CALCULATING ACCURACY & REPEATABILITY of NATURAL GAS CUSTODY TRANSFER FLOW MEASUREMENTS UNDER *INSTALLED* CONDITIONS

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Abstract

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 paper 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.

Why is Accuracy and Repeatability Worse in the Real-World than in the Laboratory?

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
- 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 degF 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 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.

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 provide much worse installed performance than smart transmitters, and are usually fixed range. This means that a small error at the transducer's full scale will become magnified at lower pressures. In the case of a highly repeatable device such as an ultrasonic flowmeter, the flow measurement uncertainty caused by the pressure “transducer” under varying ambient temperature can be **even greater than the flow uncertainty of the ultrasonic flowmeter itself**!

Best Practice #1: Users of linear and ultrasonic flowmeters should always ensure that they carefully evaluate the installed performance of the pressure and temperature measurement devices - transmitters or transducers - used for mass flow compensation.

High Static Line Pressures: In the case of orifice meters, the differential pressure 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.

Best Practice #2: In high line pressure (>300 psig) orifice meter applications, select a transmitter designed to minimize line pressure effects, and always zero the DP transmitter at an average line pressure.

Drift/Stability: The output of any analog component will vary over time. As with the ambient temperature effect described above, 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.

Best Practice #3: Calibrate transmitters as often as necessary to obtain the necessary flow accuracy and repeatability. Equivalently, select transmitters which drift within allowable limits between calibrations.

How Can the User Quantify the Impact of “Real-World” Sources of Error?

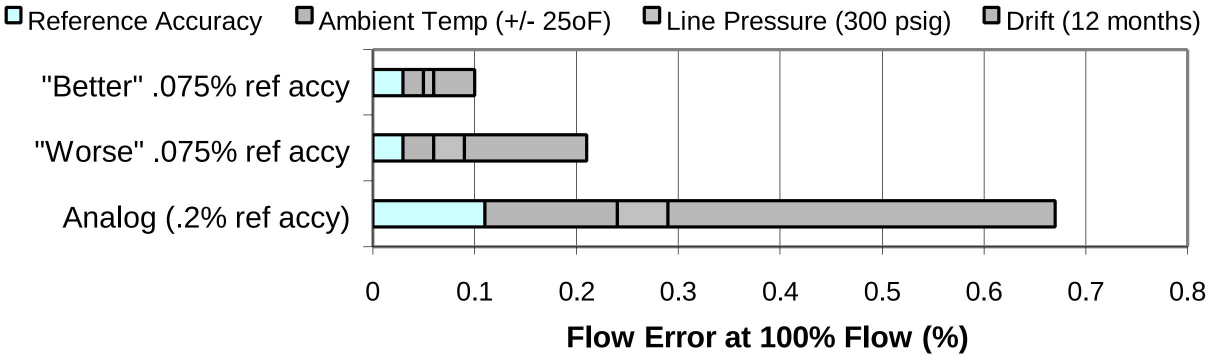
Reputable suppliers publish specifications which allow the user to calculate and predict the impact of these and other “real-world” effects on installed flow accuracy and repeatability. For the purposes of this paper, a spreadsheet was designed (Appendix 1) which uses published specifications to calculate flow error caused by the DP transmitter in an orifice meter installation. 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 below for illustration, installed accuracy is worse than laboratory accuracy for all flow technologies, including but not limited to ultrasonic, PD, turbine and Coriolis.

