

## Ultrasonic Flow Meter Calibration Considerations and Benefits

Wayne Haner

[wayne\\_haner@tccalibration.com](mailto:wayne_haner@tccalibration.com)

TransCanada Calibrations  
Box 880  
Ile des Chenes, Manitoba  
Canada, R0A 0T0

### BACKGROUND

The increased use of natural gas as the primary source of energy internationally, combined with the increased market price is driving the expansion and modernization of gas transportation infrastructure and is encouraging more accurate measurements of gas flows. To ensure the fair transaction at custody transfer locations, gas pipeline companies are demanding credibility and excellence of meter calibration as a main parameter in ensuring accountability for the gas invoiced.

The explosive growth in the application of high accuracy ultrasonic metering technology for natural gas flow measurement has corresponded to the emphasis in the importance of accurate measurement at custody transfer points. Accurate "smart" metering provided by ultrasonic metering technology has lead to greater commercial confidence and has provided the opportunity for a reduction in custody transfer disputes.

This paper presents a synopsis of some key considerations to be taken into account when calibrating an ultrasonic meter and describes a typical calibration process. Although this process may vary with the calibration laboratory, most laboratories providing calibration service for the ultrasonic technology will employ a calibration process similar to the one detailed in the following presentation.

### 1. INTRODUCTION

Although calibration is an important step for enhancing the accuracy of all measurement technologies, in ultrasonic metering, this activity plays an even more prominent role. The extended flow ranges capability of ultrasonic technology, although capacity adventitious can magnify measurement error if not corrected through proper calibration.

For ultrasonic metering, high-pressure calibration not only provides immediate performance value through measurement correction "cleaning" the meter of intrinsic uncertainty and offering traceable accurate readings at the laboratory; it provides on-going operational field value through the definition of

a meter specific performance baseline for on-going evaluation of meter health once operational in the field.

### 2. WHY FLOW CALIBRATE YOUR METER?

The figure below illustrates the mean and median corrections applied to a series of meters calibrated at TCC from 2000 to 2002. From the results shown in Figure 1, the mean correction applied to small diameter measurement systems (NPS 4 to NPS 8) ranges between 0.42% and 0.73%. The range of system corrections ranges from 0.25% to 0.56% for mid-diameters (NPS 10 to 16) and from 0.02% to

0.45% for large diameter systems (NPS 20 and larger). The median corrections, defined by the point at which 50% of the values are either higher or lower, tends to correlate well with the mean data showing that the data has not been skewed by a small number of measurement systems.

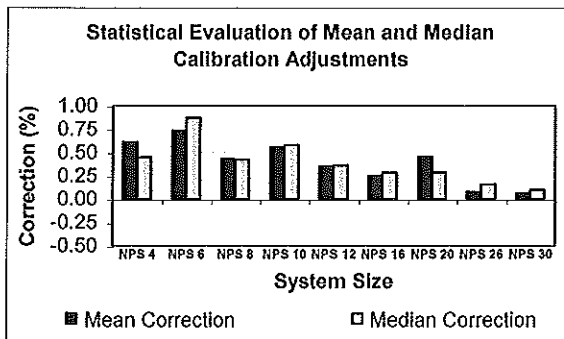


Figure 1

By applying the Median values shown above, we can calculate the financial risk to the end user if no calibration was performed. For the purpose of this example we have used a value of \$7.00 per Million BTU with the meter flowing at 50% of Qmax. As shown by the graph in figure 2, the potential risk to the end user is quite significant relative to the fixed cost of calibration. Thus, let us agree that flow calibration provides value and is a good idea.

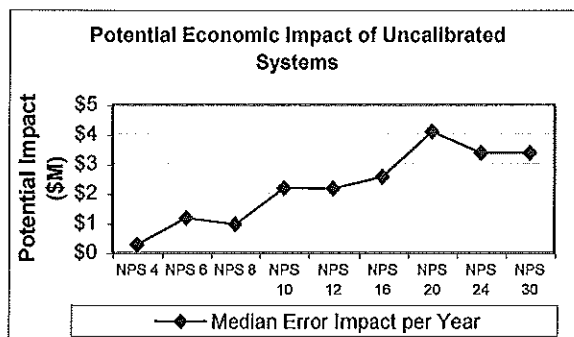


Figure 2

**3. PRECALIBRATION CONSIDERATIONS**

Typically, a number of questions come to mind prior to the actual calibration taking place. Common questions are:

- 1) What components of my measurement system should I send?
- 2) How is the test performed?
- 3) What flow points should I consider testing?

- 4) What output signals do I want used during the calibration?
- 5) What method of adjustment should the laboratory apply to my device?
- 6) Do I want the device's configuration write protected after calibration?
- 7) Should the metering package remain assembled after calibration?
- 8) What documentation does the laboratory need from me?

These questions will be answer in this and following sections.

In addition to the meter itself, the end user will typically send the upstream piping, downstream piping, flow conditioner and thermo-wells. The downstream meter tube in generally accepted as being optional for the calibration providing the calibration laboratory can supply a meter spool of the approximate meter ID while simulating the location of the temperature sensing element as close to the final installation as possible however a large percentage of calibrations performed include the immediate up and down stream piping. Some end users go to great lengths in their attempt to simulate the final installation during flow calibration.

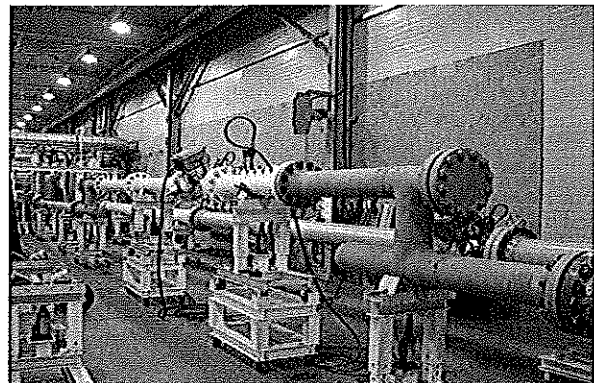



Figure 3

End user's typically do not supply pressure and temperature transmitters with the metering package as the laboratory utilizes devices maintained in house for the calibration, which allows for the validation of the facility uncertainty statement. However, installation of the customer's thermo-wells for the calibration is generally recommended.

All of the laboratories in North America provide some sort of pre-calibration checklist that is used to provide the laboratory with information about the metering package as well as specific customer

requests. In the checklist example shown below, the customer can define the calibration points desired. AGA Report No. 9, requires calibrations at Qmax, 70% Qmax, 40% Qmax, 25% Qmax, 10% Qmax and 5% Qmax as a minimum. Users will often define additional calibration points within the typical operating range of the meter. Also, a minimum of one post adjustment verification point is performed. This topic will be discussed in greater detail later in this presentation.



**PRE-CALIBRATION CHECKLIST**

The following information must be completed and returned via fax at (250) 878-4551 10 business days prior to scheduled date to proceed with calibration.

Customer Information

Company Name \_\_\_\_\_ Will customer witness Calibration? Yes/No \_\_\_\_\_  
 Address \_\_\_\_\_ Contact Name \_\_\_\_\_  
 Telephone \_\_\_\_\_  
 Fax \_\_\_\_\_  
 Email \_\_\_\_\_  
 Calibration Date \_\_\_\_\_

Meter / Meter Run Information  
 (Typical is sized 40 - 600 ANSI rated weld neck flange)  
 If different than above, please specify in special instructions below.

Type of meter \_\_\_\_\_  
 Manufacturer \_\_\_\_\_  
 Model \_\_\_\_\_  
 Size \_\_\_\_\_  
 Flange Condition: \_\_\_\_\_  
 Overall Dimensions: \_\_\_\_\_  
 ANSI \_\_\_\_\_  
 Piping Schedule \_\_\_\_\_  
 Serial Number \_\_\_\_\_

Operating Conditions:  
 Service Date \_\_\_\_\_  
 Pressure Location \_\_\_\_\_  
 \*Meters will be calibrated to manufacturer's stated Q max unless otherwise stated in Special Instructions below.

