CUSTODY TRANSFER FLOW MEASUREMENT WITH NEW TECHNOLOGIES

Stephen A. Ifft
McCrometer Inc.
Hemet, California, USA

ABSTRACT

New technologies can often bring advances to the operational processes within many industries. These advances can improve the overall production of a facility with better performance, better reliability, and lower costs. Obstacles exist, however, to the introduction and use of these new technologies. The natural gas industry has such obstacles, particularly with the use of new technology for custody transfer flow measurement. Paper standards from international organizations like the International Organization for Standardization, the American Petroleum Institute and the American Gas Association are examples of these obstacles. While these paper standards serve to protect and guide companies in their use of technology, they prevent the introduction of new and often better technology. A reform is underway in the natural gas industry to allow companies to take advantage of newer technologies that were not accessible before. This will hopefully redefine the phrase "approved for custody transfer measurement." This phrase has been used incorrectly around the world for decades since none of the organizations listed above actually approve meters for custody transfer measurement. If companies are to reap the benefits of newer and better technology, the industry must continue to reform the existing paper standards that exclude every technology but those that are decades old. As new technologies become available, the industry must have procedures ready for evaluating their possible benefits and detriments. Without these procedures, the advances of the modern world will be overlooked. McCrometer Inc. is a manufacturer of flow measurement devices, including the V-Cone differential pressure flowmeter. McCrometer has first-hand knowledge of the obstacles to bringing a new technology to the natural gas market. This paper will explain how one new technology has been used successfully in custody transfer flow measurement applications even without "custody transfer approval". Also, the author will review how the industry is transforming (and should transform) to exploit the new technologies available today.

INTRODUCTION

The natural gas industry is the leader for many other industries in terms of measurement technology and knowledge. Standards within the United States natural gas industry are often used within unrelated industries, such as chemical, paper, and power industries. These industries and others turn to the natural gas leaders for standards of measurement that can guide the installation, use, and evaluation of measurement devices.

Organizations within the United States natural gas include the American Gas Association (AGA) and the American Petroleum Institute (API). Currently the

AGA is focusing its efforts towards natural gas distribution and consumer use. The API is focusing its efforts towards gas production and transmission. Even with their different focuses, there is substantial overlap between the organizations and there is much cooperation between them.

AGA and API both have programs that write, publish, and support paper standards. These standards cover a wide range of topics including gas sampling, gas storage, safety and pollution. This paper will focus on the paper standards for flow measurement devices only. By far the most widely used standards are those written around the orifice plate differential pressure flow meter. This is because the concentric, square-edged orifice plate is used in more than 50% of flow measurement applications around the world.

The AGA and API standards concerning orifice plates are as follows:
AGA Report No. 3, parts 1, 2, 3, 4
API Chapter 14.3, parts 1, 2, 3, 4

The International Organization for Standardization (ISO) also writes, publishes and supports paper standards for measurement, including flow measurement devices. Their standard for the orifice plate is as follows:
ISO 5167-1:1991

This standard also covers other differential pressure meters, such as venturis and flow nozzles.

CUSTODY TRANSFER FLOW MEASUREMENT

AGA, API, and ISO all have one thing in common, the term "Custody Transfer". This term has many different definitions and uses. This author will define the term custody transfer as the flow measurement of a product between parties where the measurement will be used for financial purposes.

By using standards written by these organizations, a flow meter user can be assured that the flow measurement is the best possible level available by that device.

For instance, if a user buys, installs and maintains an orifice plate according to one of the above standards, that user will be making a measurement that is as accurate as can be expected from an orifice plate. This accuracy is usually in the range of 0.5 to 1.0% of reading.

Another advantage to using these standards is the legal support they give the user. Ideally a custody transfer measurement is an agreement to buy and sell a product between two parties. This is not normally just two people shaking hands over an agreement. The agreement must be in a legal environment. As a legal issue, the agreement must be binding and supportable. By referring to a paper standard for flow measurement, both the buyer and seller (through their legal departments) agree to use a certain type of meter in a certain way. For instance, if the agreement states the flow measurement must be made in accordance with AGA Report #3, then an orifice plate is the choice of meters. If any disagreement occurs between the parties, the AGA paper standard is used to determine if the flow measurement was properly made or not.

