Inter-laboratory Comparison Results for Coriolis Mass Flow Meter Calibration Facilities

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Abstract: Inter-laboratory comparison testing is fundamental to assuring the accuracy of a laboratory's stated measurement uncertainty, and a requirement for accreditation to ISO/IEC 17025:2005. Inter-laboratory comparisons using Micro Motion, Inc. (MMI), Coriolis mass flow meters support the claimed uncertainties of 0.014% (k=2) for the high-accuracy liquid flow calibration facilities, and 0.03% (k=2) for the production flow calibration facilities at Micro Motion, Inc.. This paper describes: multiple calibration methodologies, international traceability to National Metrology Institutes, test results and future design requirements of an inter-laboratory test program required to support multiple, accredited flow calibration centers around the globe.

Keywords: calibration, gravimetric, Transfer Standard Method, Proficiency testing, traceability

1. Introduction

At present, Micro Motion, Inc. operates four global flow calibration centers with locations in the USA, Mexico, the Netherlands, and China to support customers locally. These facilities are accredited, partially accredited, or actively pursuing accreditation to ISO/IEC17025 (see Figure 1 and Figure 2). Each location performs liquid mass flow, density, and volume flow calibrations with mass flow uncertainties of 0.03% or less. This paper focuses on the mass flow traceability of the flow calibration centers and the use of inter-laboratory comparisons as the proficiency tests used to quantify how these facilities compare.

