Field Verification of Ultrasonic Gas Meter Stations

Jeremy Fernandez, Geoff Hager: M3 Energy Services, LLC
4140 S. Galveston Ave., Tulsa, OK, USA 74107
Thomas Kegel: Colorado Engineering Experiment Station Incorporated (CEESI)
54043 WCR 37, Nunn, CO, USA 80648
Corresponding Author: jeremy.fernandez@mobilemastermeter.com

Introduction

Many tools are available to assure consistent measurement gas measurement. Ultrasonic meters offer several diagnostic parameters, some designs include extra acoustic paths. Meter stations are being designed with integral check meters. A remote monitoring service[1] brings a higher level of experience to the evaluation of diagnostic and check meter data. This paper discusses a new service based on bringing an independent check meter to a meter location.

1. History

Field proving is common in liquid hydrocarbon applications. Pipe provers have been in use since the 1950s; both in stationary and portable configurations. Slightly more recently (late 1970s) the small volume prover was introduced, significantly reducing the footprint and improving portability. Master meter proving is also quite common. A master meter is calibrated against a prover in a fixed location; the master meter is installed on a truck or trailer. A number of industry standards[2] describe the processes in detail.

Field proving gas meters is more difficult because of the need to handle high pressure gas. Two early designs were put into service in the 1980s. The first3, based on critical flow venturi (CFV) master meters, was applied to calibrate turbine meters. The use of CFVs and the relatively low flowrates resulted in a compact vehicle footprint. The second portable prover[4] operated based on turbine and orifice meters. The trailer was quite large and field connections were problematic at best. Neither system is currently in use.

Fixed master meters are commonly used in gas service[3]. A meter station can be designed with an extra meter run to accommodate a master. On a periodic basis the flow path is configured to place the master meter in series with one of the fiscal meters. Additional pipe and valves incorporated into the station design facilitate the verification process. Such designs impose additional capital expenses not required with a portable prover.

2. Design

The present master meter transfer standard is an eight inch ultrasonic meter manufactured by Sick. The design, identified as "4+4", provides eight ultrasonic paths using sixteen transducers. Two sets of independent electronics each process data from four transducer pairs. The design objective is to provide two independent measurements within a single meter spool. In a typical application the two measurements are designated "main" and "check".

Stated simply the meter is installed in a tube network mounted to a trailer. Given more thought it is understood that the flow path leaving the MUT will likely include multiple elbows that can produce distorted flow profiles and swirl. Three design features of the tube network on the trailer combine to provide isolation from profile distortion and swirl. The first is a straight run of 35.6 nominal diameters (23.75 ft), the second is a double in-plane elbow pair. The third design feature consists of two perforated plate flow conditioners (CPA 55E, CPA 50E) installed in series. The pipe design represents a trade off between system portability and consistency in flow profile at the master meter.

A traditional challenge with previous designs has been to provide high pressure flexible connecting lines. The present design is based on two adjustable high pressure piping assemblies designed to fit a variety of meter run end treatment geometries. An on board crane provides a wide range of options when positioning the pipe assemblies. The pipe assemblies, shown in Figure 1, are designed with unique slip joints that allow independent vertical and horizontal position adjustment. Figure 2 shows a top view, the pipe assemblies include lap joint flanges to allow rotational freedom. Jacks and air supports facilitate precise level adjustment of the trailer. Figure 3 shows the system installed in the CEESI Iowa facility for initial testing. Figure 4 shows the system installed for the field trial. The figures illustrate the range of motion available when connecting to a meter station.