New technologies

As new technologies for flow measurement enter the industry, paper standards are not automatically written around them. This is understandable for many reasons. Many new technologies enter the industry every year. The demand to write a new paper standard for each new technology would be overwhelming. AGA, API, and ISO make money off the sale of their standards, but they could not commit the resources to write a standard for so many new products. Many of these new technologies also will not last the test of time. This has been proven over and over. A new technology will appear to solve many traditional flow measurement problems. As this new product is tested and used over time, new, unforeseen problems occur that make the meter unusable for many applications. All the standards organization would not spend time writing a paper standard around a soon-to-be-obsolete product.

As expected, there is also a legal reason why these organizations do not write standards for new technologies. By writing a paper standard, these organizations are guaranteeing the success of a product. If Company X has a product that has a paper standard written around it, it would very likely do better than a product from Company Y without such a document. For this reason, these organizations will not consider writing a paper standard around a metering device with a proprietary design.

Design standards

The paper standards that exist today are considered design standards. Not only do the standards call out how the user should use the meters, but also how they should be built. Thus any meter that is covered under a paper standard could not be a proprietary design. All the AGA, API, and ISO paper standards specify exactly how the meter itself should be built. If a company with a patented design wanted to have a design standard written around the product, it would have to release the design information that makes their product unique. Obviously, most companies with new, patented technologies will not release such data.

A recent movement in the natural gas industry may be changing the very nature of the paper standards of today. API is considering making new paper standards not *design* standards but *performance* standards. Thus, a meter with the performance required for certain applications would receive approval. This movement is due mainly to the increased popularity of ultrasonic meters. Many natural gas customers would like to use ultrasonic meters for measurement but each manufacturer makes their meter slightly different. With so many different designs, API could not reasonably write a design standard for each one. A performance standard was proposed and is now being considered.

Government involvement

Within the United States, the government has surprisingly little to do with the custody transfer flow measurement of natural gas. While there exist standards regulating the flow measuring of gasoline at consumer gas stations and standards regulating the flow measurement of pasteurized milk, the government keeps a laissez-faire approach to the natural gas industry. This is understandable since the industry can safely and fairly regulate itself. While the consumer has little protection against measurement biases, large corporations have a vested interest in receiving and delivering accurate amounts of product.

This type of self-regulation exists in the United States and has been a successful approach for more than a hundred years. The governments of other countries, however, do get involved in the production and transportation of natural gas. Canada is one such example. the Canadian government regulates the custody transfer transportation of natural gas flow measurement. The branch of the government responsible for this is called Industry Canada. Under Industry Canada is the Measurement Canada division, which does this regulation. (http://mc.ic.gc.ca) Measurement Canada has a specific approval process that manufacturers of flow measurement and other products must follow before using their instrument for custody transfer measurement in Canada.

While Measurement Canada is a completely separate entity, it is closely associated with the American natural gas industry. This is because the approval processes that they follow are linked to the standards mentioned earlier. To approve a flow meter, a manufacturer must meet the design standards given by API. Therefore, new technologies are also effectively blocked from acceptance in Canada.

This pattern repeats itself through North, Central and South America. Countries in those continents refer back to paper standards from the United States. In Europe, national standards refer back to the appropriate ISO paper standards. For Asia, Africa, and the rest of the world, the particular standard referenced in government documents varies.

"APPROVED FOR CUSTODY TRANSFER"

The term "approved for custody transfer" is used throughout the world. If a vendor tries to introduce a new product to an industry, one of the first questions is "Is the meter approved for custody transfer measurement?" In the United States the answer to this question is "No." Even if the meter under question is an orifice plate, the answer is "No." This is because there is no organization that approves meters for custody transfer measurement. The United States government certainly does not. AGA and API only write standards around certain meter design. They do not approve meters in any way.

