non-volatile memory. The meter can then either continuously check all the measurements as the meter operates, or tests can be manually initiated as required. Allowable deviations for each test are fully configurable, and individual tests can be disabled if necessary. Details of the Smart Meter Verification tools are described below:

Meter signature capture

The first step for Smart Meter Verification is to record baseline values such as coil resistance, coil inductance, and electrode resistance. The baseline values provide a description of the magnetic behavior of the transmitter and sensor. Based on Faraday’s law, the induced voltage measured on the electrodes is proportional to the magnetic field strength. Therefore, any changes in the magnetic field will result in a calibration shift of the sensor. Taking an initial sensor signature when the transmitter is installed establishes a baseline for future verification tests.

Ideally, this data should be captured during startup and commissioning when the pipe is full of the typical process fluid and when there is no flow. This condition allows the most accurate measurement of the key sensor signature values.

Baseline values can be captured when the pipe is empty or when the pipe is full and has process fluid running through it, but recording a baseline signature under these conditions is less than optimal. This is because the electrode resistance cannot be measured if the pipe is empty, and measurements taken when process fluid is running through the meter will inject some signal noise.

Sensor Health Verification includes the resistance test data from the *Coil inductance and resistance* test and data from the *Electrode resistance* test. These tests are designed to check the health of the coil and electrode circuits. *Sensor Calibration Verification* is done with the *Coil inductance and resistance* test. Coil inductance is the key characteristic of the coils because it determines the magnetic field strength. These tests are described below.

Coil inductance and resistance

A magnetic flow meter is dependent upon a consistent magnetic field to generate an accurate flow signal. This magnetic field is created by a pair of coils built into the top and bottom of the meter, which are energized with pulsed DC current. Any change in the performance of these coils will impact the flow reading.

Electrode resistance

If the pipe is full, the resistance across the electrodes will be a function of the process fluid conductivity and should fall within a consistent range. The Smart Meter Verification Electrode Health Check looks for significant deviations in the resistance between the electrodes. Very low resistance suggests the electrodes are shorted to ground, likely due to a damaged liner. Very high resistance suggests an empty pipe, failed electrode, or possibly very heavy electrode coating. An advanced diagnostic check, discussed below, provides customizable alerts for electrode coating detection.

Transmitter and analog output check

The Smart Verification diagnostic simulates a voltage into the transmitter that mimics an actual flow velocity reading. The Smart Meter Verification Transmitter Check activates this simulated voltage and compares the output of the transmitter and the analog output to confirm they match the expected values. This diagnostic effectively tests the ability of the transmitter to read a sensor voltage and accurately convert it to a 4–20 mA output scaled to flow.

Test initiation

Any or all of the tests and checks listed above can be manually initiated. Additionally, the meter can be set up to continuously run the tests while it is in operation, and to generate an alert should a test fall out of specification.

Test results and report

A report can be generated showing the result of the Smart Meter Verification tests (Figure 4). This report can be populated automatically if Emerson's AMS is active on the system. If the local interface, ProLink software, or a HART® handheld device is being utilized, the data can be accessed locally and directly.

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Meter Verification
Magnetic Flowmeter

Friday, July 5, 2024
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Instrument Owner : Rosemount Flow
Company : Emerson

Contact Name/Tested By : Trever Ball
Telephone : 123-456-7890

Transmitter Identification
Transmitter Tag : EXCHANGE
Transmitter Model : 8732E
Transmitter Serial Number : 1009145

Sensor Identification
Sensor Serial Number : 0

Transmitter Configuration
Calibration Number : 1000015010000000
Line Size : 3 in
Damping : 2.00000 Sec

Test Conditions and verification Limits
Test Condition : Flow, Full Pipe
No Flow Limit : 1 %
Flowing Limit : 2 %
Empty Pipe Limit : 3 %

Sensor Health Verification Results
Coil Resistance Baseline : 15.92982 ohm
Measured Coil Resistance : 15.9560 ohm
Coil Circuit Test Result : Pass
Electrode Resistance Baseline : 31.69950
Measured Electrode Resistance : 14.06689
Electrode Circuit Test Result : Pass

