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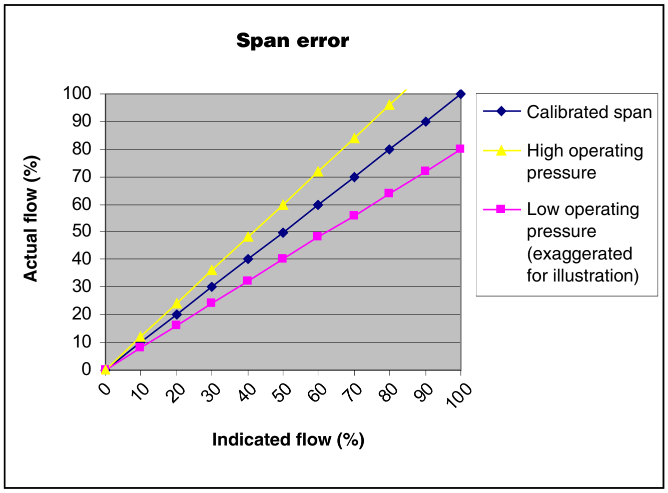
Compensating for the effects of high pressure on the measurement accuracy of Coriolis flowmeters

Introduction

In some applications that use Coriolis flowmeters for the measurement of liquid and gas, the effects of changes in pressure on the accuracy of the measurement data are insignificant. However, for custody transfer or other applications where high accuracy is required, it may be necessary to correct the flow data to compensate for the effects of an operating pressure that is different from the calibration pressure. Many meters have the built-in capability to perform this compensation automatically.



In some flowmeters that use Coriolis technology, pressure can cause a span error. Span is a generic term describing a coefficient used to establish a device's linear relationship between its input and output over a given operating range. The size and design of the meter determines whether it will have an effect, and by how much.

Pressure induced span effects are flow rate independent and are caused by internal pressure stiffening the flow tubes. This in turn makes the tubes more rigid to vibrate, directly affecting the meter's flow signal. The greater the internal pressure, the greater the tube stiffness.

In a field installation, elevated pressure may cause a Coriolis meter to under-register when compared to a known reference. For most installations, changes in pressure of ±50 psi (3.5 bar) can be ignored, and even changes of ±100 psi (7 bar) will not significantly affect flow meter measurement. However, for changes in pressure of over 100 psi (7 bar), particularly when using larger line size meters for custody transfer applications, data must be corrected for the effects of pressure for best results.

The magnitude of the effect can be calculated as follows:

$$(P_a - P_c) \times P_{comp} = E_p$$

Where:

- P_a is the pressure under operating conditions
- P_c is the pressure at calibration
- P_{comp} is the pressure compensation factor (in percent of rate per psi) as published in the sensor product data sheet (available at www.micromotion.com)

  Example: at an operating pressure of 1005.6 psig and a calibration pressure of 12.83 psig and based on a pressure compensation factor of –0.0005% per psi gives an error percentage of:
  (1005.6 – 12.83) x –0.0005 = –0.496%
- E_p is the error percentage induced by pressure if left uncorrected

Note: Zeroing at operating pressure will *not* fully compensate for pressure effect as the zeroing process does not compensate for span influences.

Pressure compensation

Where the measurement errors are outside the acceptable range, it is necessary to compensate for pressure effects. For systems operating under stable pressure conditions, this correction can be made by applying the constant error percentage factor to the data manually when the transfer is complete. However, if the pressure varies widely during the

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transfer, the pressure effect would have to be calculated and applied separately for each data point to ensure an accurate result.

While applying manual pressure compensation may be sufficiently accurate for many circumstances, there will be some applications that will require real-time pressure compensation. Real-time pressure compensation is possible with Micro Motion Coriolis transmitters by adding an appropriate external pressure transmitter. By configuring the transmitter input to indicate gauge pressure, the transmitter uses the pressure input to continuously account for effects of pressure on the flow tubes of certain sensors. This automatic compensation can also be applied without a pressure input in the case where the pressure is stable yet significantly different from the calibration pressure. This is done by entering the fixed average operating pressure into the transmitter configuration.

In this mode, the pressure effect is calculated as the percent change in the flow rate per psi change in pressure and/or the amount of change in density, in g/cm^3, per psi change in pressure.