The question above needs to be reworded to "Does your meter have an AGA or API paper standard written around its design?" The answer to this question can only be answered positively if the manufacturer is producing an orifice plate, venturi, flow nozzle, turbine, and, some would say, an ultrasonic meter. Any other type of device has no paper standard written around it.

This question also carries a lot of weight since the answer to it often defines whether a certain meter will be considered for an application or not. This question can also block new technologies from non-custody transfer applications. A meter without "custody transfer approval" is considered not equal to those that do.

McCROMETER V-CONE

The V-Cone differential pressure flowmeter, manufactured by McCrometer Inc., is an example of new technology available to industry today. The V-Cone has many benefits that could potentially help the natural gas industry, and other industries, with some basic flow measurement problems. It is also an example of how such a technology can be blocked from acceptance because of the paper standard system of the AGA, API, and ISO.

V-Cone

The V-Cone is a differential pressure flowmeter invented and manufactured by McCrometer Inc. Patented in 1986 as a new type of differential pressure flow meter, the V-Cone is based on the principles of Bernoulli.

The geometry of the V-Cone is a radically different approach to differential pressure flow metering, see Figure 1. As with other differential pressure devices, the flow constricts to create a high velocity area, which creates a lower pressure just past the constriction. By measuring the pressure upstream and downstream of the cone, a differential pressure can be calculated and related to the flowrate through the pipeline. The V-Cone's constriction, however, is not a concentric opening through the center of the pipe like traditional differential pressure flowmeters. The V-Cone creates an annular opening, forcing the fluid to flow around a cone positioned in the center of the pipe.

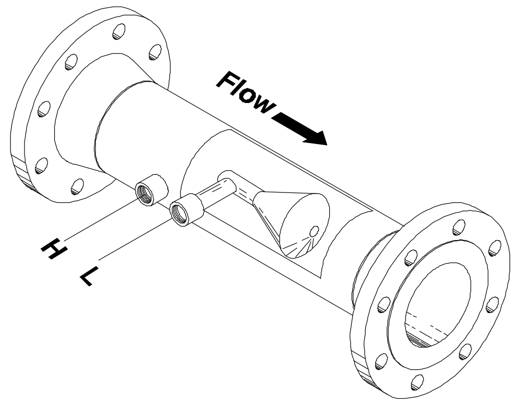


Figure 1: Illustration of a typical V-Cone design

Equations for the V-Cone are only slightly different from standard differential pressure equations. The V-Cone beta ratio follows the same principle as other differential pressure devices. Thus a V-Cone and an orifice plate beta ratio are equivalent to each other in terms of open area. The basic equation of flow for the V-Cone is similar to standard differential pressure equations.

The V-Cone offers many distinct advantages because of it geometry and engineering. A number advantages are listed below that appeal particularly to the natural gas industry:

1. Short installation requirements. The V-Cone can be installed with no or very little installation runs upstream or downstream of the meter. This can provide substantial savings during new installation planning or when a pipeline is retrofitted for flow measurement.
2. Wide turndown. The V-Cone discharge coefficient remains constant over a wide range of flows. This allows for one meter to measure the span of multiple orifice plate runs.
3. Low signal noise. The low signal noise of the V-Cone give the user

much faster response time in critical application, such as anti-surge measurement.

4. Little or no maintenance or recalibration required. The self-cleaning design of the V-Cone makes it less susceptible to coating or abrasion over time. This makes the V-Cone ideal for remote and unmanned installations.

Selling without "custody transfer approval"

The V-Cone was introduced over 13 years ago and is now well accepted through the world for accurate and dependable flow measurement. The design and use of the V-Cone is patented worldwide and so AGA or API have not been able to write a paper standard around its proprietary design. This has certainly stunted the growth of the V-Cone. More importantly to the natural gas industry, the V-Cone has been blocked as a new and potentially money-saving technology in many applications, even non-custody transfer.

