Calibration of Rosemount™ Differential Pressure Transmitters to API 21.1

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1.0 Introduction

API 21.1 is a gas measurement standard created by the American Petroleum Institute (API) that details requirements for flow measurement using electronic metering systems. API 21.1 provides concise descriptions of the minimum requirements needed for electronic gas metering systems. The standard applies to the measurement of gaseous phase hydrocarbons and other related fluids for production and transmission custody transfer applications utilizing industry-recognized primary measurement devices.

2.0 Calibration and verification requirements

API 21.1 defines a verification as the process of confirming accuracy of an Electronic Gas Measurement (EGM) device by use of measurement or reference standards. A verification is used only to “check” the device for accurate measurement, without altering transmitter output. A verification test of a differential pressure device is required on a quarterly basis using the procedure below.

2.1 Section 7.3.3 Differential Pressure

At a minimum, verifications shall be performed at these pressure points under atmospheric conditions and in the following sequence:

- *zero;*
- *approximately 25% of user defined operating range or transmitter calibration span;*
- *approximately 50% of user defined operating range or transmitter calibration span;*
- *100% of user defined operating range or transmitter calibration span;*
- *approximately 80% of user defined operating range or transmitter calibration span;*
- *approximately 20% of user defined operating range or transmitter calibration span;*
- *zero;*

API 21.1 defines a calibration as the adjustment of an EGM device or components to conform to certified reference standards to provide accurate values over the EGM’s user defined operating range. API 21.1 states the following regarding calibration and verification procedures for EGM devices.

8.2.1 *EGM components and their individual transducers, transmitters, and analyzers are substantially different in their methods of calibration. Some have zero, span, and linearity adjustments and some only zero and span. Others are calibrated electronically (intelligent devices such as so-called 'smart' transmitters) and require no mechanical adjustments. Their signal output can be a voltage, current, pulse frequency, or other forms of data signals. For this reason, refer to the manufacturer's operation guide for step-by-step calibration procedures.*

Since a calibration is changing the output of the measurement device, and has the potential to degrade measurement accuracy, Emerson recommends calibrations are only completed when required.

API 21.1 states that a calibration is only required during the initial installation of a unit (zero trim only for factory calibrated devices), following the replacement of a transmitter or other critical component, or whenever a verification test determines there is an unacceptable difference between the value measured by a certified reference device and the value measured and utilized by the EGM.

API 21.1 requires using a reference pressure device that is at least two times more accurate than the accuracy of the measurement device being verified or calibrated. API 21.1 also notes that a reference pressure device with accuracy better than ± 0.05% is not normally required.

3.0 Rosemount Differential Pressure Transmitter calibration procedure

The accuracy and performance of Rosemount Pressure Transmitters are the result of the manufacturing process and the factory calibration procedure. Rosemount manufacturing utilizes a characterization and verification process to determine each sensor's unique characteristics over a range of multiple static pressure and ambient temperature points. This data is used in a polynomial curve fit algorithm to create a set of coefficients. These coefficients are used by the internal transmitter software to linearize the output of the sensor over the transmitter's entire pressure and temperature operating range.

Due to the linearity achieved during the characterization and verification process, only an offset (zero) and slope (span) trim are required during the factory calibration procedure. A calibration process using an offset and slope adjustment can also be done by a user in the field. However, most applications only require an offset trim adjustment to correct for mounting position and line pressure effects. The procedure for calibrating a Rosemount Pressure Transmitter is detailed below.

1. Using a reference pressure device, apply the desired offset trim value (low pressure value).
2. Once the applied pressure has stabilized, use the transmitter's *offset trim* command. The offset trim point is typically done at a zero point with no pressure value applied.
3. Using a reference pressure device, apply the desired slope trim value (high pressure value).
4. Once the applied pressure has stabilized, use the transmitter's *slope trim* command.

Emerson recommends using a reference pressure device that is at least three times more accurate than the transmitter for field calibrations. Finding reference pressure equipment that is three times more accurate than the transmitter can be difficult and expensive; most users do not have equipment of this caliber. The factory calibration process uses reference equipment that is 5 to 10 times more accurate than the transmitter. It is possible to degrade the performance of the transmitter if inaccurate reference equipment is used. Because of the extremely accurate equipment used during the factory calibration, it is recommended that only an offset trim adjustment be completed in the field. Rosemount Transmitters can also be returned to the factory calibration settings if required.

3.1 Offset and slope trims

Performing an offset or slope trim adjusts the sensor characterization curve defined during the characterization and verification manufacturing process. An offset trim is an adjustment that shifts the position of the sensor characterization curve, but it does not affect the slope of the curve. This shift is illustrated in Figure 1-1. The offset trim can be used without a slope trim to adjust the output of a transmitter to compensate for mounting position and line pressure effects. Typically, only an offset trim is required to adjust the calibration of a Rosemount Transmitter in the field.

A slope trim is an adjustment that changes the slope of the sensor characterization curve. This is shown in Figure 1-2. A slope trim should only be completed in conjunction with an offset trim. The offset trim value should be completed first to establish the correct offset. Then, the slope trim should be performed to provide a slope adjustment to the characterization curve based on the offset trim value.