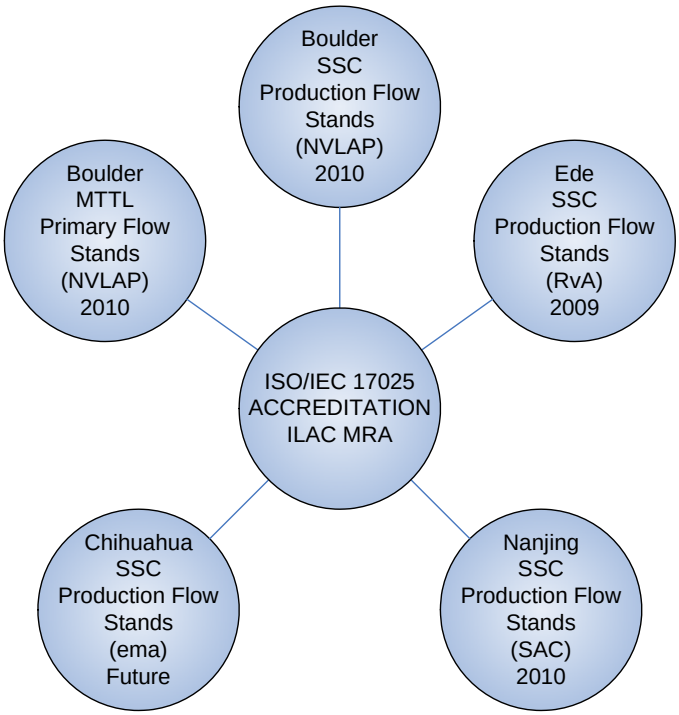

Figure 1, Global Accreditation Body Utilization Diagram

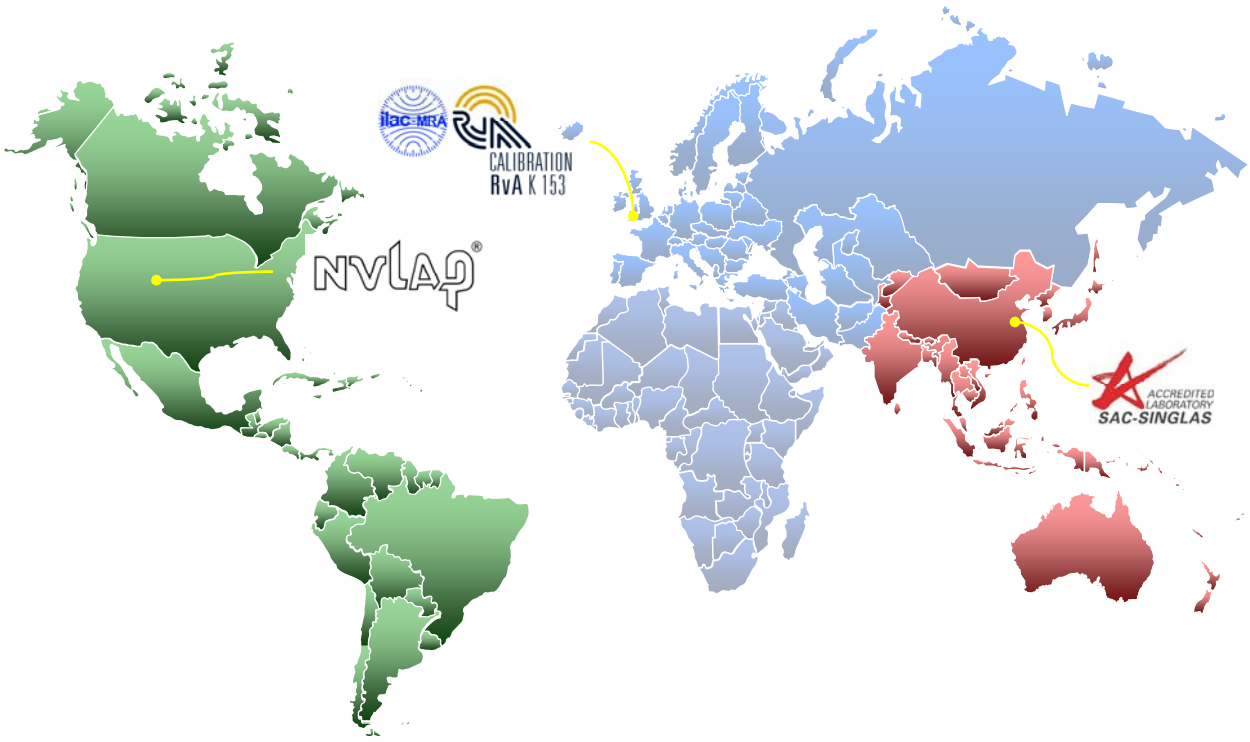

Figure 2, MMI Global Accredited Calibration Centers

2. Background

Micro Motion, Inc. produces several models and sizes of Coriolis mass flow meters that range in flow rate from less than 0.135 kg/min to over 40,000 kg/min, with the highest flow accuracy available at 0.05%. Each global calibration facility is designed to support most, if not all of Micro Motion's products, with some supporting other Emerson Process Management Divisions flow products, such as Magnetic and Vortex flow meters.

As Micro Motion, Inc. has expanded to support a global customer base, the calibration requirements have increased proportionally to meet customer expectations. International customers expect to receive the same high level of calibration results regardless of whether their product is delivered from the USA, China, or any other of Micro Motion's global facilities. To meet these requirements, Micro Motion, Inc. has developed programs to maintain and demonstrate global consistency among all locations.

Micro Motion currently maintains 11 Transfer Standard Method (TSM) flow calibration stands worldwide. In addition to the TSM flow calibration stands, 10 gravimetric flow calibration stands are also utilized. Because of certain local, legal metrology requirements, some of these systems are a hybrid that contains both TSM and gravimetric calibration methods. To support the calibration of the TSM reference meters, Micro Motion, Inc. put into place a Global Reference Meter (GRM) calibration program in 2003. The GRM process was introduced in a paper presented at FLOMEKO in 2003.

3. Traceability

To successfully demonstrate traceability, each GRM is calibrated annually on one of the Primary Flow Stands (PFS) located in Boulder, Colorado USA; and then used to calibrate reference meters on each TSM flow calibration stand. The Primary Flow Stands are gravimetric and utilize the static start/stop method. Each PFS is accredited to ISO/IEC17025 with a Calibration and Measurement Capability (CMC) of 0.014% (k=2).

To support these and all production calibration facilities, the global traceability chain has evolved into a three tiered system as shown in Figure 3, that links Micro Motion, Inc. back to: NIST, USA; VSL, the Netherlands; and NIM, China.