Flange Face to Flange Face  
 Preferred Certificate Units: Metric or English (please circle one)

Calibration Specifications  
 (Error is averaged over 100 samples, taken during a 300 second outflow for each flow test point)

Calibration Points: Gas velocity  Please check one box below  
 1st Point  Typical AGA test points:  
 2nd Point  100%, 70%, 40%, 25%, 10%, 5%  
 3rd Point  Typical Measurement Canada test points:  
 4th Point  100%, 70%, 40%, 25%, 10%, 5%  
 5th Point  Typical OIML (European) test points:  
 6th Point  100%, 70%, 40%, 25%, 10%, 5%  
 7th Point \_\_\_\_\_  
 Verification Point \_\_\_\_\_  
 8th Point \_\_\_\_\_  
 9th Point \_\_\_\_\_  
 10th Point \_\_\_\_\_

If Measurement Canada Test Points are used: \_\_\_\_\_ please circle one  
 1) Is the meter being used for custody transfer? Yes/No \_\_\_\_\_  
 2) Please provide a diagram to indicate components of meter to be sealed by TGC \_\_\_\_\_  
 3) Should meter be sealed by Measurement Canada at our facility? Yes/No \_\_\_\_\_

Special Instructions \_\_\_\_\_

Remote Calibration Witnessing \_\_\_\_\_ please circle one  
 Do you require an AGA-9 Remote Witness? Yes/No \_\_\_\_\_  
 If yes, please provide a suitable Login ID and Password \_\_\_\_\_

Notes:  
 Calibration Dates will not be confirmed until information has been received by TransCanada Calibrations  
 Meter runs will not be installed until full pressure test date is received.

Client Approval \_\_\_\_\_ Date \_\_\_\_\_

Box 654, 1044 Acadia Road  
 St. John's, NL A1B 2X6  
 Tel: (254) 774-0771  
 Fax: (254) 774-4331

Figure 4

In addition to this pre-calibration checklist, the laboratory will normally require certain test documentation relating to the fabrication of the meter run spools and meter. This documentation includes meter run drawings, hydro-test and NDT reports. Regulations may vary with geographical location of the laboratory so be sure to consult with the appropriate person within the calibration laboratories' organization.

**4. MECHANICAL INSTALLATION**

All metering components are thoroughly inspected upon receipt at the calibration laboratory. Meter run piping is inspected for both internal and external damage that may have occurred during shipping. Meters are normally shipped within a protective crate typically equipped with a shock-protection device. The status of this device is noted.

Utilizing the customer supplied engineering drawing, the installation of the meter run piping begins with the installation of the most upstream pipe following with the next meter run component (typically the flow conditioner) then continuing with the next sequential component downstream. This stepwise installation from upstream to downstream allows for the internal inspection of the piping assembly from the less critical downstream location prior to installing the final component. Meter run piping is typically marked with unique serial numbers or identifiers as outlined on the meter run schematic.

The installation of the flow conditioner should be performed in accordance with the manufacturer's instructions and the orientation of the device marked (if not done by the manufacturer) and documented. Serial numbers are also documented. A reputable flow conditioner manufacturer should provide a unique identifier on all flow conditioners that can be documented on the final calibration certificate. This eliminates the possibility of mixing up components in the case of multiple calibrations of devices of the same size.

Internal alignment of flanges is very important especially at the inlet flange of the ultrasonic meter. Misalignment can cause flow profile distortions that may affect the meter's output. Alignment dowel pins are sometimes supplied to ensure correct assembly at this location. The utilization of dowel pins at this location does not always provide a perfect bore alignment but does provide an avenue for a repeatable installation regardless of the assembler. Mated flanges are also used at the inlet and outlet of the meter for some installations.

Before the final downstream component is installed, photographs of the internal piping conditions are taken and filed for future reference.

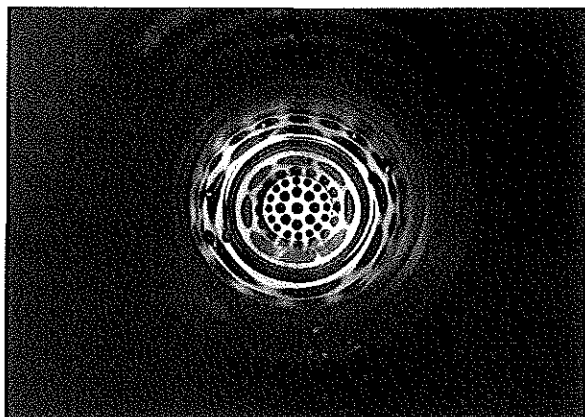


Figure 5

All flange bolts are now torqued in accordance with the facility's operation procedures or sometimes using the customer supplied specifications. Some customers will have the metering run shipped to the final installation after flow calibration as a complete unit. In such cases, customer supplied gaskets and bolting would be used and the torque procedure would be in compliance with the end user's quality assurance program. In cases where the meter run will be disassembled upon completion of the calibration, the facility bolting and gaskets are typically used.

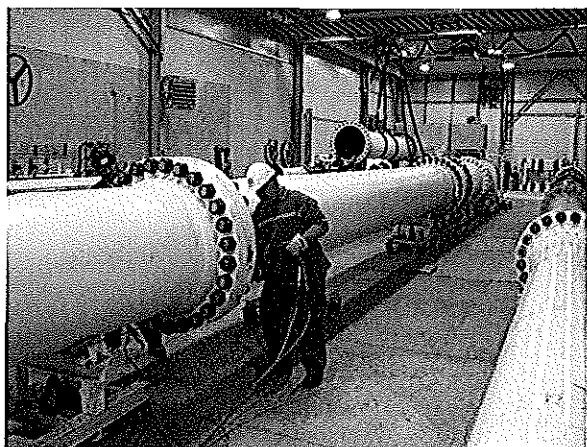


Figure 6

## 5. METER CONNECTIONS AND INSTALLATION OF ANCILLARY INSTRUMENTATION

Once the mechanical installation has been completed, pressure and temperature device can be installed. AGA Report No. 9 stipulates the temperature sensing element should be installed

between 2 and 5 pipe diameters downstream of the ultrasonic device for uni-directional applications. Following the customer supplied drawing, the temperature sensing element is installed in the indicated thread-o-let. Often, laboratories will use a second temperature element for quality control purposes. Next the pressure sensing device can be connected. Again, AGA report No. 9 documentation clearly states that the pressure measurement must be taken from the meter manufacturer supplied port on the meter body. There are many considerations that are taken into account for the placement of temperature sensing elements. For the purpose of this paper, we will assume an AGA report No. 9 compliant installation.

Connections to the ultrasonic meter can now be made. Typical connections are power, frequency output and data output signals. Power is typically 24 Vdc. The frequency outputs usually can be configured TTL or open collector. The data output is typically RS-232 or RS-485 utilizing either a Modbus protocol or a proprietary protocol. In addition to the above connections, an Ethernet connection is becoming more common.

Now that all connections have been made and the mechanical installation has been verified, the meter run can be pressurized and leak checked.

## 6. Calibration Process

The first step in the calibration process is the configuration of the facility data acquisition system. Utilizing the meter manufacturer's software and one of the data signal lines, communication is established with the meter. The meter configuration is read from the meter and stored as part of the documentation procedure. This configuration file contains information that is required for programming into the facility data acquisition system. Critical information includes k-factors, meter I.D., communication parameters, etc. Once the acquisition system is programmed, the received signals are verified. For example, if the customer has selected the frequency output as the custody transfer signal, a frequency is forced from the meter using the meter software or hardware and the receive signal is verified and documented.

Now that the meter run has been pressurized and the facility acquisition system has been programmed, the instrumentation is checked for agreement. All piping is equalized and the agreement of pressure measurement is verified.

This is performed with zero flow through the test run. Agreement of temperature measurement is normally checked with a low level of flow through the facility reference bank and test run. This low flow condition also allows for the temperature stabilization of the facility piping.

The facility valves are positioned to allow a low flow condition through the reference and test run piping. During the low flow stabilization period, the meter performance is verified. The ultrasonic meter's corrected VOS, per path VOS, corrected gas velocity, raw gas velocities (profile), gain levels, and signal to noise ratios are all verified. This ensures the meter is functioning correctly prior to calibration and prevents wasted resources due to calibrating faulty equipment.

Once the facility piping has stabilized, the isolation valves to the test section are again closed. A zero flow verification test is performed again to verify the meter's operation. Using the meter manufacturer's software, a log file is recorded and stored as a record of the meter's health prior to the calibration process commencing. AGA Report No. 9 states that all raw gas velocities must be within  $\pm 0.04$  ft/sec at zero flow conditions. This criterion is checked at this time. Generally, this criterion is applicable to the dry calibration process in which a true zero condition can be achieved but depending on the valve and piping configuration of the facility, comparable zero flow conditions can be simulated.

