

Calculating & Optimizing Repeatability of Natural Gas Flow Measurements

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Modern flow meters used for natural gas custody transfer offer very high accuracy and repeatability—typically 1% of mass flow for orifice meters, and often better for linear meters. These specifications are usually verified in a flow laboratory. Unfortunately, even with a well installed and maintained meter, every flow technology provides worse performance in the real world. This article presents the key reasons for this deviation between laboratory and real world performance, and tools that allow the user to quantify expected deviations prior to installation. Finally, best practices are detailed which will allow the user to minimize the difference between laboratory and real-world performance.

WORSE IN REAL WORLD

Even with a well-installed and well maintained flowmeter, real-world accuracy can be significantly worse than laboratory accuracy, for any flow technology. The reason for this is that real-world flowmeters are not installed and operated under laboratory conditions:

- Rigidly controlled ambient temperature;
- Low static line pressures; and
- Devices calibrated before every test (no drift).

Ambient Temperature Variation: In the vast majority of real-world custody transfer flow measurements, transmitters are installed outdoors. In some climates, ambient temperatures can easily vary up to 50°F from calibration temperature. While the AGA (and ISO) requires users to compensate for fluid temperature variation, these ambient temperature variations can have an even larger effect, especially with older, analog transmitters. These effects can be easily simulated on the bench—blow warm air over a transmitter, and watch its output change. With orifice

meters, ambient temperature variation affects the differential pressure (DP) transmitter and the static pressure transmitter. With linear meters, ambient temperature variation will affect any analog components in the flowmeter, as well as the static pressure transmitter used for pressure compensation. Even if actual line pressure is constant, the output of a static pressure transmitter—and hence the calculated mass flow—will vary with varying ambient temperature.

High Static Line Pressures: In the case of orifice meters, the DP transmitter used to infer flow can be significantly affected by a high line pressure. To simulate this effect on the bench, the user should apply a small differential pressure across a transmitter. Then, add several hundred pounds of additional static pressure to both sides of the transmitter. In theory, the measured differential pressure should not change. In reality, it does.

DP Flow

Drift/Stability: The output of any analog component will vary over time. As with the ambient temperature effect described, this can affect all flow technologies. Better, smart transmitters are more stable than older, analog transmitters or transducers. Within regulatory and contractual restrictions, a more stable transmitter will allow the user to obtain equivalent accuracy and repeatability when calibrated less frequently. An inferior device will need to be calibrated more frequently to maintain acceptable performance.

FIGURE 1. Total Probable Flow Error Due to DP — does not include effect of process pressure/temperature variation or primary element



IMPACT OF REAL-WORLD EFFECTS

Reputable suppliers publish specifications which allow the user to calculate and predict the impact of these and other realworld effects on installed flow accuracy and repeatability. For this article, a spreadsheet was designed (Figure 1) which uses published specifications to calculate flow error caused by the DP transmitter in an orifice meter installation. The Total Probable Flow Error TPFExls spreadsheet runs in Microsoft Excel, and is available at www.Rosemount.com. The results at 100% flow, under "typical" installed conditions, are shown in Figure 2.

Note that:

- Reference (laboratory) accuracy is a trivial component of total transmitter installed error.
- Two DP transmitters with identical 0.075% "reference accuracies" can provide dramatically different installed accuracies.
- If a supplier does not publish specifications for "real-world" effects, this does not mean that their products are immune to these effects — usually, the reverse is true.
- Although the example of an orifice meter is used for illustration, installed accuracy is worse than laboratory accuracy for all flow technologies, including but not limited to ultrasonic, PD, turbine and Coriolis.
- Although the example of a DP transmitter is used, similar effects can be observed in flow computers with integrated pressure sensors, although "reference accuracy" in these cases refers to the "1% mass flow accuracy" certified by a flow laboratory.

FIGURE 2. Flow Error from DP Transmitter

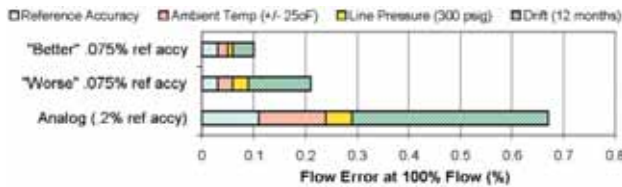


Table 1. Flow Error from DP Transmitter

Flow rate (scfm)	DP	"Better" .075%	"Worse" .075%	Analog
1000	100	0.09%	0.21%	0.65%
750	50	0.16%	0.38%	1.16%
500	25	0.37%	0.85%	2.60%
250	6.25	1.48%	3.40%	10.40%

Table 1 & Figure 3 on page 3 show the impact of this error at lower flowrates. Note that:

- These errors apply to accuracy and repeatability, and are fixed over the entire DP range
- $DP \propto flow^2$ —since DP declines twice as fast as flow, small errors at 100% - and small differences in transmitter accuracy—are magnified at lower flowrates

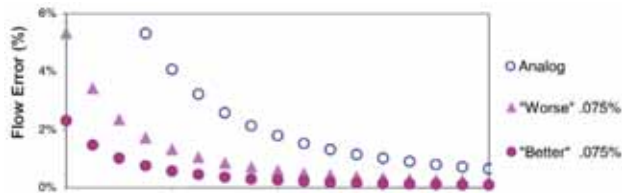
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Seemingly trivial improvements in transmitter accuracy yield significantly better flow accuracy and repeatability at normal flows—the effect is dramatic at lower flows.