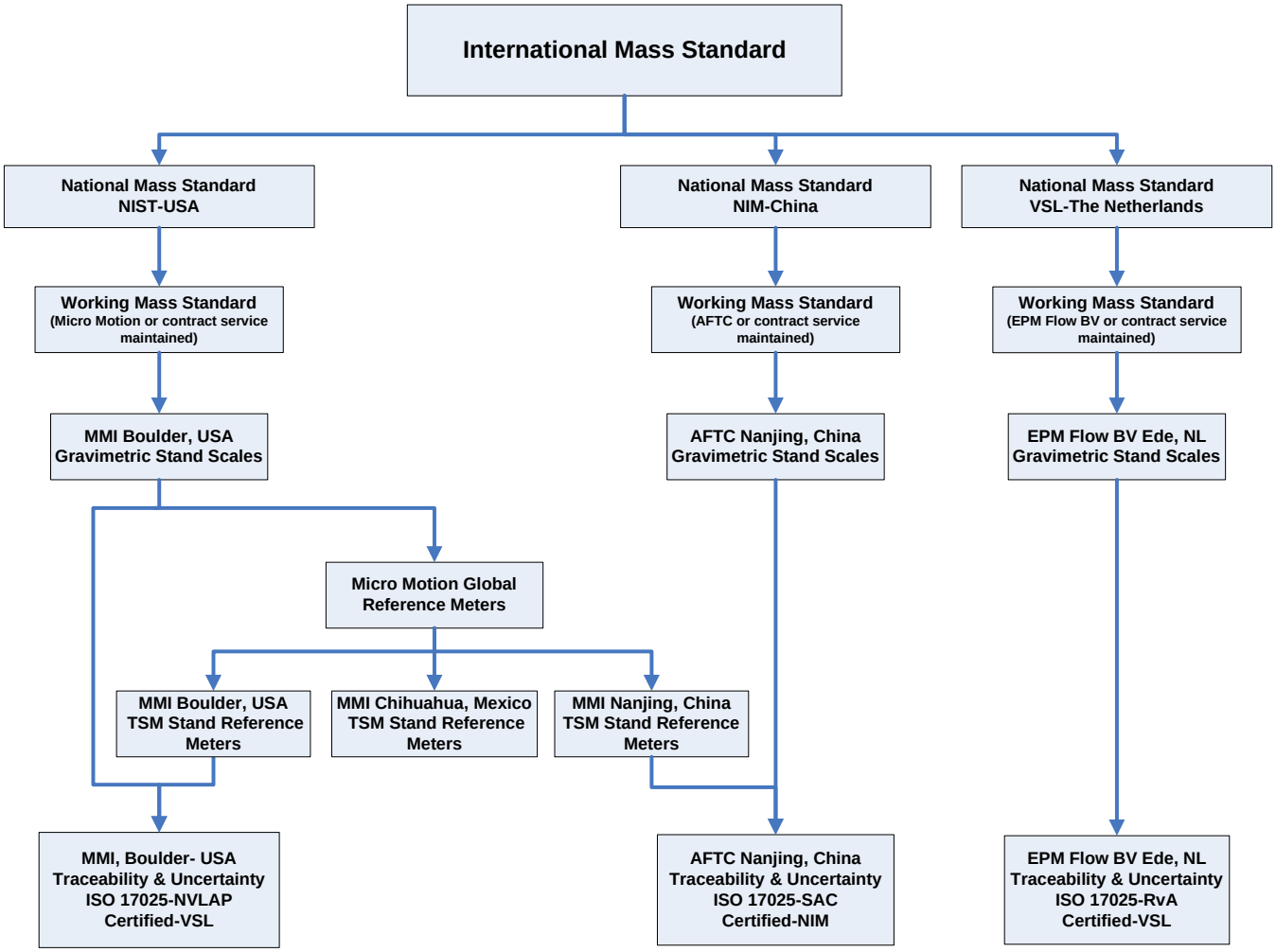

Figure 3, MMI Global Traceability Diagram

4. Current Proficiency Testing

In support of the ISO/IEC17025 traceability requirements, the current inter-laboratory test program was developed for the largest Primary Flow Stand (PFS7K) in Boulder utilizing two of the first GRM's, a 1" (CMF100 S/N: 467065) and a 3" (CMF300 S/N: 11021217). Using these meters, it was possible to cover all accredited flow ranges. The current procedure requires that an Elite model Coriolis flow meter is used as the test artifact. Comparison flow rates are chosen to minimize other influences, such as zero errors. In addition, the procedure defines steps to verify the stability of the meter in a particular installation, prior to performing the comparison flow rates. From 2003 until 2006, no partner labs were identified with comparable uncertainties, so internal checks were performed. Starting in 2006 one partner lab VSL, the Dutch Metrology Institute, became available with a CMC of 0.020% and is being used for comparison.
In 2009 a second calibration center with three calibration facilities, located in Ede the