Results have shown a very good correlation between the facility findings and those documented during the dry calibration for the same device. This procedure is not intended to replace the dry calibration procedure but is only intended as verification. We have found that many meters, especially meters that have been in service for a number of years, will exhibit some sort of zero flow bias on one or more paths while showing very good performance under flowing conditions. This zero bias can skew calibration results, especially at lower flow rate. In our six years of operation we have only found one new meter that failed the low flow verification test due to a bias on the RGVs. Now that the meter's health has been verified, the calibration process can commence.

Facilities within North America are all quality system certified and traceable to recognized standards so for the purpose of this paper we will assume the flow laboratory is using standards maintained in accordance with the ISO-17025 standard.

The calibration process involves flowing gas through one or more reference devices and through the customer metering package. Flows are achieved at rates provided by the customer on the pre-calibration checklist. The following schematic shows a typical layout of an open loop calibration system.

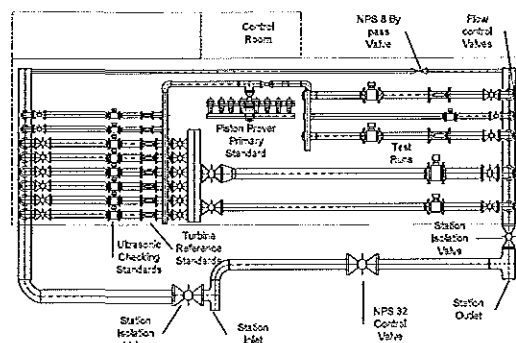


Fig 1. Schematic TransCanada Calibrations High Pressure High Volume Gas Meter Test Facility

Figure 7

The calibration process begins with the highest flow rate. The flow of the facility is slowly increased until the high flow rate is established. The stability of the systems is allowed to stabilize before any data is sampled. The facilities acquisition system provides stability indicators for all input parameters during the calibration process and the stabilization period. This information can be reviewed both graphically and in a tabular format.

In an open loop system, the facility has no direct control over the loop pressure and temperature so to ensure that the stability of these inputs is not influencing the error calculations, it must be checked against control limits and documented for reference. Operators of closed loop systems may also perform stability checks but have direct control over the pressure and temperature set-points. The following figures show both the graphical and tabular format of the input data stability.

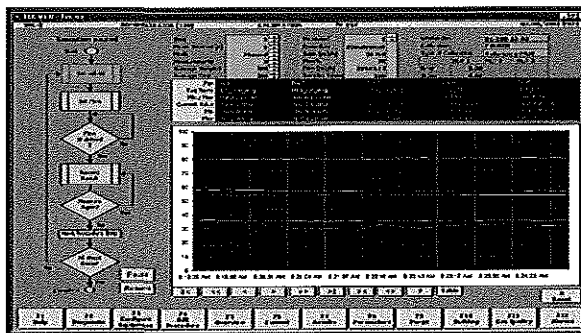


Figure 8

TCC Calibration Report  
 Date of Test: July 6, 2005  
 Time: 12:55:03 PM  
 Samples: 100  
 Tests: 3  
 Calibration Step: 4

Serial Number	34245	E9228	65009158	64906	
Imped	1130.87	836.654	1000	1547.31	
Snapshot	MUT1	MUT2	MUT3	Ref USM	Ref Turbine
Flow	1223.65	1213.82		1215.74	1211.14
Pressure	384.4028	314.3326			557.098
D	1220.00	1219.37		1220.21	1218.03
StdDev	5.04	5.83		3.53	8.54
St	8.13	5.14		7.75	7.71
Error %	0.3259	-0.4361		0.6583	-0.01
StdDev	0.04	0.06			
St	6212.52	6221.77		6247.83	6223.02
StdDev	0.09	0.09		0.11	0.14
St	462	462		30.67	1331
StdDev				0.17	0.08
St	29.13	29.14		29.24	29.22
StdDev	0.02	0.02		0.03	0.01
St	0.239471	0.155423		0.49317	0.25944
St	45.731	49.752		49.941	48.782
Corr 1				1.0045	1.0016
Corr 2				69.3249	68.4743
Corr 3				-2.9124E-01	-1.1910E-05
PCF				1.0045	1.0016
Accuracy	1.3E-02	1.3E-02		1.30265E-02	1.30717E-02

Averages	MUT1	MUT2	MUT3	RFP	Ref
Err Ref 1 MUT 1 Avg	-0.61	0.69	0.00		
Err Ref 1 MUT 1 StdDev	0.17	0.15	0.00		
Err Ref 1 MUT 1 StdDev %	0.15	0.05	0.00		
Qmax Avg	1222.64	1222.59	0.00		1222.45
Qmax StdDev	2.51	2.32			2.05
Qmax StdDev %	0.20	0.24			0.21
Err Ref 1 MUT 1 Avg	-0.59	0.61			
Err Ref 1 MUT 1 StdDev	0.18	0.19			
Err Ref 1 MUT 1 StdDev %	0.02	0.03			0.03
RR 1000Avg	1222.43				
RR 1000StdDev	2.15				
RR 1000Avg	1222.18				
RR 1000StdDev	2.02				
RR 2000Avg	1222.42				
RR 2000StdDev	2.73				

Filename: FM\_174\_80.xls  
 Printed: 7/6/2005 14:42

Figure 9

Sampling times may vary depending on the calibration facility but the total sample time per flow point is always over 300 seconds. TransCanada Calibrations takes 100 samples over 300 seconds and repeats this sampling at least two times.

Data recorded during the calibration sampling period includes, pressures, temperatures, flow rates (pulse counts or flows polled using serial communication), and gas composition. Flow, density, compressibility, error, and stability (stdev) calculations are performed on each data set and stored in a data base. This data acquisition and storage is typically redundant for quality assurance purposes.

At the same time the calibration acquisition system is sampling data, a second system is used to acquire meter performance data (log or maintenance file) via the meter manufacturer's software. At least 2 minutes of logged data is desired. This diagnostic information is used as a base line against which historical data can be compared. It is also useful during the commissioning process. The data can be used to qualify the meters output and performance in the field where a reference standard is not accessible. This will be discussed later in the paper if time permits.

In addition to the calibration data and log file collection, a SOS comparison is performed at all flow rates. This involves calculating a theoretical

SOS as defined by AGA report No 10 and comparing it against the meter corrected SOS. It should be noted that the theoretical SOS can not be compared against the individual SOS (per path or chord) at high velocities for some manufacturers because there is a correction performed on the raw individual SOS before the final corrected SOS is reported. A SOS comparison spread sheet is produced as part of the final document set.

7. Calibration Adjustment and Verification

Once this process has been completed for all requested flow points, an as-found calibration error curve can be produced and adjustment factors can be determined.

AGA Report No. 9 provides for three acceptable methods of adjustment for an ultrasonic device. They are

- 1) FWME adjustment method
- 2) Polynomial adjustment
- 3) Piece-wise linearization

In this first example, we will calculate an adjustment using the FWME method.

Qmax 280,000			
Meter Flow Rate (ACFH)	Error (%)	Full Scale Normalized	Weighted Error (%)
279354	-0.56	0.998	-0.5587
195825	-0.53	0.699	-0.3707
140223	-0.53	0.501	-0.2654
69554	-0.5	0.248	-0.1242
27963	-0.42	0.100	-0.0419
13992	-0.36	0.050	-0.0180
Sum =		2.596	-1.379

Figure 10

The data in the flow rate and error columns are determined during the flow calibration. The full scale values are calculated by taking the indicated flow rate of the meter for each calibration point and dividing by the full scale value (Qmax). The weighted error is then calculated by taking the indicated error and multiplying it by the full scale value for each flow rate.

Full Scale = Indicated Meter Flow Rate/ Qmax

Weighted Error = Indicated Error \* Full Scale value

The FWME can be calculated as follows:

FWME = Sum of the Weighted Errors/ Sum Full Scale Weighting

$$\text{FWME} = -1.379/2.596 = -.5312\%$$

Now that the FWME has been calculated, an adjustment factor can be calculated.

$$\text{Adjustment Factor} = 100/100+\text{FWME}$$

$$\begin{aligned} &= 100/100+ (-.5312) \\ &= 1.0053 \end{aligned}$$

Most meter manufactures allow for an adjustment factor up to four decimal places in resolution to be entered into the adjustment factor field in the meters configuration.

How does this factor work?