FIGURE 3. Flow Error from DP Transmitter



IMPACT OF STATIC PRESSURE TRANSMITTER

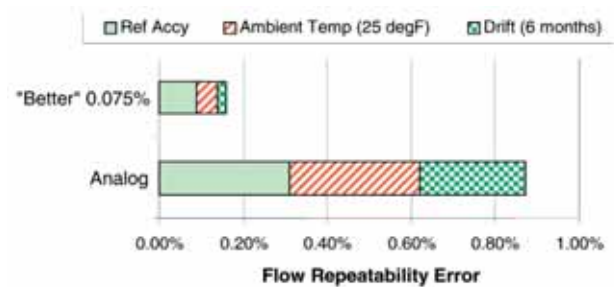
Both linear and DP flowmeters require additional static pressure transmitters to compensate for changes in density from changing line pressure. From the AGA-7 (turbine) and AGA-9 (ultrasonic) equations, a change of line pressure of 1% results in a change in calculated mass flow of 1%. For this reason, an error of 1% in the static pressure transmitter results in an error of 1% in calculated flow.

As with the DP transmitter used in the orifice meter, the static pressure transmitter used in the linear meter can be more or less repeatable, depending upon the device selected and the operating conditions. Ironically, while linear and ultrasonic flowmeters typically provide better laboratory accuracy and repeatability than orifice meters, they often include built-in analog pressure transducers instead of true smart transmitters for pressure compensation. Transducers are usually comparable to analog transmitters, providing much worse installed performance than smart transmitters. They are also usually fixed range, which means that a small error at the transducer's full scale will become magnified at lower pressures.

Figure 4 shows the installed flow repeatability error contributed by the static pressure transmitter. Note that:

- As with the DP transmitter used in the orifice meter, reference accuracy is again a trivial component of installed performance.
- The flow repeatability error contributed by an inaccurate analog pressure transmitter or transducer can be much greater than the error from the ultrasonic or turbine meter itself.

FIGURE 4. Flow Repeatability Error From Static Pressure Transmitter



IMPACT OF DYNAMIC PERFORMANCE

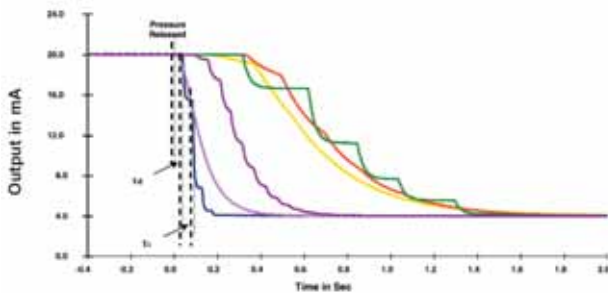
Flows which vary quickly or which pulsate require fast measurements for good accuracy and repeatability. To achieve a fast measurement with a pressure transmitter—both the DP transmitter used with an orifice meter and the static pressure transmitter used for the linear and orifice meter—the user should:

- minimize impulse line time delays close coupling the transmitter to the pipe; and
- select a transmitter with fast response.

DP Flow

Note that there are vast differences in dynamic response both between and within different flow technologies. For example, Figure 5 shows response times for a variety of transmitters which are widely used in natural gas custody transfer. In some cases, the supplier will publish specifications; however, these results are often obtained only through testing.

FIGURE 5. Response Times For Differential Pressure Transmitters



BEST PRACTICES

In any custody transfer application, a true random uncertainty has an equal chance of favoring either party, the net impact should be zero to both parties, and measurement repeatability should not be valued. The reality, of course, is that most sellers do value measurement repeatability for the simple reason that many users install check meters. Discrepancies between a billing meter and a check meter—especially those that favor the seller—can cause demands for independent auditing or even retroactive reimbursement.

Therefore, the first step in designing any custody transfer system is to determine the mutual measurement performance expectations of the supplier and the user over the range of flowrates. This determination of mutual performance expectations should be made by individuals who have a clear understanding of all of the costs of measurement disputes caused by poor repeatability.

The second step is to quantify the operating conditions which are not controllable. For a flow measurement, these can include:

- expected ambient temperature variation;
- maximum static line pressure;
- static line pressure and temperature variation;
- maximum allowable permanent pressure loss;
- flow turndown; and
- expected frequency of flow variation and/or pulsation.

The third and final step is to select hardware, installation and maintenance procedures which will ensure that the measurement provides the required installed performance under the expected (uncontrollable) operating conditions. For example, the user can:

- Select a static and/or differential pressure transmitter which has better or worse performance under the given real-world operating conditions.
- Calibrate the transmitter(s) frequently or infrequently.
- In the case of a DP flowmeter, size the primary element for a higher or lower differential pressure (higher DP's provide higher accuracy, at the expense of higher pressure loss).
- Select a flowmeter and pressure transmitter with faster or slower response.
- Use long or short impulse lines, or direct connect for fastest response.

While the first and second steps involve gathering data, the third step may require calculations and/or testing, which may be facilitated by the spreadsheet shown in Figure 1 on page 2.

CONCLUSION

Most flowmeters provide excellent accuracy and repeatability under laboratory conditions. Unfortunately, under realworld conditions, which may include changing ambient temperature, high static line pressures, and drift between calibrations, the same flowmeters will provide worse performance.

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Using published specifications, it is possible to calculate prior to installation the impact of these real-world effects on installed flowmeter performance. This will allow the user to both predict installed performance for any given application and flow technology, but also to select transmitters which will meet the needs of the specific application.

NOTE

(This article was adapted from a presentation made at the Acadiana Flow Measurement Show in Lafayette, LA in April 2000).

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Rosemount Inc. is the world leader in process measurement, and is part of Emerson Process Management, platform of Emerson Electric. Mark has a degree in Chemical Engineering from the University of Toronto, and an MBA from York University (also in Toronto).

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