Coriolis proving

Proving customers will also notice the influence of pressure effect on proving results. Pressure affects not only mass flow output, but also density. Since the volumetric output of a Micro Motion Coriolis meter is derived from the mass and density outputs combined, volumetric flow is impacted. As pressure is increased from the original calibration pressure, volume results will show negative error when compared to a known reference (similar to mass flow).

Although it is always possible to correct for the influence of pressure on volumetric output by independently adjusting mass and density compensation factors, adjusting the volume meter factor can accomplish the same task. Adjusting a Coriolis sensor's meter factor based on proving at elevated pressures combines the necessary compensation into a single factor. The combined effect of pressure on mass and density is present in the volume proving results, and can therefore be corrected by applying a volume meter factor.

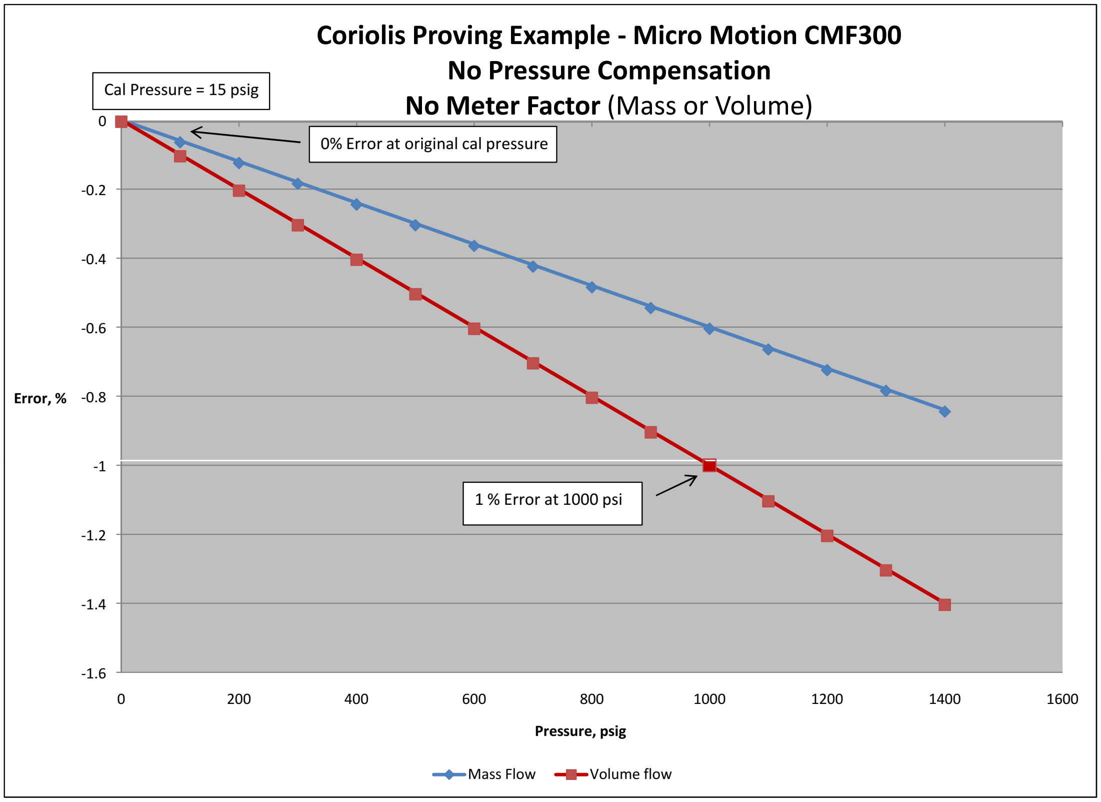
The meter factor determined by the method just described is valid if the pressure does not vary more than ±100 psi (±7 bar). If the pressure will vary by more than that, then online, real-time pressure correction should be used. For installations using on-line (real-time) pressure correction, mass and density should be corrected for pressure effect independently, and the meter factor is not needed to compensate for any of the pressure effects.