- 1) The meter calculates multiple delta times and calculates multiple RGVs
- 2) Using proprietary algorithms, the meter calculates a single corrected gas velocity.
- 3) The meter then multiplies this corrected gas velocity by the programmed adjustment factor to derive an adjusted corrected gas velocity.
- 4) Utilizing the programmed meter bore (area) and the adjusted corrected gas velocity, the meter then calculates a volumetric flow rate.
- 5) Utilizing the programmed k-factor, the meter then outputs a frequency proportional to this corrected flow rate.

Often, end users confuse the term Adjustment Factor with K-factor. K-factors are used for the scaling of frequency outputs and the adjustment of turbine meters. Adjustment factors are used for the calibration adjustment of ultrasonic meters. One can see from the example above, that even if the meter adjustment factor changes, the meter K factor does not. The meter K factor is used for scaling the frequency output that is outputted proportionally to the corrected flow rate. Because the calibration adjustment factor is applied before the frequency scaling, even when the adjustment factor is changed at the time of calibration, the K-factor will remain the same.

This is in contrast to how turbines are adjusted. Each and every time a turbine is calibrated and adjusted, a new K-factor is calculated. When you

receive the newly calibrated turbine meter with the new K-factor, the factor programmed in the flow computer must be changed to match the factor determined at the turbine meter calibration so the flow computer can properly convert the frequency input into flow. This need not be done for USMs. The K-factor in the flow computer of a USM will remain the same even after calibration.

The results of the FWME adjustment method is shown below in figure 11.

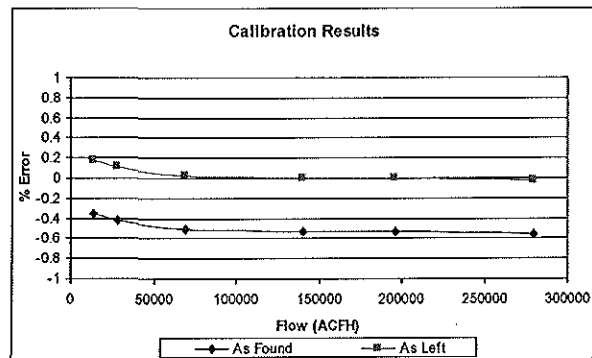


Figure 11

In our second example we will calculate and apply a polynomial adjustment to the same meter. Different manufactures use different methods of calculating and applying a polynomial. In the example below the following formula is applied to the gas velocity as follows.

$$\text{Velocity (adj)} = b_0 + b_1 * \text{Velocity (corr)} + b_2 * \text{Velocity} * (\text{vel}/30)^2$$

Please note that in this equation, the meter uses the velocity in metric units to apply the correction.

Factors determined are  $b_0 = -0.0024$ ,  $b_1 = 1.0051$  and  $b_2 = 0.0181$

Using the highest flow rate as an example:  
Velocity (corr) = 50.08 ft/sec = 15.264 m/s

$$\begin{aligned} \text{Velocity(adj)} &= -0.0024 + (1.0051 * 15.264) + \\ &0.0182 * \sin(15.264) * (15.264/30)^2 \\ &= 15.340 \text{ m/s} \\ &= 50.334 \text{ ft/sec} \end{aligned}$$

Results of the polynomial adjustment method are shown in Figure 12.

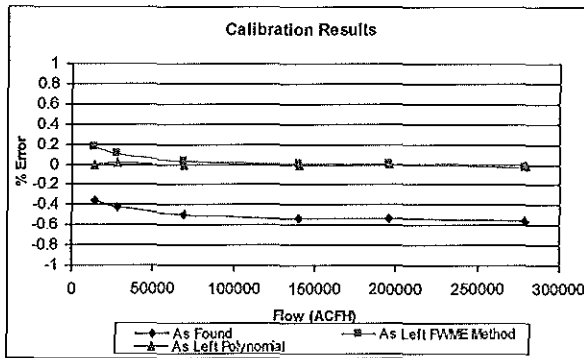


Figure 12

Finally, using our third adjustment method, an adjustment factor is calculated using the same formula as in example #1, only in this example, a factor is calculated and entered into the meter configuration for every flow rate tested and the individual errors are used in the formula in place of the FWME. Keep in mind that the meter's firmware must allow for this type of adjustment method. Please consult with your meter manufacturer about the methods of adjustment available within your devices.

The following table shows the adjustment factors calculated for each flow rate.

Qmax 280,000				
Meter Flow Rate (ACFH)	Error (%)	Full Scale Normalized	Weighted Error (%)	Adjustment Factor
279354	-0.56	0.9977	-0.558708	1.0056
195825	-0.53	0.6994	-0.37066875	1.0053
140223	-0.53	0.5008	-0.265422107	1.0053
69554	-0.5	0.2484	-0.124203571	1.0050
27963	-0.42	0.0999	-0.0419445	1.0042
13992	-0.36	0.0500	-0.017989714	1.0036
	Sum =	2.596	-1.379	

Figure 13

The result of using the Piece-wise linearization method is shown in Figure 14.

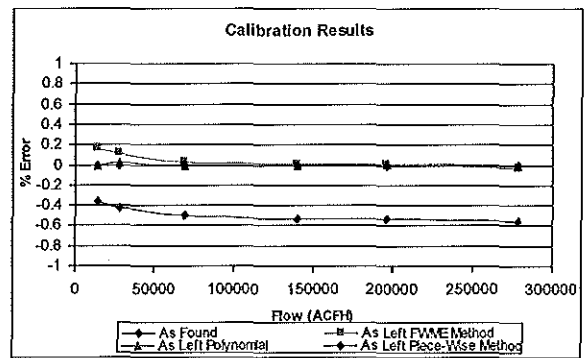


Figure 14

Numerical results of the individual adjustments methods are shown in Figure 15.

Qmax 280,000		After Adjustment Errors		
Meter Flow Rate (ACFH)	As Found Error (%)	FWME (%)	Polynomial (%)	Piece-Wise (%)
279354	-0.56	-0.03	0.00	0.00
195825	-0.53	0.00	0.01	0.00
140223	-0.53	0.00	-0.01	0.00
69554	-0.5	0.03	-0.01	0.00
27963	-0.42	0.11	0.01	0.00
13992	-0.36	0.17	-0.01	0.00

Figure 15

Once the adjustment method is selected, the factors are entered into the meter's configuration and the verification is performed. During the verification process, the meter is tested as in the original process of calibration at predetermined flow rates. AGA Report No 9 requires a minimum of one verification point but often more points are selected depending on the method of adjustment. Particularly when a polynomial adjustment is performed, verification of the meter output will occur at a high and low flow rate to verify the application of all factors. The results of the verification will be shown on the calibration document along with the as found data.

## 8. CALIBRATION DOCUMENTATION

The calibration document set typically includes:

- 1) Calibration Certificate
- 2) Final Meter Configuration File
- 3) SOS Comparison Spreadsheet
- 4) Soft copy of meter log files (flow and zero)

Figures 16 through 20 show examples of a typical document set.





TransCanada Calibrations Ltd.  
 Box 880  
 Ile des Chenes, Manitoba, Canada  
 R0A 0T0

**Certificate of Calibration**

<b>Applicant:</b>	Company A 1901 34th Street Houston, Texas 78093 E. Kentucky Meter Stn.	<b>Certificate Number:</b>	2804
		<b>Work Order:</b>	08-109-462-02
		<b>Date of Calibration:</b>	December 3, 2006
		<b>Units:</b>	US
<b>Meter Under Test</b>			
<b>Type:</b>	Ultrasonic	<b>Medium:</b>	Natural Gas
<b>Manufacturer:</b>	Instromet	<b>Pressure: (PSI)</b>	892.74
<b>Model:</b>	Qsonic-5	<b>Temperature: (°F)</b>	84.17
<b>Serial Number:</b>	05-XXXX-Q512064	<b>Density: (Lbs./ft³)</b>	2.85
<b>Meter ID (In)</b>	11.9290	<b>Compressibility:</b>	0.90148
<b>Year of Manufacture:</b>	2005	<b>Direction:</b>	Unidirectional
<b>Meter Details</b>			
<b>Transducer Type:</b>	L2		
<b>Firmware Version:</b>	6.21		
<b>Pulses/ft³:</b>	50.00		
<b>Pipe Spool S/N:</b>	06-XXXX-PS12064, 06-XXXX-PS12064, 06-XXXX-PS12064		
<b>Run Configuration:</b>	UST 120", CPA 50E, UST 120", METER, DST 96.375"		
<b>Flow Conditioning:</b>	CPA 50E Type A		
<b>Flow Conditioner S/N:</b>	22456293		
<b>Witness:</b>	None		
<b>Comments:</b>	Meter adjustment factor calculated with 761ps-10fps data.		

