ONSITE PROVING OF GAS METERS

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Introduction

With the increased use of Natural Gas as a fuel, and higher natural gas prices buyers and sellers of natural gas are seriously looking at ways to improve their natural gas measurement and reduce the error in natural gas measurement.

A 6" Turbine or Ultrasonic meter operating at 1,000 Psi will move 100 MMSCF/Day. An error in measurement of only one tenth of one percent (0.1%) on 100 Million Standard Cubic Feet (MMSCF) of Natural Gas selling at $4.00 per Thousand Standard Cubic Feet (MSCF) will cause an over or under billing of $400.00. Therefore the error in a year is ($400 X 365) $146,000.00 This will more than pay for a proving or verifying system.

The Btu in one barrel of oil is equivalent to the Btu in approximately 5,600 cubic feet of natural gas. At $4.00 per thousand cubic feet, the natural gas equivalent of one barrel of oil is $22.40 which is much less than a barrel of oil so natural gas is becoming the fuel of choice.

In the petroleum liquid industry, no custody transfer liquid measurement system would be complete without a method to prove the meter, either as part of the equipment, or through connections provided to connect a portable prover.

Under billing causes loss of revenue and over billing can cause a future correction that can cost the company millions of dollars to correct over billing.

For this and many reasons gas meter proving is important and necessary to insure precise measurement of natural gas that both the buyer and seller can agree upon.

With the publication of AGA Report No. 6 "Field Proving of Gas Meters Using Transfer Methods" there is now guidance on how to prove Gas Meters in the field.

Unfortunately there are no volume devices like in liquid proving currently on the market, but there are other methods such a sonic nozzle proving and master meter proving that can be used.

In the ASME standard MFC-7M-1987 Reaffirmed 2001 "Measurement of Gas Flow by Means of Critical Flow Venturi Nozzles" it is stated "The Venturi nozzles specified in this Standard are called primary devices." Nozzles have been used for many years to prove natural gas meters. Sonic Nozzles have a long history, are well documented and the formulas, although a bit complicated, are in most flow computers.

Reasons for proving a field meter

Although the installed field meter has been completely checked and calibrated at the factory, and a performance curve developed, there are many things that can affect a meter on site causing measurement errors.

Any meter system can have changes during operation that will cause errors in measurement. The installation effect caused by different piping configurations on site than at the test will cause an error. Orifice plates can become damaged, bearings on Turbine Meters can wear, and dirt and trash can accumulate on flow conditioners and in piping. Trash can accumulate on straightening vanes, and Ultrasonic and other meter runs can become dirty causing the meter to error.

The inputs into flow computers and other electronic devices can be changed in error

New meter installations could have debris from construction that can catch on the straightening vanes or in the meter itself. Proving, checks not only the meter, but also the complete system.

One of the more important reasons for meter proving in the case of Custody Transfer is to give both the buyer and seller confidence the volumes they transfer are acceptable to both the buyer and seller, thus eliminating disputes

Meter Proving Devices

Figure 1 Sonic Nozzle

There are many different methods and devices available that can be used to prove Natural Gas Meters. Some of them are calibrated Master Meters, Sonic Nozzles, Bell Provers, and Volume Provers. Each device has its advantages and disadvantages.

These proving devices can be divided into two categories, primary and secondary. A primary measurement device, such as a bell or volume prover is one that has had its volumetric flow rate measurement accuracy checked and verified against measurements for which there are national or international standards (e.g., mass, time, length, etc.) This device can then be used to verify Master Meters. A Master Meter that has been calibrated becomes a secondary standard and can then be placed in series with a field meter to verify the accuracy of the Field Meter. A secondary device is one that has been checked against a primary device and is then used to prove another meter. An example of a secondary device is an In-Situ Meter Prover using a Master Meter. An In-Situ Meter Prover is the Master Meter and its associated piping that can be either taken to the site of the meter in the field or is installed permanently on the meter skid.

Volume provers which are relatively new, are primary devices and very accurate. They are however very expensive and work best at higher line pressures and lower volumetric flow rates.

Bell provers, which are also accurate, work only at low pressures and cannot be used for large flow volumes. They can be used to calibrate a Master Meter, which can then be used to prove other devices at higher pressures and higher flows. Bell Provers are relatively expensive to build and maintain.

The sonic nozzle although it is precise and considered a primary standard, (+/- 0.25% total measurement uncertainty) can only check a field meter at one flow rate and line pressure. The sonic nozzle also causes a permanent pressure drop in the system.