Even with this extra-hurdle to clear, the V-Cone has been used successfully and has also measured many custody transfer applications. There are two main reasons for this.

First, the V-Cone is a completely traceable and accurate means to measure flowrate. Each V-Cone is calibrated on a flow measurement standard traceable to the national standards of the United States, the National Institute of Standards and Technology (NIST). Many V-Cones intended for custody transfer applications are calibrated outside of McCrometer at an independent facility. As completely separate entities from McCrometer, the testing and calibration facilities produce results from the meter that are reliable without question. This means the end-user will receive a meter that has received a full calibration and testing prior to installation. Any defects, inaccuracies, or problems with the V-Cone would be evident during the testing. This type of custody transfer traceability has been used in the natural gas industry, as well as other industries such as power and municipal.

Second, McCrometer has successfully proven the superior performance of the meter to the government of Canada. In March of 1998, Industry Canada approved the V-Cone for the measurement of custody transfer natural gas. This may seem illogical since the Canadian government uses API standards to approve or disapprove meter manufacturers. The remainder of the paper will discuss the obstacles and eventual success of McCrometer in this endeavor.

CANADIAN CUSTODY TRANSFER APPROVAL

The approval process with the Canadian government is well-defined in documents such as the Specifications for Approval of Type of Gas Meters and Auxiliary Devices (LMB-EG-08). This document states, among others, the requirements for approval of certain types of flowmeters. These meters are generally defined as:

1. Diaphragm meters	Section 5
2. Rotary meters	Section 6
3. Turbine meters	Section 7
4. Orifice meters	Section 8
5. Mass flow meters	Section 9

The V-Cone is a differential pressure type device and McCrometer's intention was to have the V-Cone certified under the same principles and requirements as an orifice plate.

After receiving the application for type approval for the V-Cone, Measurement Canada reviewed the product data and existing performance data regarding the V-Cone. Even though the V-Cone is based on the same principles as the orifice place, the V-Cone could not be evaluated under the same requirements as the orifice meter's section.

Section 8 of the specifications refers extensively to the American National Standard, ANSI/API 2530, "Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids." This standard deals exclusively with the orifice plate design and could not be correlated to a V-Cone application. Measurement Canada then needed to decide how to deal with the V-Cone and under what section the evaluation should proceed.

For two apparent reasons, the V-Cone application would be evaluated under Section 7 of the specifications regarding turbine meters. The first reason was the performance specifications of the V-Cone. The standard accuracy and turndown of the V-Cone is stated as ±0.5% of rate over a 10:1 turndown. The requirements for turbine meters under this section call for 1% of rate for the entire measurement system over a 10:1 flow turndown. A system accuracy of ±1% of rate is easily possible with a combination of the V-Cone and the correct measurement and calculation equipment.

The second reason was the issue of calibration. Similar to turbine meters, V-Cone meters need initial in-line calibrations for the best accuracy. Each custody transfer V-Cone will be flow calibrated at a laboratory directly traceable to Canadian or American national measurement standards. These laboratories are typically independent companies whose expertise is in compressible gas flow and calibration.

Performance Test

A performance test was a necessary part of the evaluation process. Measurement Canada required a witnessed test of the performance of the meter and instrument system. This test would support the documented data already produced during the evaluation process.

A typical turbine meter calibration would take place in Measurement Canada's gas flow facility. This system operated at atmospheric pressure and was not suited for the higher-pressure performance test of the V-Cone. With consent from both Measurement Canada and McCrometer, the Colorado Engineering Experiment Station, Inc. (CEESI) was selected as the test laboratory for the performance test. CEESI is well acquainted with the V-Cone and well equipped for the type of calibration required.