**Test Method:** The actual flow of the gas meter is established with the aid of standard gas meters, pressure and temperature  
**Results:** The measurement results are stated on page 2 of 2. The total uncertainty in the measurement is based on 2x the standard  
**Traceability:** The measurement methods utilized in the calibrations and measurements are traceable to primary standards and/or  
**Facility Uncertainty:** 0.21% for Flow Rates less than 1600 m³/hr, 0.19 for Flow Rates above 1600 m³/hr  
**Test Date:** December 3, 2006      **Tested By:** Jeff Dahlin  
**Date of Issue:** December 3, 2006      **Reviewed:**

Figure 16, Calibration Certificate, Page 1



**Ultrasonic VOS Comparison**

<b>Applicant:</b>	Company A																																										
<b>Meter Details:</b>	Certificate Number: 2804																																										
	Meter Serial Number:	06-XXXX-Q512064																																									
	Manufacturer:	Instromet																																									
	Model:	Qsonic-5																																									
	Meter I.D.:	11.9290 in	0.302997 meters																																								
	Meter Capacity:	25000 scfh	7829 acm/h																																								
	Flow Conditioner:	CPA 50E Type A																																									
<b>Test Conditions (Arg)</b>	Medium: Natural Gas																																										
	Pressure:	892.74 psia	6156.20 kPa																																								
	Temperature:	84.17 °F	28.98 °C																																								
	Density:	2.85 lbs/ft³	45.68 kg/m³																																								
	Compressibility:	0.901481																																									
<b>VOS Comparison</b>	<table border="1"> <thead> <tr> <th>FlowRate (Acft/h)</th> <th>Velocity (ft/s)</th> <th>Meter Vos (ft³)</th> <th>Calc. Vos (ft³)</th> <th>Diff. Vos (ft³)</th> </tr> </thead> <tbody> <tr><td>272000</td><td>97.35</td><td>1406.53</td><td>1406.69</td><td>0.07</td></tr> <tr><td>212429</td><td>76.03</td><td>1410.01</td><td>1410.01</td><td>0.00</td></tr> <tr><td>140734</td><td>50.37</td><td>1410.61</td><td>1410.50</td><td>0.11</td></tr> <tr><td>70105</td><td>25.09</td><td>1410.87</td><td>1410.76</td><td>0.12</td></tr> <tr><td>28715</td><td>10.28</td><td>1410.03</td><td>1409.89</td><td>0.14</td></tr> <tr><td>14741</td><td>5.28</td><td>1409.18</td><td>1408.03</td><td>0.15</td></tr> <tr><td>7365</td><td>2.64</td><td>1407.93</td><td>1407.80</td><td>0.13</td></tr> </tbody> </table>			FlowRate (Acft/h)	Velocity (ft/s)	Meter Vos (ft³)	Calc. Vos (ft³)	Diff. Vos (ft³)	272000	97.35	1406.53	1406.69	0.07	212429	76.03	1410.01	1410.01	0.00	140734	50.37	1410.61	1410.50	0.11	70105	25.09	1410.87	1410.76	0.12	28715	10.28	1410.03	1409.89	0.14	14741	5.28	1409.18	1408.03	0.15	7365	2.64	1407.93	1407.80	0.13
FlowRate (Acft/h)	Velocity (ft/s)	Meter Vos (ft³)	Calc. Vos (ft³)	Diff. Vos (ft³)																																							
272000	97.35	1406.53	1406.69	0.07																																							
212429	76.03	1410.01	1410.01	0.00																																							
140734	50.37	1410.61	1410.50	0.11																																							
70105	25.09	1410.87	1410.76	0.12																																							
28715	10.28	1410.03	1409.89	0.14																																							
14741	5.28	1409.18	1408.03	0.15																																							
7365	2.64	1407.93	1407.80	0.13																																							

Figure 18, SOS Comparison Spreadsheet

**Measurement Results**

		<b>Certificate Number:</b>	2804
<b>Qmax =</b>	280000 Acft/h	<b>Serial Number:</b>	05-XXXX-Q512064
<b>Qmin =</b>	7000 Acft/h		
<b>Average Error Adjusting</b>	-0.33 / 0.33	<b>Adjust Fact. (found)</b>	1.0000
		<b>Adjust Fact. (left)</b>	1.0033

Uncorrected	Nom. Flow (Acft/h)	Act. Flow (Acft/h)	Velocity (ft/s)	Deviation (%)	StDev (2σ)	Deviation (%)	StDev (2σ)	Check Pt. (%)
	280000	272000.18	97.35	-0.35	0.04	-0.02	0.04	
	210000	212429.96	76.03	-0.33	0.04	0.00	0.04	
	140000	140733.59	50.37	-0.33	0.03	0.00	0.03	
	70000	70104.75	25.09	-0.34	0.04	-0.01	0.04	
	28000	28715.47	10.28	-0.34	0.03	-0.01	0.03	
	14000	14741.02	5.28	-0.38	0.09	-0.05	0.09	
	7000	7365.47	2.64	-0.41	0.15	-0.02	0.15	
	190000	192832.11	63.64					0.00
	28000	28514.69	10.21					-0.01

**FWME METHODOLOGY: AGA**

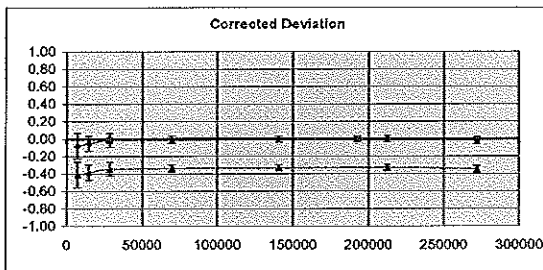


Figure 17, Calibration Certificate, Page 2

```

TRANSCANADA
CALIBRATIONS
*****
* Ultrasonic Flowmeter *
* Configuration Information *
* (Uniform version 3, 0, 1) *
*-----*
* Instromat Ultrasonic Technologies *
*****

File Name: 05-XXXX3.doc
Customer: Company A
Meter S/N: 05-XXXX-Q512064
Certificate: 2804

UNIFORM Settings:
=====
InstrumentType: 24
> 'Q.Sonic-5 Series-III QL Meter (Stand-alone SPU)'
COM settings: UNIFORM point-to-point
4800,N,8,1

Parameter Setup:
=====

PROSON II Configuration:
Instrument Type:24
> Q.Sonic-5 Series-III QL Meter (Stand-alone SPU)
Parameter 1: 0xC102
Parameter 2: 0xA0
Parameter 3: 0x818A
Parameter 4: 0x07
Parameter 5: 0x7104

Module Information:
Flowmeter Serial Number: XXXX
Software Version: V5.21
Flowmeter Identification: 05-XXXX-Q512064 05F288,

Spool Piece Parameters:
Diameter: 11.9290 Inch.
Line 1:
Path Length: 27.6120 Inch.
Beam Angle: 60.00 deg
Line 2:
Path Length: 35.8400 Inch.
Beam Angle: 60.00 deg
Line 3:
Path Length: 27.6270 Inch.
Beam Angle: 60.00 deg
Line 4:
Path Length: 35.7670 Inch.
Beam Angle: 60.00 deg
Line 5:
Path Length: 27.6420 Inch.
Beam Angle: 60.00 deg
    
```

Figure 19, Meter Configuration, page 1

```

V-Module Parameters:
Application-specific Parameters:
Velocity of Sound Range:
Lower Limit: 1000.00 ft/s
Upper Limit: 1600.00 ft/s
Gas Velocity Range:
Lower Limit: -130.00 ft/s
Upper Limit: 130.00 ft/s
Device-specific Parameters:
Sample Rate: 15 Hz
Timing Constant 1: 1140
Timing Constant 2: 0
Timing Constant 3: 0
Pulse Length: 195

Profile Correction Parameters:
Reynolds Number Computation:
Density: 2.90 lb/cu.ft
Dynamic Viscosity: 1.30e-002 cP
Profile Correction Coefficients:
Axial Path(s):
p1: 3792.0000
p2: 26.0000
p3: 0.7502
p4: 0.9711
p5: 0.0231
p6: -3.3190
Swirl Paths:
p1: 3401.0000
p2: 66.0000
p3: 1.0037
p4: 1.0993
p5: 0.0175
p6: -3.2090

Calibration Parameters:
Coefficients: c1 c2 c3 c4
s=1 0.1590 0.8410 0.0080 0.0000
s=2 0.0300 0.0200 0.0500 0.0000
s=3 0.0500 0.0060 0.0000 0.0000
s=4 0.0300 0.0000 0.0000 0.0000
s=5 0.0000 1.0000 0.0000 0.0000
s=6 1.0000 0.0000 0.0000 0.0000

Adjust Factor:
Adjust Factor: 1.0033

Low Pass Filter: OFF
Low Flow Cut-off: OFF

Frequency Output: Vol. Flow (Line Cond.)
Vol. Flow (Line Cond.) Range:
Lower Limit: 0.00 CFH
Upper Limit: 360000.00 CFH
Frequency Range
Lower Limit: 0.00 Hz
Upper Limit: 5000.00 Hz
Error: 6000.00 Hz
Meter Factor: 50.00 Impulses/acf
    
```