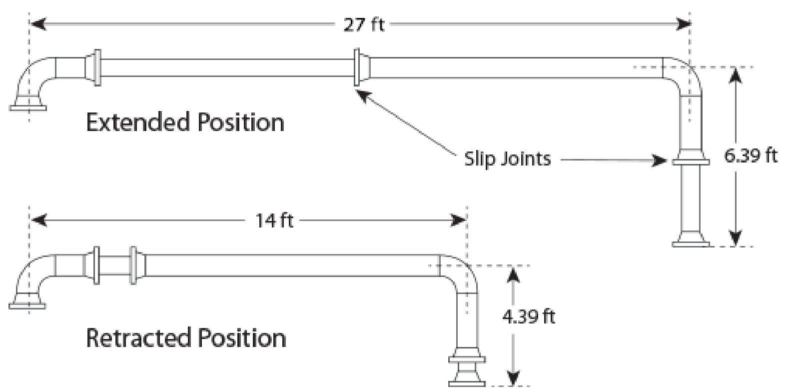

Figure 1: Pipe Assemblies

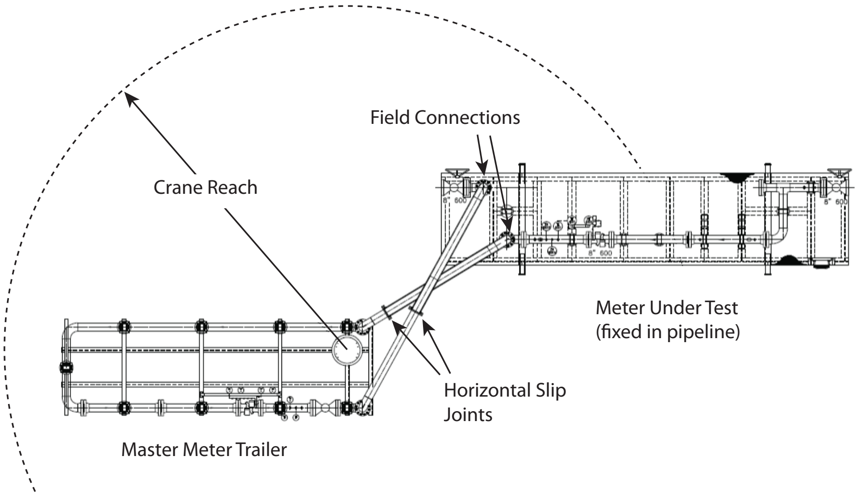

Figure 2: System Overview

Figure 3: System Installed in Iowa Calibration Facility

Figure 4: System Installed for Field Trial

The design includes a complete set of "ancillary" instruments that are independent of the MUT (meter under test). These include pressure and temperature measurements at the master meter and MUT and a gas chromatograph. Redundant measurements allows for troubleshooting if necessary. A laboratory grade data acquisition system provides faster scan rates and lower uncertainty when compared with field grade equipment. A complete log of diagnostic parameters from MUT and master meter also facilitates troubleshooting.

This unique patented design has been given the name "M3" which is an abbreviation for mobile, master, meter.

3. Benefits

There are several benefits to field proving completed under flowing conditions. The meter is evaluated based on flowing pressure, and gas composition. Installation conditions can include flow profile distortion, swirl,or pulsation resulting from the meter station design. The meter performance will include any influence from these effects. Additionally, an ultrasonic meter will deform with changes in pressure and temperature. It is noted that the master meter is subject to the same conditions MUT, some effects may cancel out.

4. Verification Process

This section briefly describes the process of on site verification of a customer meter.

***Pre Verification Site Assessment:** Prior to bringing M3 to field site, a survey of the meter under test (MUT) and surrounding area is completed. The survey identifies or confirms line size, process operating parameters, shutdown schedule, adverse pipe conditions, special tooling, safety training, and accessibility. With acceptable survey results in-hand, the verification process continues with M3 deployment.*

***Position Trailer:** The M3 system is driven on site, and parked within 15-27 feet of the MUT field connections. The trailer and piping is leveled using the jacks and air supports.*

***Establish Field Connections:** The pipe assemblies are positioned by adjusting the slip joints and flanges. The crane helps with the positioning. The M3 meter and pipe are then connected in series with the meter under test.*

***Record Instrument Readings:** The quantity of gas passing through the MUT is compared with the quantity of gas passing through the master meter. The operating ranges are:*

- *4"-12" 600# ANSI*
- *15 ft - 27 ft (3.66m to 7.62m)*
- *0 to 120 ºF (255 to 322 K)*
- *0 to 1440 psig (0 to 99.28 barg)*

***Verification Report:** The data are reviewed and a verification report is issued.*

5. Initial Calibration and Testing

The initial calibration and testing was completed at the CEESI Iowa facility. It consisted of eight distinct flow calibration and verification tests. In this section the process is described and the results are presented.