Figure 2 - Flow Error from DP Transmitter



Figures 3 & 4 show the impact of this error at lower flowrates. Note that:

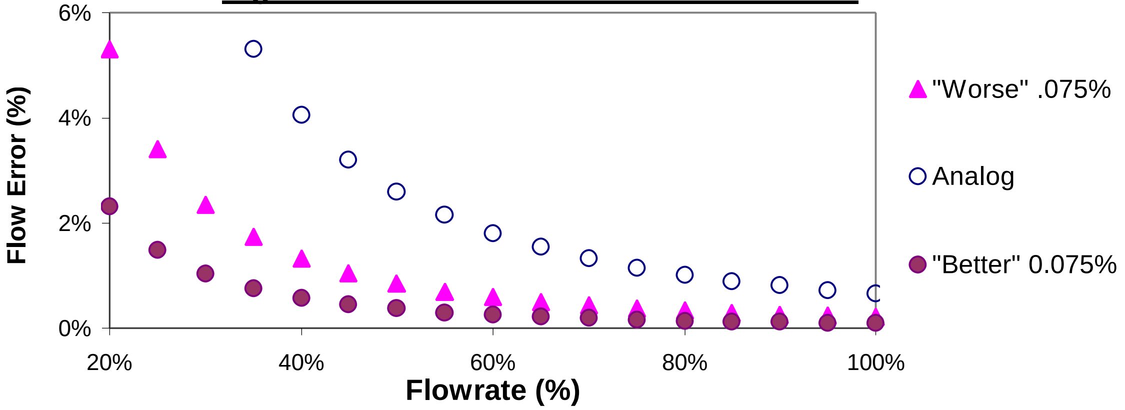
- these errors apply to accuracy and repeatability, and are **fixed** over the entire DP range
- DP α flow^2 – since DP declines twice as fast as flow, small errors at 100% - and small differences in transmitter accuracy - are **magnified** at lower flowrates

Figure 3 – Flow Error from DP Transmitter

Flowrate (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%

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

Figure 4 - Flow Error from DP Transmitter



Although a comparison of flow technologies is beyond the scope of this paper, the user should note that this deviation between “reference” and “installed” accuracy can be observed for all technologies, including but not limited to Ultrasonic, PD, Turbine, Coriolis and Vortex. “Reference accuracy” for any of these technologies may be stated in the form of a “nominal” specification – “1% over 20:1 turndown” – or may be the output of the supplier’s sizing program. As with a DP flowmeter, the user needs to convert reference to installed accuracy by adding “real-world” effects, which may include “D/A error”, “zero stability”, etc.

Also, many flow technologies require pressure and temperature compensation. In addition to causing errors in the flow measurement, real-world conditions cause additional errors in the pressure and temperature measurements used for compensation.

Conclusion

Many flowmeters provide excellent accuracy and repeatability under laboratory conditions. Unfortunately, under “real-world” conditions, which may include:

- changing ambient temperature
- high static line pressures
- drift between calibrations

the same flowmeters will provide worse performance.

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.