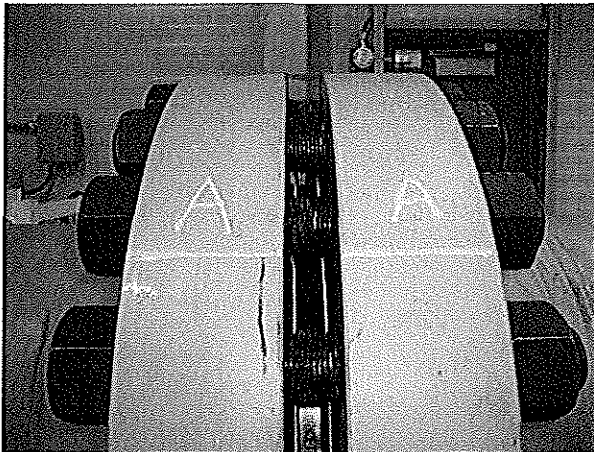
Figure 20, Meter Configuration, Page 2

AGA Report No 9 Requires the calibration laboratory to maintain a copy of the calibration documentation for a minimum of 10 years.

## 9. POST CALIBRATION PROCESS

Upon completion of the flow calibration the meter is again subjected to a zero flow state so that the calibration technician can once again obtain a meter calibration log which is used as a record of the meter's health prior to disassembly and shipping to the final destination.

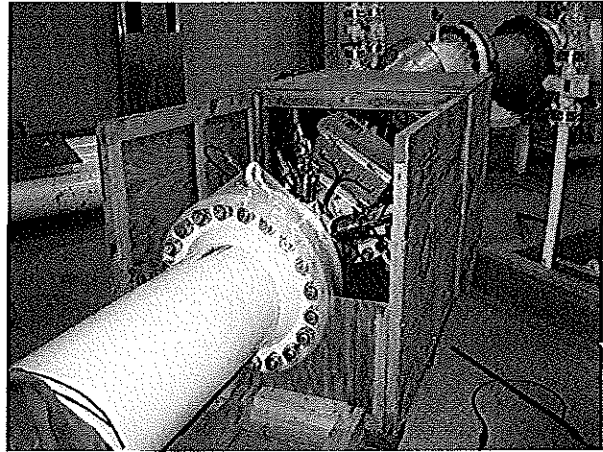
Once the final zero flow verification is complete, the calibration test run is vented and purged until free of gas. All meter run flanges are marked and given an identifier to assist the field personnel in the re-assembly process. The duplication of flange alignment is critical to ensure similar flowing conditions in the field.



**Figure 21, Flange Marking and Alignment**

All piping is end capped and wrapped with a vapour barrier to ensure no damage to piping internals occurs during return shipment. The meter's write-protect jumper is installed when required and the meter is repackaged in its original shipping container. The meter internal may be coated with a rust preventing oil for the return shipment, upon request. This oil should be removed prior to the meter being put into service.

As previously stated, some USM users will supply meter run skids to allow for entire metering package to shipped as a complete unit to the final installation site.



**Figure 22, Crating of Assembled Meter Package**

The calibration documentation is submitted to a final ISO review to ensure documented process compliance. Once the review is completed, the original calibration document set is sent to the user for their records.

## 10. ULTRASONIC METER CALIBRATION KEY CONSIDERATIONS

Fig 21 from the American Gas Association AGA, Report No 9, highlights the industry minimum requirements for ultrasonic meter performance specification before any adjustment is introduced to correct the output of the meter. Two main components are considered: the maximum meter bias as compared with a traceable facility reference value and the combined effect of facility stability and meter response under installation effects.

### 10.1. Intrinsic Uncertainty Factors and the Facility Reference Values

The bias reported by the meter under calibration is determined by the intrinsic uncertainty components linked to the meter design and data interpretation for determining a flow rate, weighed against the quality of the components associated with the traceability, reproducibility and integrity of the facility reference values at the calibration laboratory.

**Performance Specification Summary**

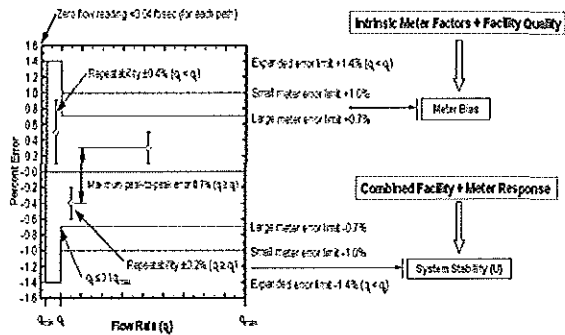


Figure 1 from AGA Report #9.

**Figure 21**

As an example, a large meter error limit of  $\pm 0.7\%$  represents the minimum meter out of the box accepted performance under the impact of the design's remaining uncertainties when that performance is evaluated by a proven reference value.

**10.2. Facility Stability and Meter Response Under Installation Effects**

The calibrated/adjusted meter output represents a baseline that agrees with the facility reference values to within the combined meter and facility repeatability.

AGA Report No 9 specification states repeatability values of  $\pm 0.2\%$  for large meters and  $\pm 0.4\%$  for small meters.

During testing, the combined facility and meter repeatability of the error resulting from comparing the ultrasonic meter output with the reference values is affected by following conditions:

- drifting beyond tolerances of the gas flows and process pressure and temperature,
- Unstable flow and process conditions
- Environmental influences
- Data acquisition and processing system

On the data acquisition side, the quality of the sampling and the sampling time to define a calibration point must be sufficient to minimize the Type-A uncertainty contribution [ISO GUM] to the calibration under operational dynamic conditions influence.

Figure 22 depicts the baseline result of a 12" ultrasonic meter after being corrected and validated at the TransCanada Calibration facility.

Repeatability results well within the recommended AGA #9 values are achieved.

**Table #1. Verification Results**

Qref (Acf/hr)	Velocity (ft/s)	Deviation (%)	Repeat. (2σ)
276950	99.10	-0.02	0.04
209992	75.14	0.00	0.03
139840	50.04	-0.01	0.04
70088	25.08	0.01	0.05
28568	10.22	-0.01	0.08
14889	5.33	-0.01	0.10

**Figure 22**

**11. Meter Diagnostics During Calibration**

The calibration and adjustment of the ultrasonic meter (bias removal) is the first step toward a complete ultrasonic meter validation at the laboratory, prior to the meter installation in the field.

Each manufacturer has a unique design and data integration technique developed to calculate an average flow velocity. Accordingly, the meter overall performance is an integrated response closely related to the flow conditions developed by the pipe arrangement at the facility.

The log files captured during meter calibration provide the necessary information to diagnostic the flow and operating conditions presented at the facility during meter calibration, at the same time making available a meter specific performance baseline relating the diagnostic data with the corrected meter output.

Together with the calibration certificate, the delivery of meter log files must be a requirement for the following reasons:

- It provides evidence to the customer that the ultrasonic meter was calibrated under acceptable operational conditions.
- It makes available a tool to extrapolate the calibration result to the field attending the laws of similarity between both the laboratory and the field

## 12. RELEVANT METER DIAGNOSTIC PARAMETERS

The validity of the meter calibration once in the field can be traced back using the diagnostic data gathered at the lab and the performance of the meter has a direct link to those diagnostic variables.

Relevant variables include the following:

Raw Gas Velocities (Profile Factor and Ratios)  
SOS (Both per path/chord and Avg. corrected)  
Gain Control Levels and Limits/SNR  
% Performance

An analysis of real logged data taken during the calibration process will be performed and its relationship to the field diagnostic data will be discussed (time permitting). A log analysis spreadsheet is included in Appendix A.

