

LEVERAGING MAG METER DIAGNOSTICS TO UNDERSTAND FLOW, PROCESS, & PERFORMANCE

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INTRODUCTION

Electromagnetic flow meters, commonly known as mag meters, are part of a growing family of 'smart' flow meters in the oil & gas industry. Smart flow meters are meters which provide additional information, or diagnostics, other than flow data. This diagnostic data can be used to understand fluid flow and process conditions occurring inside of the pipe and indicate the health and performance of the electronics within the meter. These diagnostics can be used to maintain accuracy, trend various data points, and establish key performance indicators (KPIs).

DESIGN & THEORY OF OPERATION

Mag meters are commonly made up of two main parts: the sensor (or body) and the transmitter (or head). Within the sensor there will be at least one pair of electrodes and a set of magnetic coils. The transmitter will send power to drive the magnetic coils and receive signals from the sensor to calculate the flowrate. A mag meter will also be equipped with a process ground. This is used to mitigate any excess voltage that would impair the meter's performance and accuracy. Mag meters can only measure electrically conductive fluids.

Mag meters operate using Faraday's law of induction (Faraday's law). Faraday's law predicts how a magnetic field (the coil) will interact with an electronic circuit (the electrode) and is mathematically expressed as:

$$E = k * B * D * V \text{ (Equation 1)}$$

Where:

- E = induced voltage
- k = proportionality constant
- B = magnetic field strength
- D = distance between electrodes
- V = velocity

The induced voltage (E) is proportional to the velocity (V). To determine this, the transmitter will apply power to the magnetic coils which creates a magnetic field (B) between the coils. As the electrically conductive fluid moves through the sensor, the negatively and positively charged particles of the fluid are separated by the force of the magnetic field. Particle separation is what causes the induced voltage. The induced voltage from the sensor is delivered to the transmitter, where it is converted to a flow velocity using the proportionality constant (k) and distance between electrodes (D). The velocity is then used to calculate the volumetric flow rate using the area of the pipe.

DIAGNOSTICS

Many mag meter manufacturers offer diagnostic capabilities with their meter. These diagnostics may vary between manufacturers so it is important to know what is offered and how it can be used in an application prior to selecting your mag meter. The diagnostic results can be used to understand process conditions, meter health, and help in making decisions to adjust process operations or perform meter maintenance. Some diagnostic values will be set at the factory, others will be set in the field by the user, and some values can be adjusted based on results.

A mag meter's process diagnostics can indicate if a process or installation issue is present that would contribute to poor meter performance. Process diagnostics offer insight into a condition happening inside of the meter sensor which could affect measurement performance. Conditions like poor fluid quality, multiphase flow, empty pipe, and electrical issues are a few examples. Alarms from a process diagnostic allow the user to understand if something other than the meter is causing inaccurate measurement. Below is a table of process diagnostics offered by one manufacturer, known as DA1:

DA1 Diagnostics	Purpose	Base Line Value	Trigger	Comment
Empty Pipe Value	Detection of any non-conductive fluid movement	Trend	300	High values (>300) indicate a pipe is not full of conductive fluid; can impact electrode coating value
Electrode Coating Value	Indicate a non-conductive coating on the electrodes	Trend	500	Optimize the setting based on field data; some coatings may have a different impact on measurement than others
Line Noise Value	Alerts potential grounding/wiring issues or process noise	0	~0	Measures noise from process, grounding, or static at 50 Hz & 60 Hz; results should be close to zero
Signal to Noise Ratio	Identify high levels of white noise and confirm signal stability	Trend	25	Higher ratio is better (high signal to low noise). If it is less than 25, consider changing the frequency setting