McCrometer was to supply the V-Cone and the necessary instrumentation. Measurement Canada would witness and certify the test. An existing four-inch V-Cone with a beta ratio of 0.45 was selected. This size meter and cone would fit easily into the CEESI test lab and require only moderately high flowrates to generate a sufficient differential pressure. A Rosemount 3095MV was the secondary instrumentation chosen for the flow measurement system. The 3095MV, when programmed to work with the V-Cone, would output a 4-20 mA signal proportional to the mass flowrate through the meter. McCrometer chose a multivariable transmitter to simplify the verification of the flow calculations.

CEESI's laboratory is referenced using critical flow venturi nozzles. These nozzles and the entire instrumentation system are completely traceable NIST. A large volume of high-pressure air supplies the test system. The system vents air back to atmosphere a sufficient distance downstream of the test section.

The results of the test indicate performance well within the required specifications for Measurement Canada. See Appendices A & B for tabular and graphical results. Absolute pressure during the test was approximately 200 psia and covered a Reynolds number range of approximately 1 million to 75,000. Over this flow range of 13:1, the system accuracy of the V-Cone and Rosemount 3095MV was +0.30 to -0.54% of rate. By adjusting the flow coefficient according to the calibration, the system accuracy could be stated as ±0.42% of rate. This exceeds the specifications of the V-Cone primary element. When considering the added uncertainty of the instrumentation and flow calculations, this test shows very good performance.

Notice of Approval

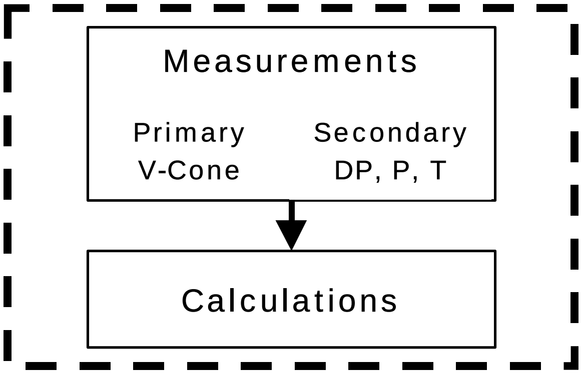
Following the performance tests, several drafts of the notice of approval were reviewed. After the review and translation of the document were complete, the final Notice of Approval (NOA) was granted March 19, 1998. The notice states "The V-Cone meter is a differential pressure type flowmeter approved for custody transfer of natural gas."

Following the guidelines of Section 7 of the specifications, the installation requirements must be in accordance with McCrometer's recommendations. The markings on any Canadian custody transfer V-Cone must include certain information, including the departmental approval number.

Also following Section 7, the V-Cone must be verified either in-situ or at "a high pressure gas meter calibration facility acceptable to Industry Canada." CEESI and other laboratories are available for this testing if necessary. The NOA states "This V-Cone meter uses any approved and compatible flow transmitter or flow computer that is approved to perform V-Cone meter calculations for determining the volume of gas through the meter at standard conditions." This sentence refers to the method of calculation used to determine mass flowrate of gas through the meter. Two methods are currently being used by the natural gas industry. This author will label these methods "traditional" and "multivariable".

Both methods utilize the same basic principles. As displayed in Fig. 2, the measurements take place separately from the calculations. The measurements are also split between the primary element measurement, in this case the V-Cone, and the secondary measurements of differential pressure, pressure and temperature.

Figure 2: Basic differential pressure flow measurement system



In traditional calculation methods, the measurements are done separately from the calculations. Transmitters would be used for the measurements of differential pressure, pressure, and temperature. Signals from these transmitters would be sent to a flow computer or a distributed control system (DCS). The flow calculations would be done separately from the measurement area and displayed and used in various ways.

A relatively new method of flow calculation is now being accepted in the natural gas industry. The multivariable method uses a single instrument to measure differential pressure, pressure and temperature. This reduces the instruments and pipeline connections necessary in the differential pressure flow meter. The multivariable system uses these inputs and calculates the flow in the same instrument. This blurs the line between the measurement and calculation areas.