## 13. CONCLUSIONS

The calibration of an ultrasonic meter requires the careful control of the environment and operating conditions at the facility.

The economical impact at stake as a result of the correction applied to the meter after calibration requires that the quality of the references values at the calibration facility be properly traced and their

calibration status accepted by a recognised quality system.

The calibration facility not only corrects a bias in the meter but also collects critical diagnostic information revealing the meter and facility performance during calibration. The user can use that information to assess both the quality of the calibration and to baseline his meter response in the field

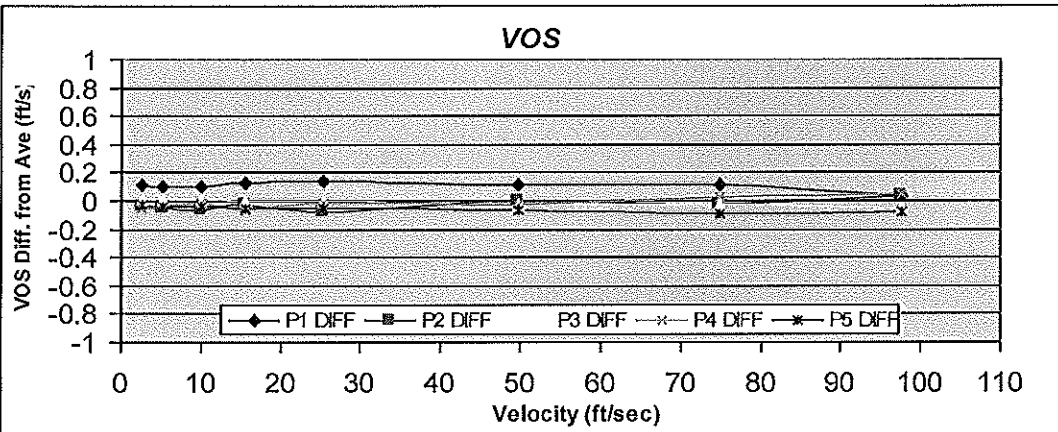
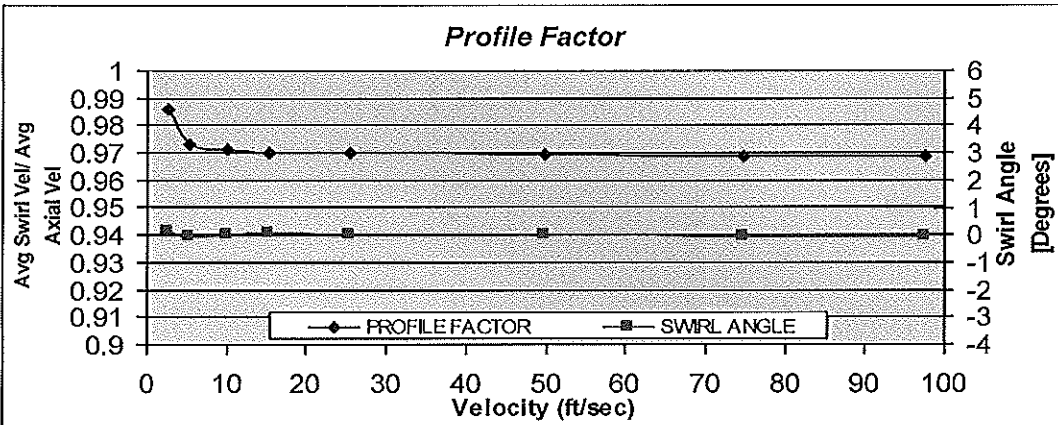
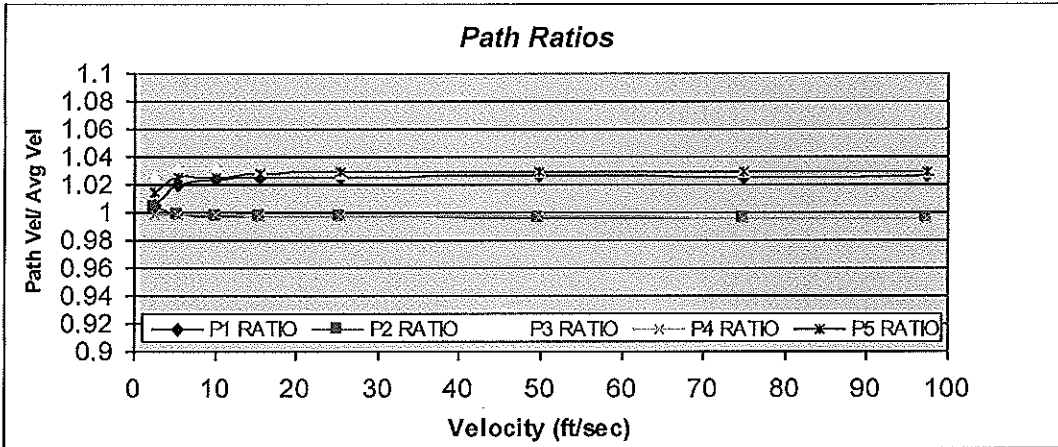
A close agreement between diagnostic parameters at the facility and at the meter station is a certain indication of flow conditions similarity and proper meter performance/operation in the field

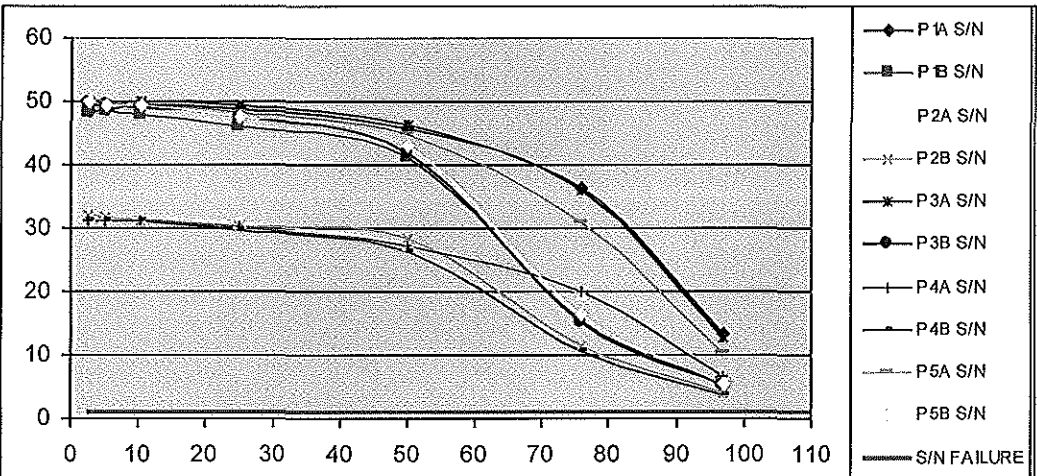
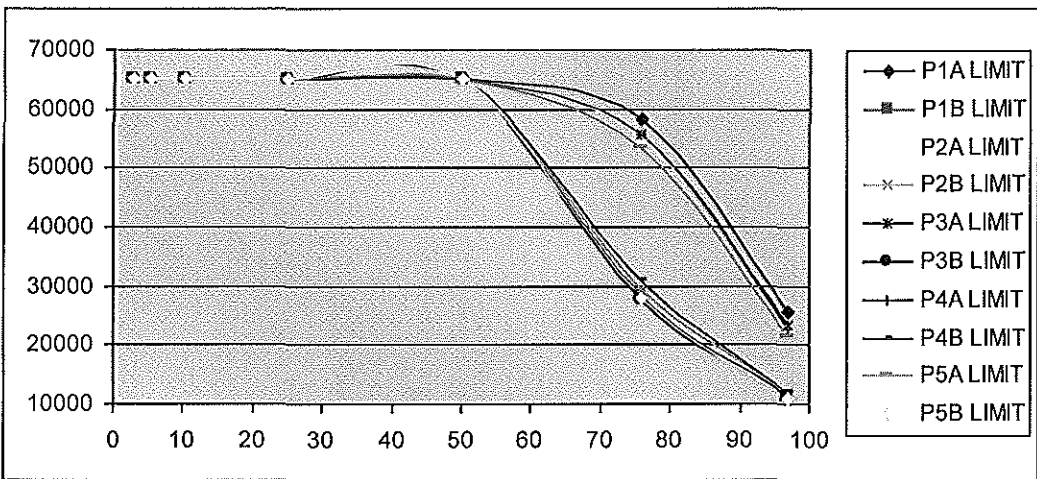
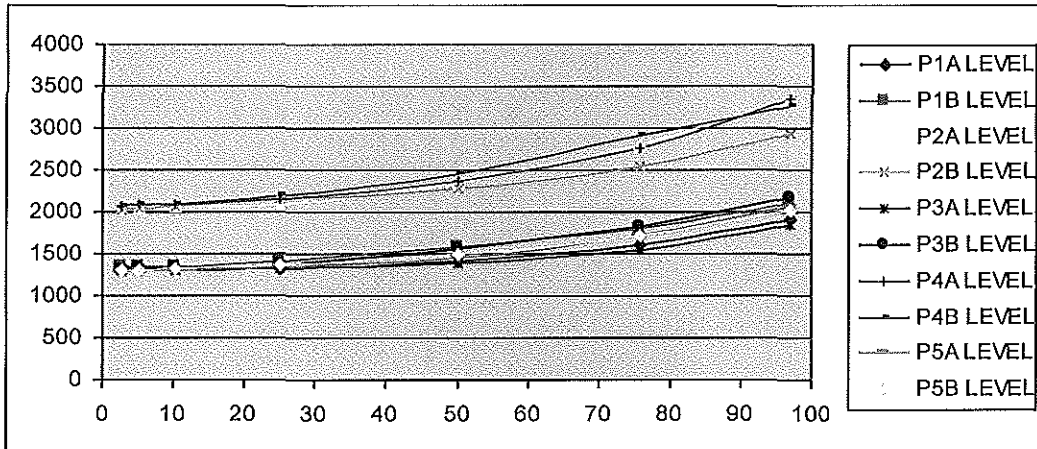
Tracking of meter performance in the field is a procedure that originates at the calibration laboratory and encompasses the use of critical relevant diagnostic parameters generated both in the laboratory and in the field.