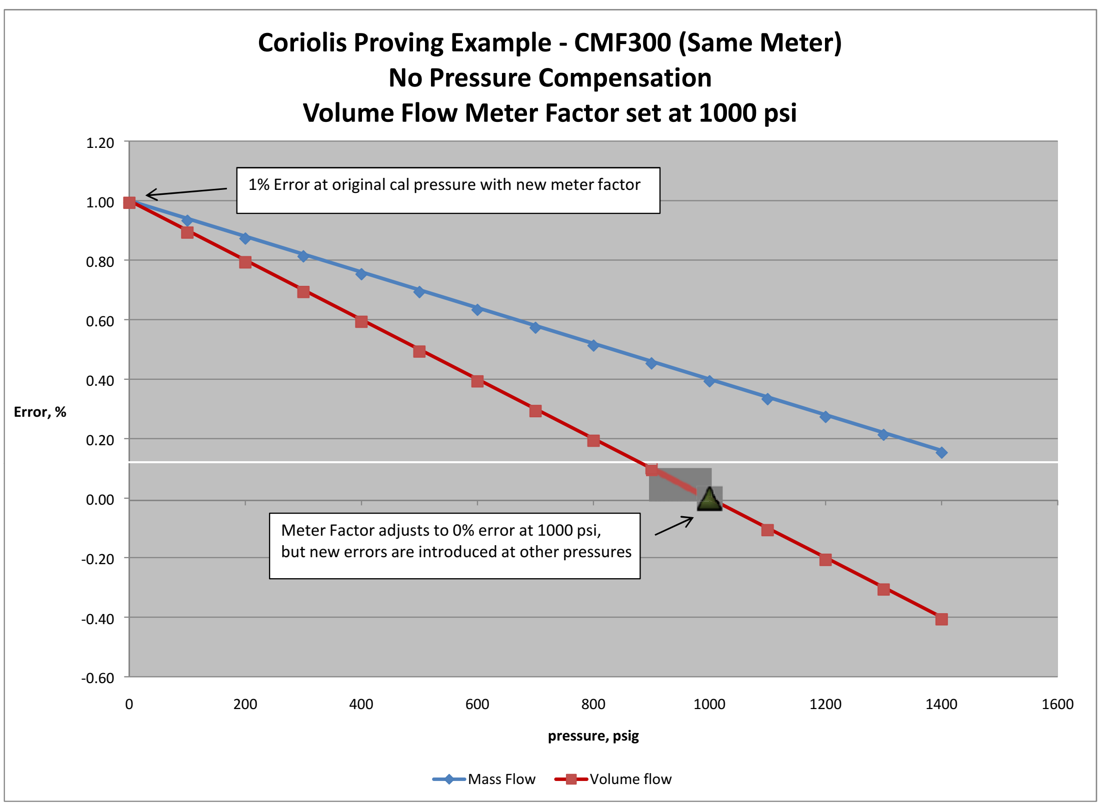
The charts on the following page show an example of volumetric proving at 1000 psi. The adjustment of the meter factor at this fixed pressure adjusts for the influence of pressure on both flow and density, as well as any bias between the Prover and the test sensor. The chart also shows the expected impact on performance as pressure moves away from proving pressure (1000 psi).

Summary

Pressure compensation is not required in many installations: where a small coriolis flowmeter is used (less than 2 inch [50 mm]) or the variation in operating pressure is less than 100 psi (7 bar).

For larger instruments and pressure variations in excess of 100 psi (7 bar), correcting for the effects of pressure is necessary using a simple formula. Data can be corrected manually based on the pressure readings. Alternatively, where pressure varies during a transfer, or greater accuracy is required, real-time pressure correction can be automatically applied using a separate pressure sensor connected to the Coriolis transmitter.


Coriolis Proving Example - Micro Motion CMF300
No Pressure Compensation
No Meter Factor (Mass or Volume)
Cal Pressure = 15 psig
0% Error at original cal pressure
1 % Error at 1000 psi
Error, %
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
0
200
400
600
800
1000
1200
1400
1600
Pressure, psig
Mass Flow
Volume flow


Coriolis Proving Example - CMF300 (Same Meter)
No Pressure Compensation
Volume Flow Meter Factor set at 1000 psi
1% Error at original cal pressure with new meter factor
Meter Factor adjusts to 0% error at 1000 psi,
but new errors are introduced at other pressures
Error, %
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
0
200
400
600
800
1000
1200
1400
1600
pressure, psig
Mass Flow
Volume flow

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