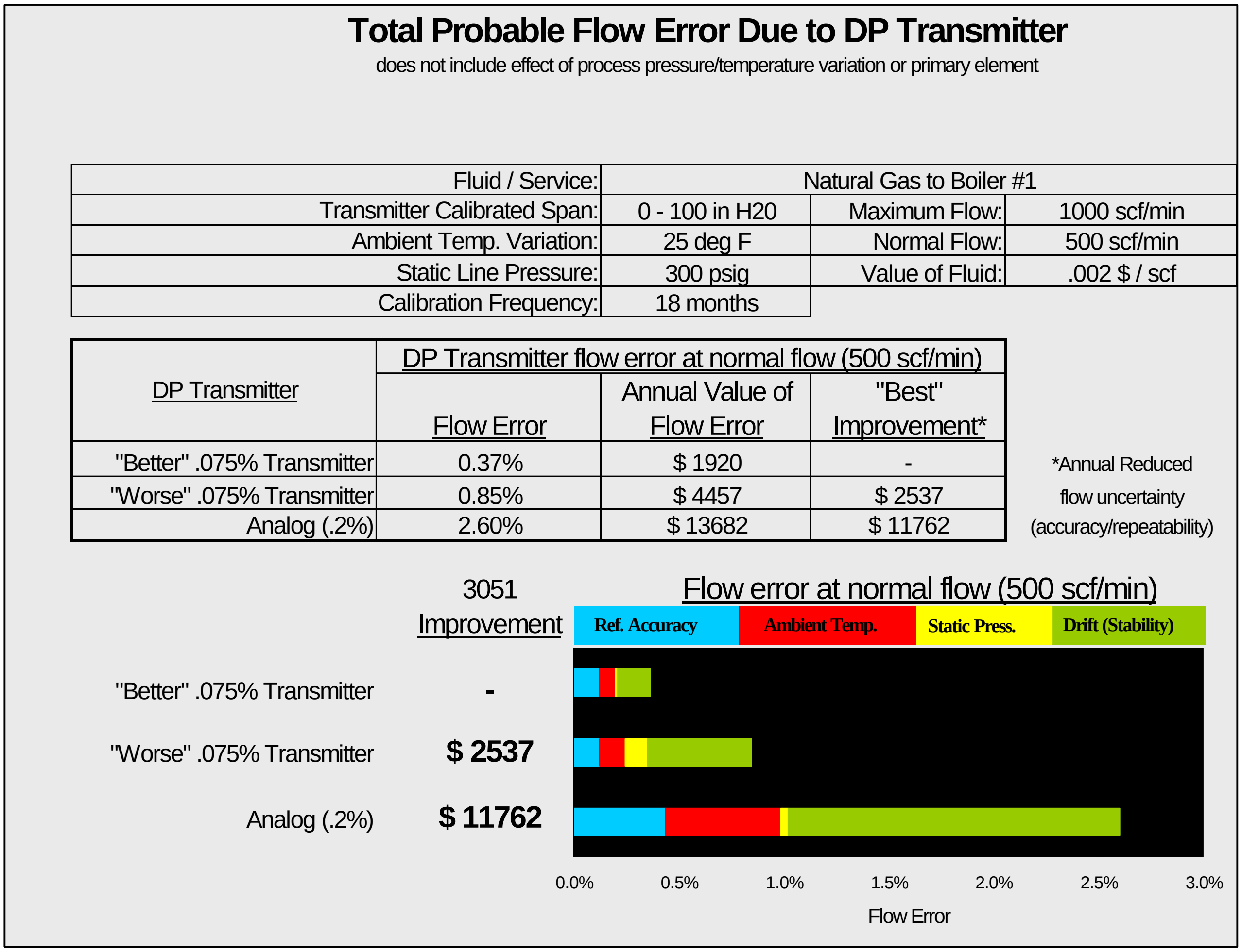
Appendix 1: TPFE.XLS

The Total Probable Flow Error (TPFE) spreadsheet calculates flow error due to the DP transmitter, using:

- user-entered application conditions
- manufacturers' published specifications

and clearly shows all calculations.

The TPFE.xls spreadsheet runs in Microsoft Excel, and is available at www.Rosemount.com.



Total Probable Flow Error Due to DP Transmitter

does not include effect of process pressure/temperature variation or primary element

Fluid / Service:	Natural Gas to Boiler #1		
Transmitter Calibrated Span:	0 - 100 in H20	Maximum Flow:	1000 scf/min
Ambient Temp. Variation:	25 deg F	Normal Flow:	500 scf/min
Static Line Pressure:	300 psig	Value of Fluid:	.002 $ / scf
Calibration Frequency:	18 months		

DP Transmitter	DP Transmitter flow error at normal flow (500 scf/min)		
	Flow Error	Annual Value of Flow Error	"Best" Improvement*
"Better" .075% Transmitter	0.37%	$ 1920	-
"Worse" .075% Transmitter	0.85%	$ 4457	$ 2537
Analog (.2%)	2.60%	$ 13682	$ 11762

*Annual Reduced flow uncertainty (accuracy/repeatability)

	3051 Improvement
"Better" .075% Transmitter	-
"Worse" .075% Transmitter	**$ 2537**
Analog (.2%)	**$ 11762**