The process began with an eleven point "as-found" calibration (File 1) over a velocity range of 1 - 150 ft/s. A second eleven point "as-found" calibration (File 2) quantified reproducibility without disconnecting the meter. Third was a four point verification (File 3) to confirm that the proper correction factors were installed.

Figure 5 show the Files 1 and 2 data. The "Main" electronics head is used for measurement, the "Check" electronics head reading is available for troubleshooting. The symbols represent individual data points, the lines are curve fits. Agreement between the curve fits is less than 0.1% for most of the operating range; well within the short term reproducibility of the facility.

On a second day a five point verification (File 4) further quantified reproducibility without disconnecting the meter. The M3 trailer was then disconnected and driven on rough rural roads to subject the equipment to significant acceleration loads. Upon returning to the laboratory a four point verification (File 5) confirmed consistent operation.

Figure 6 shows the data from Files 3-5; the lines represent a statistical interval intended to contain 95% of the data points. The data are well centered about zero, confirming that the proper correction factors were entered. File 4 further verifies short term reproducibility and File 5 verifies that the overall system can be transported without affecting uncertainty. It is noted that the statistical interval width varies with velocity, this behavior is commonly observed with ultrasonic meters.

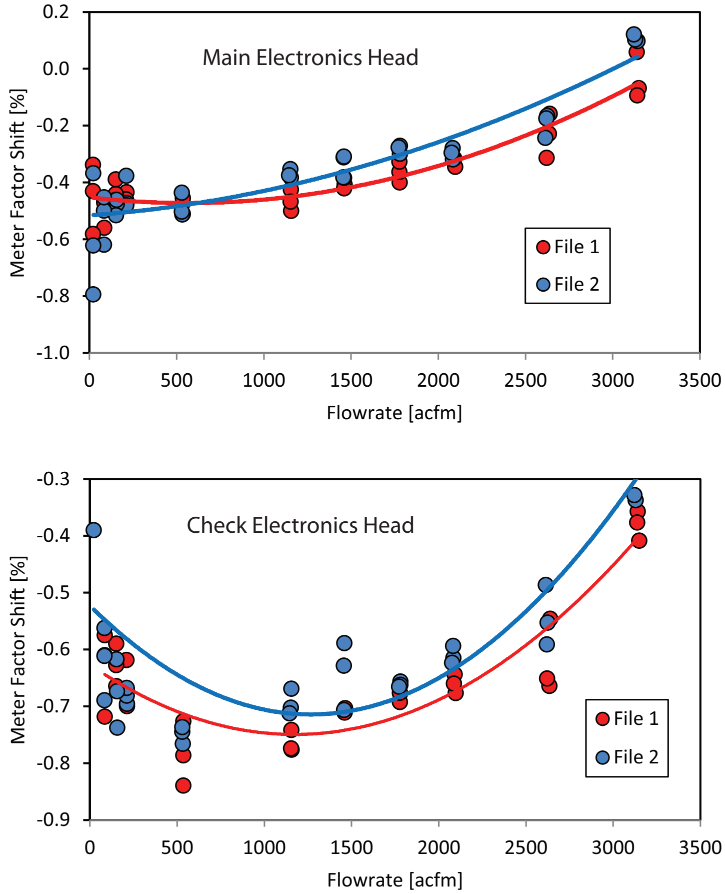

Figure 5 Two Calibration Runs

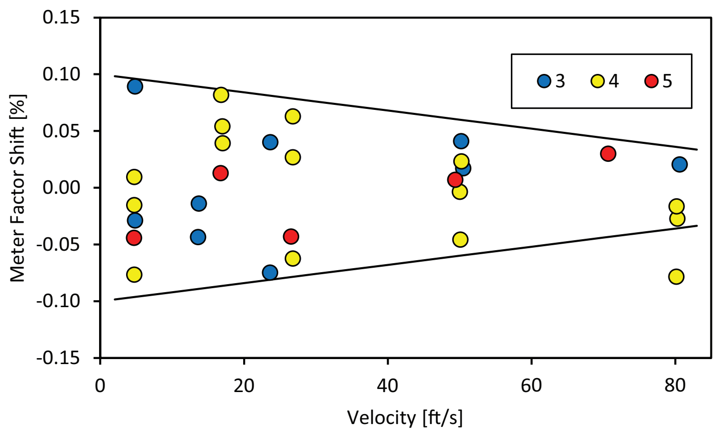

Figure 6: Verification Files 3, 4, and 5