Sensor Calibration Verification Results
Coil Inductance Baseline : 13.48115
Measured Coil Inductance : 13.52486
Sensor Deviation : 0.32420 %
Sensor Calibration Test Result : Pass

Transmitter Calibration Verification Result
Simulated Velocity : 30.00000 ft/s
Actual Velocity : 30.01789 ft/s
Transmitter Deviation : 0.05962 %
Calibration Test Result : Pass

Meter Verification Test Result
Result : Pass

Customer Signature

Figure 4. The results of Smart Meter Verification tests can be documented in an auto-generated report that lists details on the equipment, testing limits, and functional test results.

The report provides information on the meter itself (tag number, model number, serial number, size, etc.), as well as the test conditions, verification limits, and test measurements and results.

Diagnostic Options

All diagnostic options include basic features, such as empty pipe detection, reverse flow detection and grounding and wiring alarms; additional diagnostics are offered as an option. Process Diagnostics detect and warn of abnormal situations throughout the life of the meter related to:

High Process Noise

High process noise detects if there is a process condition causing an unstable or noisy reading that is not an actual flow variation. A common cause of high process noise is slurry flow, such as pulp stock or mining slurries. If unusual noise or flow variation is seen, this diagnostic will activate and deliver an alert. If this situation exists and is left without remedy, it will add additional uncertainty and noise to the flow reading.

Coated Electrode Detection

Coated electrode detection provides a means of monitoring insulating coating buildup on the measurement electrodes. If coating is not detected, buildup over time can lead to a compromised flow measurement.

		8700 Basic Diagnostics	Process Diagnostics	SMV Diagnostics
	Ordering Code	Standard	DA1 / DS1	DA2 / MV
PROCESS DIAGNOSTICS	Empty Pipe	✓	✓	✓
	Reverse Flow	✓	✓	✓
	Electrode Saturation	✓	✓	✓
	Grounding and Wiring	✓	✓	✓
	High Process Noise		✓	
	Coated Electrode		✓	
SMART METER VERIFICATION	Overall SMV Pass / Fail			✓
	SMV Baseline			✓
	Continuous SMV			✓
	SMV Coil Health			✓
	SMV Electrode Health			✓
	SMV Transmitter Check			✓
	Print Report			✓
	Configure Test Criteria			✓

Figure 5. Smart Meter Verification is one part of the diagnostics packages offered by Emerson. For assistance in selecting the right diagnostic packages for your application, please contact your local Emerson representative.

Case Study

A large wastewater treatment plant used magnetic flow meters to measure sludge flows in their process to maintain a consistent mass balance and ensure viable biological activation. The flow readings were critical to the process, but meter calibration was not possible without removing the meters from service, which created significant operability and safety issues. As a result, the meters went untested, creating sub-optimal performance and a burdensome requirement for multiple manual measurements.

The plant replaced these magnetic flow meters with Rosemount 8750 Magnetic Flow Meters featuring Smart Meter Verification. This allowed the plant to verify meter calibration without removing the meters from service. Initially, the meters were fully verified every three months, but the consistent performance allowed the maintenance staff to extend testing to once every 12 months. The improved flow measurement accuracy allowed the facility to optimize their sludge management, and to significantly reduce both operating and maintenance costs.

Conclusion

Magnetic flow meters offer cost-effective and reliable flow measurement for a broad range of applications, but they have historically been difficult to calibrate without process interruption. That problem has been solved with Smart Meter Verification diagnostics. With this advancement, meter functionality from the sensor through the analog output can be fully tested without removing the meter from service. While testing with a full pipe and no flow is preferred, the meter can be tested to a very high degree of certainty even with flow moving through the pipe, providing testing options for mission critical applications that cannot be interrupted.

For customers with existing Rosemount magnetic flow meter sensors, it may be possible to upgrade only the transmitter to access the Smart Meter Verification toolbox. If this option is of interest, contact your local Emerson partner for alternatives and options for specific meter models.

For additional information on Emerson's products, visit
Emerson.com/MagneticFlowMeters

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