Transfer Proving Systems

A Transfer Prover is a proving system that checks the field meter against the Master Meter at Atmospheric Pressure. The Master Meter, and its associated piping, is placed in series with the field meter and an adjustable flow rate blower draws air through the two meters.

Air at atmospheric pressure and at various flow rates is then pulled through the two meters and a comparison is made between the Master Meter and the Field Meter.

Figure 2 Transfer Prover

A Transfer Prover System can be used to calibrate field meters brought into a shop or the Transfer Master Meter Prover can be portable and taken to the field. The atmospheric Transfer Prover is best suited for checking meters operating at lower pressures. The disadvantage to Transfer Provers is that many Flow Meters exhibit line pressure sensitivity that can introduce a measurement bias if they are calibrated at a test pressure significantly different than their field operating pressure. Advances in Ultrasonic Flow Meters with up to eight paths and the ability to measure accurately at atmospheric pressure now allow some to be used as Master Meters.

The higher pressure In-Situ Master Meter Prover is a Master Meter usually placed immediately downstream and in series with the operating Field Meter. It is connected on site and is used for proving at actual operating conditions of flow, temperature, pressure and density. The Master Meter is either mounted permanently on the metering equipment skid or is portable and connected to an existing three-valve manifold when needed.

A Portable High Pressure Proving System consists of a number of different sized Master Meters in parallel meter runs with provisions for installing a field meter for test downstream of the master meter.

A sonic nozzle can be placed downstream of each of the two meters in series to limit the flow and to verify the accuracy of the Master Meter. Since the Sonic Nozzle is a precision mass measurement device, it works very well to determine the mass flow at a pressure and temperature. It can be used as a check for any variable flow Master Meter.

Since proving with a Master Meter is currently one of the least expensive ways to calibrate an existing field meter we will discuss the various Master Meter systems.

It is noted that AGA Report No. 6 on Transfer Meter Proving using Master Meters is published.

Provisions needed on the Field Meter Station to Connect the Master Meter

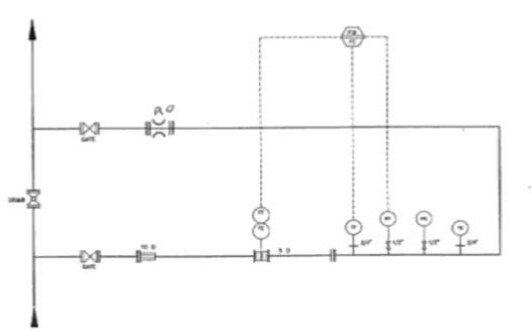

Figure 3 Field Prove System

There are two ways to install a Master Meter on an existing Field Meter skid. One way is to use a three-valve manifold downstream of the existing meter run shown in the P&ID above. Downstream of the field meter is the preferred location because the flow profile into the Field Meter is not disturbed.

A Flow Conditioner should be installed upstream of the Master Meter in the Master Meter prerun piping to eliminate any problems in the flow profile caused by the elbows and valves going into the Master Meter Run. If a three-valve manifold is used the inline valve must be a Block and Bleed type valve to insure all the flow is going through the Master Meter Run. As a cost saving, extra valves are not needed going into and out of the Master Meter Run. Blind Flanges can be used to cover the connections. However closing in the Field Meter and bleeding down the pressure to install a Master Meter without the valves is time consuming and costly.

The second method is to install a Master Meter in series with the Field Meter on the existing Field Meter Skid. With this arrangement it is necessary to provide space downstream of the Field Meter for an additional Master Meter run. The advantage of this system is that no additional valves are required. The disadvantage is the Field Meter run has to be closed in and bled down to install the Master Meter.

Some Meter Systems are designed in such a way that the Master Meter is permanently installed on the Meter Skid.

The Master Meter can then be used as the spare meter to be put on line if there are problems with the normal operating meters or if the flow rate exceeds the limits of flow through the installed meters.

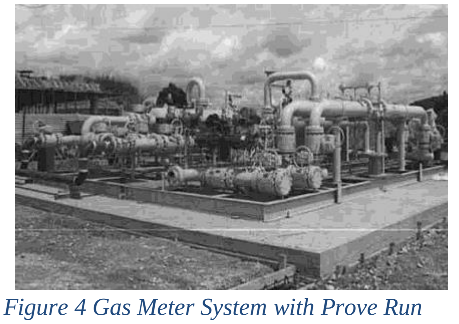

Figure 4 Gas Meter System with Prove Run

<u>Equipment required for Onsite Proving of Natural Gas</u>

Master Meter

Figure 5 Ultrasonic Meter

The meter proving device used to check the field meter should have an accuracy that is at least several times the accuracy of the meter it is checking. Repeatability, the ability of a meter to give the same answer every time, is critical. Some Ultrasonic Flow Meters are well suited for this as well as Sonic Nozzles both with no moving parts are repeatable and accurate.