The NOA calls for “approved” devices to calculate the flow through a V-Cone. Currently no flow transmitters or flow computers are approved for use with the V-Cone. McCrometer is currently working with Measurement Canada to define the approval process for V-Cone calculation devices. Since the V-Cone is based on the same principles as traditional differential pressure devices and uses virtually the same mass flow equations as a venturi, this process should go rapidly. Several manufacturers of flow transmitters and flow computers have already incorporated the V-Cone into their devices. The Measurement Canada approvals for these devices will need only updating to show the current changes.

The option available to users at time of printing is the use of a DCS system. A DCS could be programmed to correctly calculate mass flow rate through a V-Cone, similarly to what is done for orifice plates. These systems must be individually approved through Measurement Canada.

Conclusions

The McCrometer V-Cone meter has been approved for custody transfer measurement of natural gas in Canada. The V-Cone performed above the requirements given by Measurement Canada.

This approval is significant for the V-Cone and will have impact well beyond Canada or even North America. The Measurement Canada approval process is the only government-based process in North America. The United States government does not provide this service. Independent organizations such as the American Gas Association (AGA) and the American Petroleum Institute (API) are expected to provide such standards and guidelines. The “approval process” through these organizations is not clearly defined, since the standards deal with meter design rather than performance. A patented meter design such as the V-Cone could not be covered with such a design standard. This may be changing as ultrasonic technology is entering the industry. Ultrasonic meters, while all use the same basic principles, have proprietary designs. Current drafts of standards within AGA and API deal with design and performance issues in different ways.

The impact of this approval has been noticed in Canada and worldwide. Canadian users recognize the importance of this approval and have opened previously closed doors to the V-Cone technology. Users in the United States acknowledge the importance of the only approval process in North America. This author has been asked about this approval in places as far away as Australia and Norway.

References

1. Specifications for Approval of Type of Gas Meters and Auxiliary Devices (LMB-EG-08), Consumer and Corporate Affairs Canada, Legal Metrology Branch, 1987.
2. Notice of Approval, V-Cone Meter (AG-0428), Measurement Canada, March 19, 1998.