Figure 6 shows the data from Files 3-5; the lines represent a statistical interval intended to contain 95% of the data points. The data are well centered about zero, confirming that the proper correction factors were entered. File 4 further verifies short term reproducibility and File 5 verifies that the overall system can be transported without affecting uncertainty. It is noted that the statistical interval width varies with velocity, this behavior is commonly observed with ultrasonic meters.

The M3 trailer was then installed in series with a twelve inch MUT for an additional verification test. Two files are compared, the first contains the previous MUT verification using CEESI standards. The second file contains verification data of the same MUT using M3. The results are shown in Figure 7; The CEESI and M3 standards agree within better than 0.1%. It is encouraging that the files predict very similar MUT data curve shapes.

An eighth calibration was completed approximately one month later. The results are shown in Figure 8, the average values (solid lines) are within 0.1% of the original calibration.

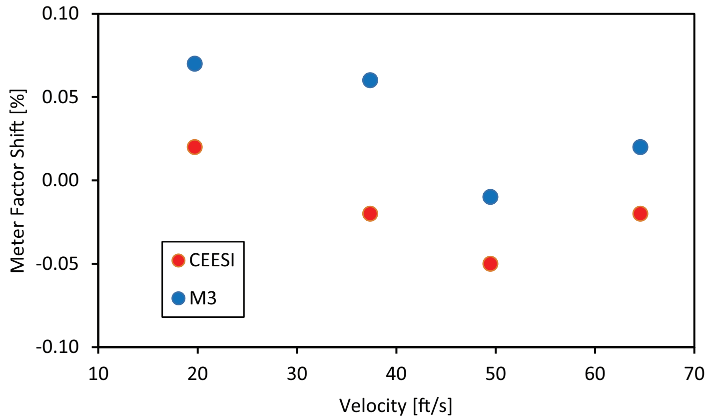

Figure 7: MUT Verification, M3 Compared to CEESI Standards

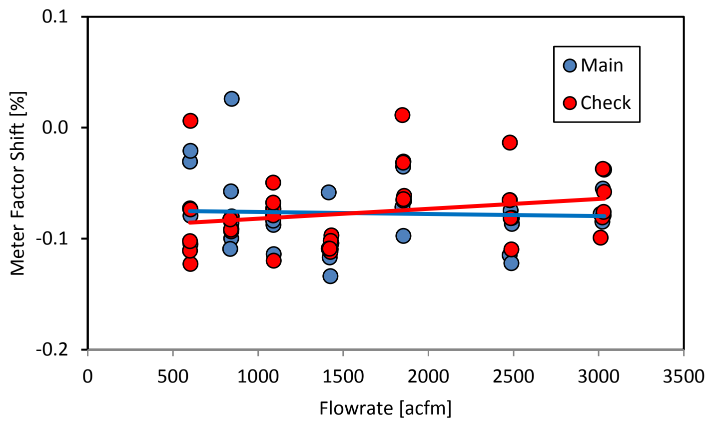

Figure 8: Calibration Run One Month Later

6. Field Trial

Field trial verifications were completed in comparison with an eight inch (MUT8) and twelve inch (MUT12) meters. The client meters had been installed for approximately two months. The expectation therefore was that M3 would register acceptable performance. Surprisingly the first test indicated meter errors of approximately 0.6%; not a finding that inspired optimism.