Netherlands, was accredited to ISO/IEC 17025 by the Dutch Accreditation Council (RvA) and included in this inter-laboratory comparison. The following figures (Figure 4 and Figure 5), summarize the results of the inter-laboratory testing that has taken place since 2006 using the CMF100 and CMF300 listed above. The Evaluation Numbers (En) are calculated using the following formula:

$$E_n = \left| \frac{Lab_{Err}\% - PFS7K_{Initial\ Err}\%}{\sqrt{(U_{Lab})^2 + (U_{PFS7K})^2}} \right| \quad (1)$$

Where: U_{Lab} is the expanded calibration uncertainty of the inter-comparison laboratory, and U_{PFS7K} is the expanded calibration uncertainty from the PFS7K. Lab_{Err} is the current calibration error and $PFS7K_{Initial\ Err}$ is the calibration error from the initial PFS7K calibration. Starting in 2010, these meters were also calibrated at NIST, the National Institute of Standards and Technology in USA, to provide another link in the traceability chain. Additional testing is planned in 2010 at the National Institute of Metrology in China.

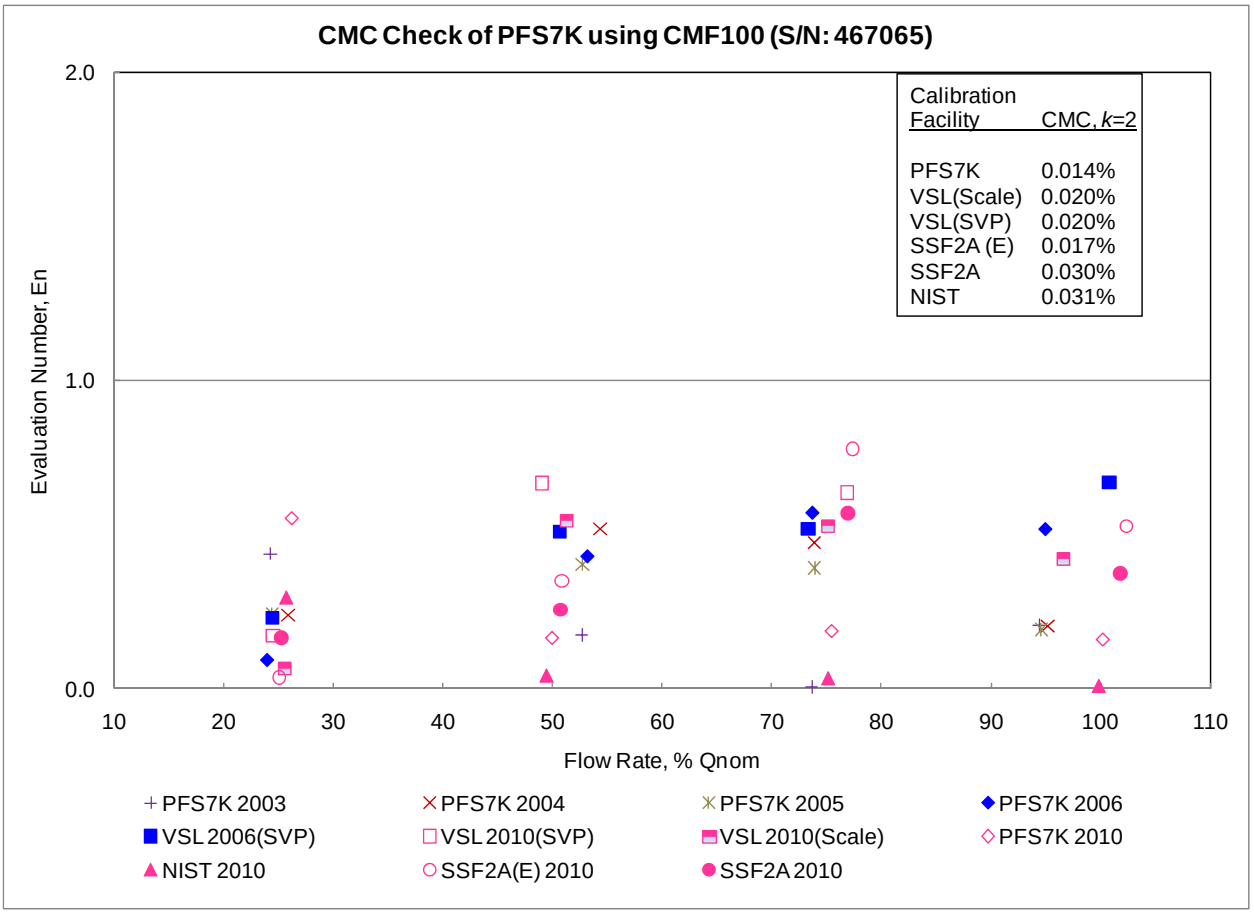

Figure 4, CMF100 Inter-laboratory Comparison Results

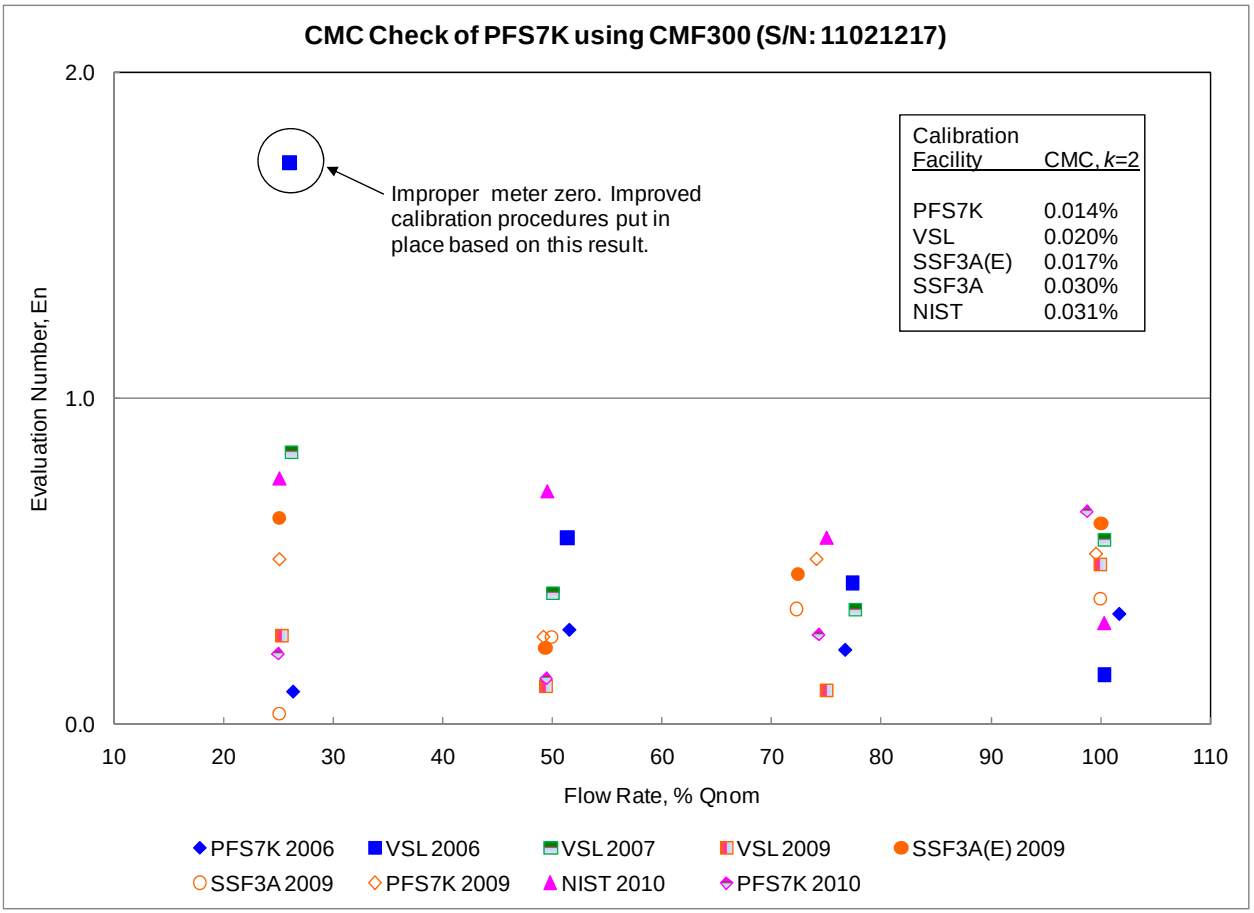

Figure 5, CMF300 Inter-laboratory Comparison Results

As shown in these graphs, Micro Motion, Inc. has successfully demonstrated the ability to maintain the claimed CMC of its calibration flow facilities and provide evidence of traceability to national metrology institutes.