Appendix A

**COLORADO ENGINEERING
EXPERIMENT STATION, INC.**

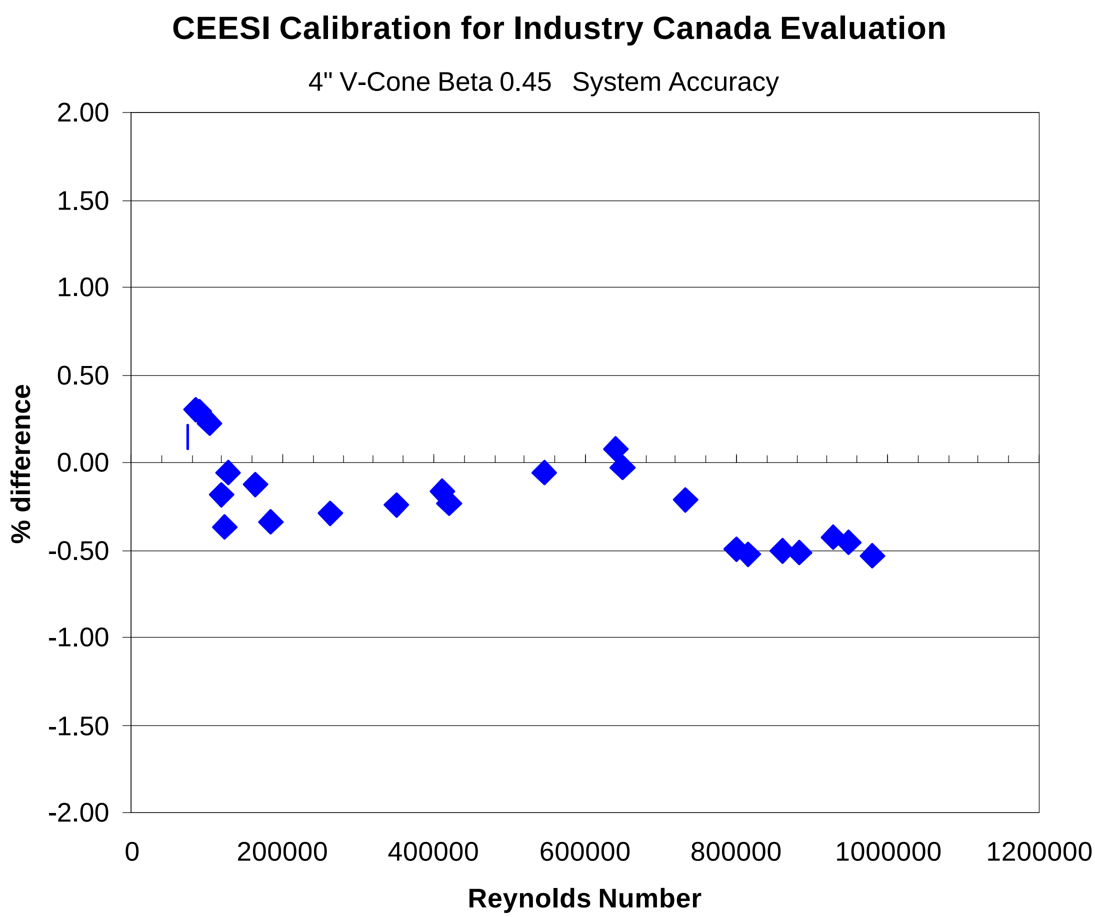
Calibration of a McCrometer V-Cone

Model: V5104   Serial No. 97042300
For: McCrometer   Order:
Data File: 97MCC022   Disc: 0997-018 Date: 24 September 1997
Inlet diameter: 4.09 inches   Throat diameter: 3.659 inches
Test gas: AIR   Standard density= .074915 lbm/cu-ft
at standard conditions of 529.69 deg R, and 14.696 psia
Mtr Read: Meter reading in volts DC across a 99.995 ohms resistor
Mdot: Mass flowrate in Lbm/sec
Rey No: Inlet (pipe) Reynolds number
Mtr Read2: Meter reading in Lbm/sec

L	Mtr Read	Mdot	Rey No	Mtr Read 2
1	2.04827	3.107034	979671.9	3.0903
2	1.96022	2.937754	929007.2	2.9252
3	1.877705	2.784982	882329.4	2.7705
4	1.988706	2.992303	949333.8	2.9786
5	1.83909	2.711715	861650.7	2.6981
6	1.736693	2.51872	801073.4	2.5061
7	1.62633	2.304196	733300.8	2.2992
8	1.75828	2.560127	815130.8	2.5466
9	1.486764	2.038151	649239.9	2.0375
10	1.315351	1.717084	546966.2	1.7162
11	1.473358	2.010799	640427.2	2.0124
12	1.101089	1.317516	419555.6	1.3144
13	0.985557	1.100524	350291.8	1.0978
14	1.089277	1.294442	411758.4	1.2923
15	0.841574	0.830255	263978.5	0.8279
16	0.709143	0.581577	184854.3	0.5796
17	0.62474	0.421559	128848.2	0.4213
18	0.599846	0.375346	119100.3	0.3747
19	0.683298	0.531777	164978.3	0.5311
20	0.61198	0.398872	123801.4	0.3974
21	0.578701	0.334258	103731.1	0.3350
22	0.54688	0.27452	85167.09	0.2753
23	0.528939	0.241366	74870.05	0.2417
24	0.554899	0.28954	89840.09	0.2904

Average values for above results:
Press: 204.53 psia   Density: 1. 0919 lbm/cu-ft
Temp: 508.89 Deg R   Viscosity: .00000098726 lbm/inch-sec
Compressibility factor: .99379

Appendix B


CEESI Calibration for Industry Canada Evaluation
4" V-Cone Beta 0.45   System Accuracy
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
% difference
0
200000
400000
600000
800000
1000000
1200000
Reynolds Number