A review of the MUT diagnostics indicated potential buildup of material on the internal surfaces. The meter run was opened and an inspection confirmed the presence of a buildup. The tubes and meters were cleaned; additional data were within 0.1% of M3. It is noted that the M3 verification improved the measurement without adjusting the meter.

A quick ROI (return on investment) analysis illustrates one benefit of field verification. The station value is $600 thousand per day. The shift of 0.5% represents $3000 per day, which corresponds to over $1 million per year. There was no cost, this having been a field trial; a paid M3 verification would cost approximately $30,000 (in the US). The analysis predicts a payback period of 10 days.

7. AGA 6 Discussion

The M3 process represents an implementation of the AGA 6[6] standard. This section discusses specific topics from AGA 6 starting with some definitions.

First, the definition of proving is: "The process of determining the relationship between the output (or response) of a MUT to the value produced by a master meter." Proving does not include taking action based on the relationship; the action is defined by calibration or verification. Further, it is noted that proving can take place in a laboratory or the field. The M3 process can be identified as proving, and the portable hardware can be considered to be a prover. The liquid hydrocarbon master meter prover is very similar.

Moving on within AGA 6, calibration is defined as: "The process of determining, under specified conditions, the relationship between the output (or response) of a device to the value of a traceable reference standard with documented uncertainties." The definition continues with: "Any adjustment to the device, if performed, following a calibration requires verification against the reference standard." Meanwhile, verification is defined as: "The process of confirming or substantiating that the output of a device is within the specified requirements."

Two important interpretations are proposed based on the definitions. First, verification does not include adjustment. The M3 verification process therefore does not include adjustment. Second, calibration is performed under specified conditions, typically a range of flowrates with repeat points at each flowrate. These are conditions that are not always possible in the field.

"The master meter should have a lower uncertainty than the uncertainty required for the MUT". While this is an intuitive the uncertainty is not quantified. Statistics enters into the discussion when measurement uncertainty is included in a pass/fail decision. The concept of "risk management"quantifies the risk of making an incorrect decision. The decreases as the uncertainty of the MUT increases relative to the master meter (called test uncertainty ratio). It is noted that the risk of false decisions must be estimated by a laboratory as part of the accreditation process[7].

Several quotes from AGA 6 are reproduced and discussed below:

"Field proofs should not be used to replace the initial calibration factor(s) of the MUT obtained in a qualified laboratory unless the reason for the differences can be determined." From this statement field proving is interpreted a verification.

"Under steady-state conditions all necessary parameters, such as pressure, temperature, and meter output such as frequency (or pulses and time), are recorded. Sufficient pulses must be accumulated to achieve the desired uncertainty." The phrase "sufficient pulses" refers to turbine or displacement meters, the concept is well documented in the liquid proving standards[2]. In order to maintain the desired uncertainty, the CEESI Iowa facility maintains steady conditions for two minutes for a single data point. Three to five data points are usually obtained to evaluate repeatability resulting in up to ten minutes of steady conditions. Steady state conditions might not always be possible in the field.

Two examples illustrate different verification scenarios. Figure 9 shows laboratory calibration results from an ultrasonic meter. The meter factor is the ratio of meter reading to the laboratory flowrate. A hypothetical field verification performed at 280,000 acfh reports that the meter reads low by 0.179%. Without information at additional flowrates it is assumed that the meter reads low at all flowrates. Applying the 0.179% correction at 70,000 acfh will result in an error of 0.159%; at 14,000 acfh an error of 0.289%

A second example is contained in Figure 10. For flowrates greater than 3000 acfh the corrections are all within ±0.06%. A hypothetical field verification at a single point could be applied over most of the flowrate range. The problem is that a user will not know if their meter is reporting the same error at most flowrates.