TABLE 1. DA1 Diagnostic Suite

Figure 1 (below) illustrates how the DA1 diagnostic suite can be used with the flow rate data to elevate confidence in the flow data. The flow rate line in the figure shows approximately 30 minutes of flow for three hours of downtime over a 12-hour period. During periods of flow, the Signal-to-Noise ratio increases. This is an indication of the flow rate being established by a pump turning on. The Empty Pipe Value and the Line Noise Value are both very low and remain relatively stable throughout periods of flow and no flow. However, the most meaningful diagnostic in this chart comes from the Electrode Coating Value. When the pumps are running and the meter is measuring flow rate, the Electrode Coating Value will decrease. Once the pumps are off and no fluid is flowing through the meter, the Electrode Coating Value will slowly increase. Once flow is established again, the Electrode Coating Value sharply decreases. This is an indication of a non-conductive material depositing on the surface of the electrodes when there is no flow, and the material being washed away during periods of flow. This value can be trended over time and used to decide when preventive maintenance should be performed. The DA1 diagnostic values must be baselined after the meter is installed and flowing conditions have been established since these results will be affected by the installation and the process fluid. A user can use these baseline results and compare them to trended results over time to make informed decisions for maintenance and process adjustments.

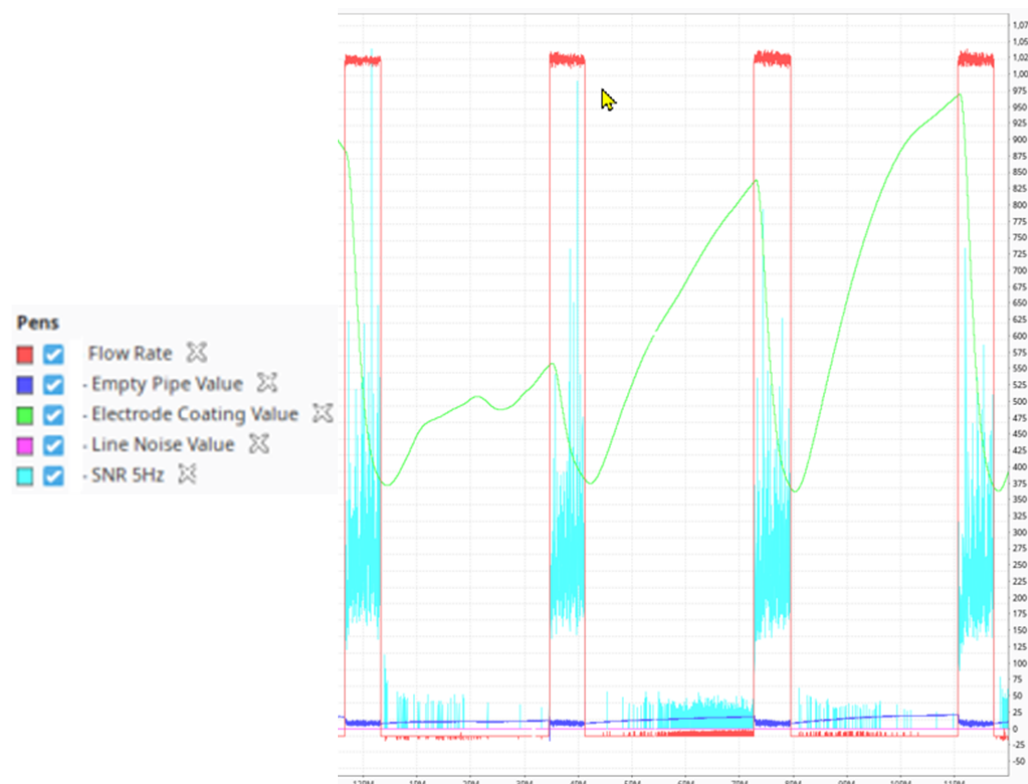


Fig 1. DA1 Diagnostic Dashboard

A mag meter's health diagnostics can indicate if the meter's internal electrical signals have changed over time. These signals can be determined at the factory, or in the field, and will be used as a baseline comparison to indicate any deviation. It is important to understand a mag meter's magnetic field strength should remain constant when operating correctly. This is because the proportionality constant (k) and the distance between electrodes (D) are fixed, making the magnetic field strength (B) the most likely variable to introduce measurement error. Below is a table of common process diagnostics offered by a manufacturer, known as DA2:

DA2 Diagnostics	Purpose	Base Line Value	Trigger	Comment
Coil Inductive Value	Verification of magnetic field strength	Factory	$\pm 5\%$	Factory signature, transmitter & sensor are paired when ordered.
Coil Resistance Value	Verification of coil circuit health	Factory	$\pm 10\%$	Factory signature, transmitter & sensor are paired when ordered.
Electrode Resistance Value	Verification of electrode circuit health	Field Baseline	± 150	Signature established in field after install and with process fluid in meter. Electrode coating and empty pipe value can affect ERV.
Internal Flow Simulation	Verification of simulated flow velocity against actual transmitter measurement	30	$\pm 1\%$	A comparison of simulated vs. actual velocity as measured by the transmitter.

TABLE 2. DA2 Diagnostic Suite

Coil Induction and Coil Resistance are both indications of the sensor's magnetic health and is a factory signature unique to the sensor and transmitter pairing. Electrode Resistance Value (ERV) is not a factory setting but instead is a field signature. Since the conductivity of process fluids will differ, the ERV signature must be established after the meter is installed and is filled with the actual fluid to be measured. It will be important to ensure the pipe is full and the electrodes are clean when establishing this baseline value since empty pipe and electrode coating values can affect this baseline. Flow simulation will introduce a simulated velocity to verify calibration of the transmitter.

Figure 2 shows the Coil Inductance comparison. This is a verification of the magnetic field strength and is measuring the intensity of the magnetic field within the sensor. The trended results in figure 2 are within a user defined threshold ($\sim 1.5\%$) to the signature value. This indicates the magnetic field strength generated by the coils has not changed and the sensor is still within the factory calibration.



Fig 2. Coil Inductance Comparison

Figure 3 shows the Coil Resistance comparison. This is a verification of the coil circuit itself, and the results of this comparison can indicate different issues with the coil. If the coil resistance value is lower than the signature, it could be an indication of a short circuit condition. If the coil resistance value is higher than the signature, it could be an indication of loose contacts, corrosion, or damaged wire. The trended results in figure 3 are within a user defined threshold ($\sim 10\%$) and indicate the coil circuitry is operating correctly.



Fig 3. Coil Resistance Comparison

Figure 4 shows the Electrode Resistance comparison. This is a verification of the electrode circuit health and is measuring the opposition (resistance) of the electrical current across the electrode. As stated previously, this signature must be established in the field since it will be dependent on the process fluid. It is common to see fluctuations in Electrode Resistance value since this can be affected by changes in flow rate and fluid quality. The trended results in figure 4 are within a user defined threshold and indicate the electrode circuitry is operating correctly.



Fig 4. Electrode Resistance Comparison

ALARMS & NOTIFICATIONS

Most mag meters will have an internal verification process to review the status of the available diagnostics and provide pass/fail results of each diagnostic. Some mag meters will also produce a report providing the result of the test and the measured result of each data point. These verifications are looking at the diagnostic data at that moment and may not show if an event took place previously. This is why it is most helpful to pair diagnostic data with other analytical tools.

Diagnostic data can be polled by a SCADA system similar to how the flow data is polled. By polling this data, and loading it into other analytics tools, the data can be trended over time. These trends can be used to set upper and lower limits on diagnostic data which would be considered out of tolerance. When the diagnostic data exceeds these setpoints, an alarm or notification can be sent via email or text to inform a user of this event. The user can use this information to take further action if deemed necessary.

Alarms and notifications are like any other data setpoint. They can be set so tightly that a user is flooded with alerts, or they can be set so loosely that the user never sees a potential issue. Understanding the application the meters is placed in, and how varying process conditions may impact the diagnostic data are critical to having meaningful alarms and notifications.

CONCLUSION

'Smart' flowmeters and diagnostic data provide powerful insight into how measurement analysts, engineers, and technicians identify and troubleshooting issues, confirm performance, and complete maintenance tasks. However, not all data is good data, and most data must be compared with other data to tell a complete story. A mag meter's diagnostic tools complement the existing best practices of proper installation, understanding process conditions, and maintenance by allowing users to confirm the health and integrity of the meter and ensure there are no internal, or external, factors which may contribute to measurement error.