## 14. REFERENCES

1. AGA Report No 9
2. AGA Report No 10
3. Jairo Mantilla, Wayne Haner and Garnet Grudeski, Operational and Field Value of a Ultrasonic Meter Calibration, Canadian School of Hydro Carbon Measurement, March 2006-05-11

Appendix A

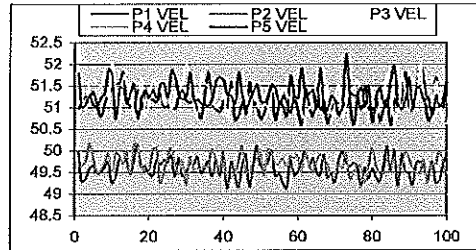




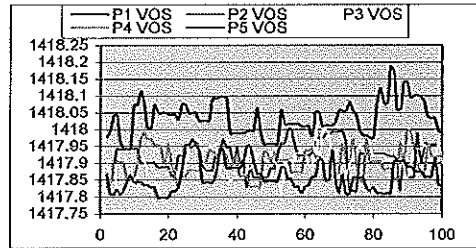


Profile Factor: 0.96926 Average Velocity: 49.8307

	P1 VEL	P2 VEL	P3 VEL	P4 VEL	P5 VEL
AVG	51.14	49.61	51.26	49.70	51.29
MAX	51.95	50.14	52.07	50.16	52.23
MIN	50.53	49.14	50.63	49.23	50.61
STDEV	0.29	0.23	0.32	0.22	0.30



	P1 VOS	P2 VOS	P3 VOS	P4 VOS	P5 VOS
AVG	1418.04	1417.92	1417.90	1417.90	1417.86
MAX	1418.19	1418.00	1418.00	1418.00	1417.97
MIN	1417.94	1417.82	1417.81	1417.83	1417.80
STDEV	0.05	0.04	0.04	0.04	0.04



	P1 PER	P2 PER	P3 PER	P4 PER	P5 PER
AVG	100.00	99.93	100.00	99.56	100.00
MAX	100.00	100.00	100.00	100.00	100.00
MIN	100.00	92.86	100.00	92.31	100.00
STDEV	0.00	0.71	0.00	1.76	0.00

	P1A level	P1B level	P2A level	P2B level	P3A level	P3B level	P4A level	P4B level	P5A level	P5B level
AVG	1483	1513	2322	2267	1556	1489	2377	2402	1427	1312
MAX	1675	1700	2675	2575	1750	1625	2775	2675	1575	1475
MIN	1325	1350	2000	2000	1425	1325	2075	2125	1225	1175
STDEV	72	70	146	119	63	58	136	126	72	63

	P1A limit	P1B limit	P2A limit	P2B limit	P3A limit	P3B limit	P4A limit	P4B limit	P5A limit	P5B limit
AVG	64975.9	32632.8	65025	51760.6	63737.6	30839.63	65025	51560.62	64719.18	30819.94
MAX	65025	65025	65025	65025	65025	65025	65025	65025	65025	65025
MIN	61344	7103	65025	17293	45156	6790	65025	18428	55105	7625
STDEV	386.422	20774.3	0	14416.2	4332.7	18178.69	0	15648.68	1507.883	18860.56

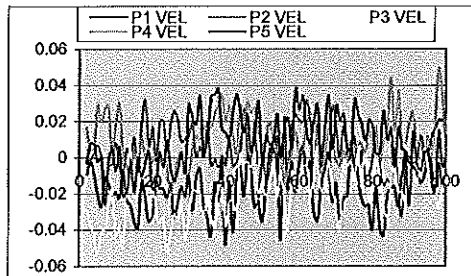
	P1A S/N	P1B S/N	P2A S/N	P2B S/N	P3A S/N	P3B S/N	P4A S/N	P4B S/N	P5A S/N	P5B S/N
AVG	43.80	21.57	28.01	22.83	40.96	20.72	27.36	21.47	45.35	23.49



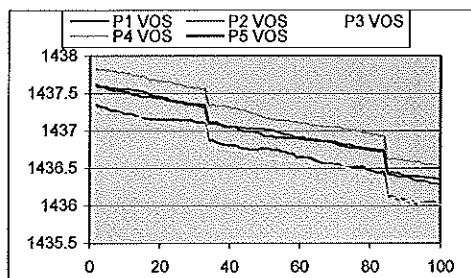


Profile Factor: N/A

	P1 VEL	P2 VEL	P3 VEL	P4 VEL	P5 VEL
AVG	-0.02	0.00	-0.02	0.01	0.01
MAX	0.02	0.03	0.01	0.05	0.04
MIN	-0.05	-0.03	-0.05	-0.02	-0.03
STDEV	0.01	0.01	0.01	0.01	0.02



	P1 VOS	P2 VOS	P3 VOS	P4 VOS	P5 VOS
AVG	1436.72	1437.00	1436.67	1437.21	1436.98
MAX	1437.34	1437.82	1437.28	1437.82	1437.60
MIN	1436.02	1436.28	1436.01	1436.52	1436.33
STDEV	0.40	0.40	0.39	0.40	0.38



	P1 PER	P2 PER	P3 PER	P4 PER	P5 PER
AVG	100.00	100.00	100.00	100.00	100.00
MAX	100.00	100.00	100.00	100.00	100.00
MIN	100.00	100.00	100.00	100.00	100.00
STDEV	0.00	0.00	0.00	0.00	0.00

	P1A level	P1B level	P2A level	P2B level	P3A level	P3B level	P4A level	P4B level	P5A level	P5B level
AVG	1625	1625	2590	2590	1662	1662	2539	2539	1671	1671
MAX	1675	1675	2650	2650	1700	1700	2575	2575	1700	1700
MIN	1600	1600	2525	2525	1625	1625	2500	2500	1650	1650
STDEV	16	16	25	25	16	16	16	16	12	12

	P1A limit	P1B limit	P2A limit	P2B limit	P3A limit	P3B limit	P4A limit	P4B limit	P5A limit	P5B limit
AVG	65025	65025	65025	65025	65025	65025	65025	65025	65025	65025
MAX	65025	65025	65025	65025	65025	65025	65025	65025	65025	65025
MIN	65025	65025	65025	65025	65025	65025	65025	65025	65025	65025
STDEV	0	0	0	0	0	0	0	0	0	0

	P1A S/N	P1B S/N	P2A S/N	P2B S/N	P3A S/N	P3B S/N	P4A S/N	P4B S/N	P5A S/N	P5B S/N
AVG	40.02	40.02	25.10	25.10	39.14	39.14	25.61	25.61	38.91	38.91