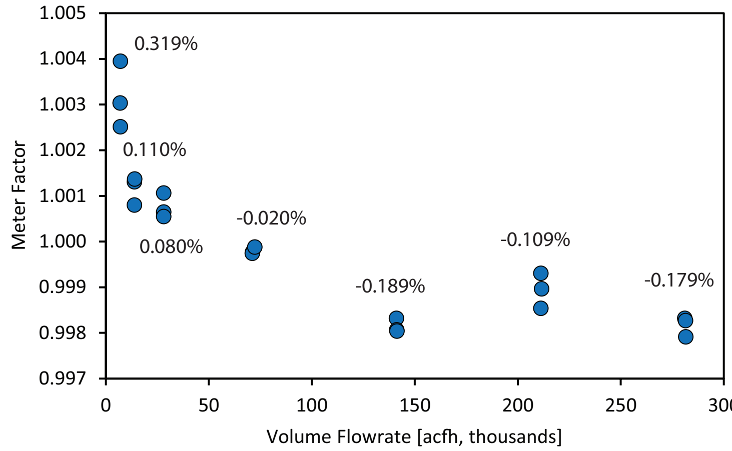

Figure 9: Sample Calibration Data

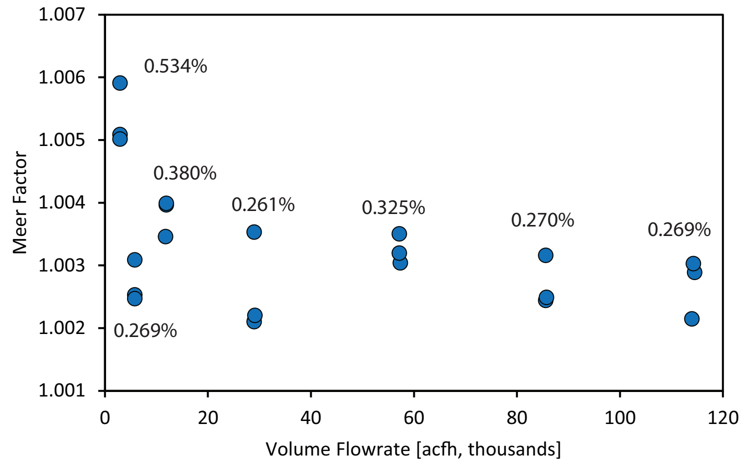

Figure 10: Sample Calibration Data

Summary

The design and operation of the M3 portable high pressure gas prover has been described. Initial calibration and test data were obtained at the CEESI Iowa natural gas flow laboratory. A second calibration was completed one month later. A field trial identified material buildup in the meter under test. After cleaning proper operation was confirmed by M3.

References

1. *Lansing, J., "A Complete Meter Station Monitoring System," 2013 Ultrasonic Meter User's Workshop, Denver.*
2. *"Manual of Petroleum Measurement Standards Chapter 4 - Proving Systems," American Petroleum Institute.*
3. *Beeson, J., "Onsite Proving of Gas Turbine Meters," ISHM, 1989.*
4. *Nu-Tech Industries Corporation; Oklahoma City, Oklahoma; Mobile In-Line Prover by Feb. 1986; 2 page brochure.*
5. *Rudroff, D J., "Onsite proving of gas turbine meters," ASGMT, 2004.*
6. *AGA Report No. 6, "Field Proving of Gas Meters Using Transfer Methods," 2013.*
7. *Dobbert, M. and Stern, R., "A Pragmatic Method for Pass/Fail Conformance Reporting that Complies with ANSI/NCSL Z540.3,ISO/IEC 17025, and ILAC-G8," Measure, March 2010.*