Figure 1-1. Offset Trim

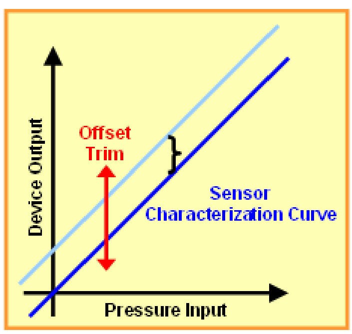
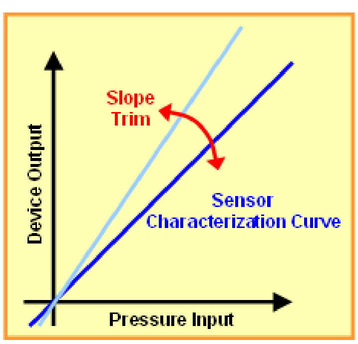


Figure 1-2. Slope Trim

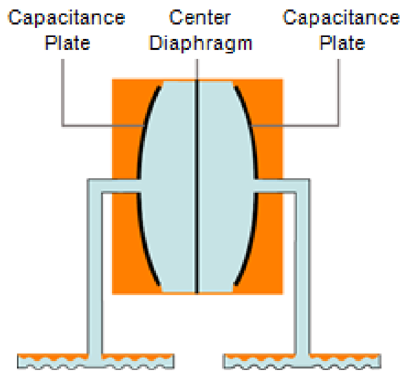


3.2 Basis and technology

There are multiple suppliers of differential pressure measurement instrumentation that can be used in API 21.1 compliant applications. The design and manufacturing techniques used to produce this instrumentation differs between suppliers. It is because of these design and manufacturing differences that API 21.1 states to use the manufacturer's recommended procedure to calibrate each device.

Rosemount Transmitters are designed to be the highest performing devices with the best long term stability. Rosemount Differential Pressure Transmitters use capacitance sensor technology (see Figure 1-3). Capacitance sensors are composed of two fixed capacitors deposited on a backup plate and a common diaphragm located in the center. As pressure is applied, the center diaphragm deflects causing a change in capacitance between the two fixed plates. This change is measured electronically to infer a differential pressure measurement reading.

Figure 1-3. Capacitance Pressure Sensor



Capacitance pressure sensors are inherently high-performance devices. They require very little compensation, resulting in a sensor that delivers high-performance in real world applications that have dynamic pressure and temperature effects. Other sensor types that are more affected by variables such as pressure and temperature changes require additional compensation techniques.

The Rosemount manufacturing procedure takes the best performing capacitance sensor design and linearizes the sensor's output over the entire pressure and temperature operating range. The linearity is achieved by the characterization and verification manufacturing process. This process achieves a high degree of linearity by using extremely accurate reference equipment and minimizing the effects of hysteresis.

Extremely accurate pressure and temperature equipment along with controlled conditions are used during the characterization and verification process. This equipment is 5 to 10 times more accurate than the Rosemount Pressure Sensor itself. The reference pressure and temperature equipment is also maintained in accordance with standards from the National Institute of Standards and Technology (NIST).

Hysteresis is a non-correctable error inherent to pressure measurement devices. While hysteresis is non-correctable, its effects are minimized through the Rosemount manufacturing process. The effects of hysteresis at an individual measurement point are dependent on the size and direction of the pressure change that occurred to arrive at the measurement point. Because the characterization and verification process uses an automated pressure and temperature cycling routine, the size and direction of each pressure change is known. The coefficients generated during the characterization and verification process consider the effects of hysteresis and are designed to minimize hysteresis effects resulting in a more linear measurement output.

Rosemount Transmitters are designed and manufactured to maintain long term stability. Changes in differential pressure, line pressure, temperature, and power cycling can cause a sensor to drift, resulting in errors. Rosemount devices maintain the linear characteristics gained through the characterization and verification process over the long term. Devices have been rigorously tested and are exposed to ongoing audit tests for verification of long term stability.

Because the characterization and verification process results in a transmitter that has an extremely linear output, minimized hysteresis effects, and a high degree of long term stability, only an offset and slope adjustment are used for calibrating Rosemount Pressure Transmitters. Adding midpoints to the Rosemount calibration procedure is not necessary and will not increase the accuracy of our devices. This is an advantage because the more points that are used during a field calibration, the greater the likelihood that measurement accuracy will be degraded if less accurate calibration equipment and an uncontrolled environment are used. Finally, adding unnecessary calibration midpoints will more than double the amount of time required to calibrate a device.

4.0 Summary

Rosemount Transmitters are characterized with equipment that is 5 to 10 times more accurate than the Rosemount Pressure Sensor itself. In order to maintain the high level of performance this characterization process gives the transmitter, users should not calibrate the device unless required. Emerson recommends after a new installation of a transmitter that a zero offset is completed on the device to eliminate any mounting or line pressure effects. Then a verification can be completed to ensure the transmitter meets specification. Emerson recommends that a slope trim (span) is not completed until a verification has shown the device is outside of specification.

API 21.1 requires that the accuracy of a differential pressure measurement device is verified on a quarterly basis. Should the device not meet the accuracy requirement, the device should be calibrated in accordance to the manufacturer’s recommended procedure. After initial installation, Rosemount Transmitters use a 2-point calibration procedure (offset and slope trim) to maximize the benefits of the sensor design and manufacturing process. This procedure provides the most efficient calibration method and minimizes the potential of degrading a device’s accuracy due to inaccurate calibration equipment.

The Emerson recommended best practice is to only use calibration and verification equipment that is at least three times as accurate as the transmitter (API 21.1 requires using a reference device that is at least two times as accurate as the transmitter). Using equipment that does not meet this recommendation has the potential to degrade device accuracy.

Following Emerson best practices, along with API 21.1, will allow users to get the highest accuracy readings from their devices, while ensuring they meet measurement standards.

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