5. Future Proficiency Testing

Proficiency testing has been done for seven years at Micro Motion using a single flow meter as the transfer standard for specific flow rates. As Micro Motion, Inc. continues to expand the calibration capabilities in other world areas as shown in Table 1, and pursues accreditation to ISO/IEC 17025 for these calibration flow facilities, a more robust Proficiency testing program will be required. One solution is to conduct the Proficiency testing programs using 2 meters of each size, not tested in tandem. The benefits over a single meter, and the additional data analysis allowed to give further confidence in the results, are outlined in Table 2.

Table 1, MMI Flow Meter Calibration Center Capabilities

Location	Flow Stand Name	Minimum kg/min	Maximum kg/min	Type	Current (May 2010) ISO/IEC 17025 Accreditation	Planned (Aug 2010) ISO/IEC 17025 Accreditation	CMC %
Boulder, USA							
	CFG01	7.5E-04	0.23	DSF			0.067
	SSF1A	0.065	22	SSF		NVLAP	0.030
	TSM1A	2.50	292	TSM		NVLAP	0.030
	TSM1C	0.273	292	TSM		NVLAP	0.030
	TSM2A	22.00	3175	TSM		NVLAP	0.030
	TSM3A	70.00	11400	TSM		NVLAP	0.030
	PFS150	0.018	68	SSF	A2LA	NVLAP	0.014
	PFS7K	0.227	3175	SSF	A2LA	NVLAP	0.014
Ede, NL							
	SSF1B	0.010	36	SSF	RvA	RvA	0.017 / 0.030
	SSF2A	0.5	2750	SSF	RvA	RvA	0.017 / 0.030
	SSF3A	20.0	18000	SSF	RvA	RvA	0.017 / 0.030
Nanjing, China							
	SSF1C	0.065	36	SSF		SAC-Singlas	0.030
	TSGCNG	2.8	66	TSM		SAC-Singlas	0.030
	TSGCNG	2.5	70	SSF		SAC-Singlas	0.030
	TSG2A	3.0	2268	TSM		SAC-Singlas	0.030
	TSG2A	3.0	3000	SSF		SAC-Singlas	0.030
	Large Flow Stand	3	9100	TSM		SAC-Singlas	0.030
	Large Flow Stand	3	75000	DSF		SAC-Singlas	0.040

Table 2, Tabulation of Proficiency Testing Strategies

Item	Two Meters Tested in Tandem	Two Meters Not Tested in Tandem	One Meter	NOTES
Data "Slope" Corrected	Yes	Yes	Yes	1
Correlation Technique Used	Yes	No	No	2
"Youden" Plots Feasible	2	1	0	3
Lab Diff Diagnosis Feasibility	Yes	No	No	4
Redundancy of Lab Comparisons	Yes	No	No	5
En Capability	Best	Better	Acceptable	6

Notes:

1. This correction reduces Meter Factor uncertainty due to flow sets different from Cardinal Target flows.
2. This technique categorizes Meter Factor uncertainties and allows extraction of Transfer Standard contribution, thereby enabling a clearer assessment of lab-to-lab differences.
3. These plots graphically (and clearly!) display lab performances.
4. This feasibility enables assessments for causes of lab differences and, where pertinent, for initiating "improvements".
5. This redundancy is a very strong contributor to participants' confidence in the lab

comparison results.

6. For comparisons using E_n (the "noise" level associated with comparison), the smaller the E_n, the easier it is to show "signal" (lab differences).

6. Conclusion

Micro Motion, Inc. continues to recognize the benefits, and necessity, to provide customers consistent and globally traceable calibrations. Due to the growing number of calibration facilities requiring the ISO/IEC 17025 Proficiency testing, the use of multiple national labs as traceability sources, and through the continuous improvement process that is part of Micro Motion's culture; Micro Motion, Inc. continues to expand our inter-laboratory comparison program. This will include additional sizes of flow meters for an expanded flow rate range, and the use of redundant flow meters allowing the comparison data to be more statistically robust.