Flow Computers can take advantage of the repeatability of the Ultrasonic Meters by using linearization to improve the precision of the meter.

Flow Computer

The engineering calculations performed in the Flow Computer should follow the procedures described in the existing AGA and API specifications.

The report from the Flow Computer must be presented in such a way that the calculations from raw information to final compensated volumes can be verified using hand calculations if necessary.

Using modern Flow Computers, the typical meter calibration curve of a precision master meter can be linearized. During the meter proof, the stated volume of both the calibrated Master Meter and the field meter being proved can be measured precisely during the prove cycle by using Pulse Interpolation as described in the API Manual of Petroleum Measurement Standards, Chapter 4, Section 6, Pulse Interpolation.

Pressure and Temperature Transmitters

The gas pressure, temperature and differential pressure on DP meters, must be precisely measured at the Master Meter and at the meter being proved. Because of the small pressure drop between the Master Meter and the meter being proved the pressure can best be measured with another differential pressure transmitter. By using a Multi-variable Transmitter between the meters, any pressure or calibration error of using two transmitters is eliminated. The lower the line pressure the more difficult it is to determine the difference in line pressure between the two flow meters.

With atmospheric Transfer Meter Prover systems, a differential pressure transmitter can be used to determine the gage pressure at the first meter.

The high-pressure port of the Differential Pressure Transmitter is left open to atmosphere and the low-pressure port is connected to the pressure port of the meter. Atmospheric pressure can also be a manual entry based on weather bureau data or a precise atmospheric pressure transmitter can be used.

The gas temperature must be measured at a point in the line at least three pipe diameters downstream of each meter. There will normally be a slight difference in the gas temperature between the two meters. This difference will be due, in part, to the pressure drop between the meters. Since this pressure drop is very small, typically only a small change in gas temperature will occur. Extremely precise and well calibrated temperature sensors and transmitters must be used to measure this precise differential.

Maximum Gas Velocity

Care must be taken not to exceed the safe maximum velocity of the gas through the proving systems and the field measurement system. Exceeding the maximum velocity will cause erosion and wear of the piping and the components resulting in an unsafe system.

The weight of 0.6 Sp.Gr. Gas at 1,440 psi is approximately 5.727 lbs./cu.ft. The max velocity recommended by API RP 14E is 78 ft/sec.

Excess velocity will cause pipe wear especially at elbows and bends.

Piping per AGA

Piping for both the master meter and field meter preruns and post runs should be configured per the specifications that apply. Usually the axial lengths of the post-run of the first meter and the pre-run of the second meter (in series) can be combined making the minimum axial length separating the two meters a total of the required pipe diameters. If any piping manifolds, elbows or bends are located upstream of either the Master Meter or the field test meter, as is the case when connecting to a three-valve manifold, a high performance flow conditioner should be installed upstream of the meter in accordance with the flow conditioner manufacturers recommendations.

In-Situ Proving with a Master Meter placed in series with the field meter

The performance of the Master Meter and the Field Meter should be compared on a mass flow rate basis. For most turbine flow meters, the measured flow rate is expressed in terms of volumetric flow rate. The line pressure (and, probably, the gas temperature) will be slightly different at the two meter locations, so the actual volumetric flow rates measured by the two meters will not be equal. As an alternative to comparing the field turbine meter and the prover on a mass flow rate basis, the volumetric flow rates recorded by the two meters can be adjusted to ‘standard’ conditions and then compared. Standard volumetric flow rate is essentially a mass flow rate that has been referenced to arbitrary temperature and pressure conditions (e.g., a predetermined pressure and temperature, such as 14.73 psia and 68ºF, respectively) for the flowing gas composition. Standard volumetric flow rate is proportional to mass flow rate through the application of standard gas density and is, therefore, conserved from the upstream to the downstream meter locations.

A calibrated Master Meter run of sufficient size and pressure rating is connected to a three-valve manifold located upstream or downstream of the meter to be tested. Tests have shown that some of the commonly-used turbine meters are relatively insensitive to upstream piping effects. However since piping and field conditions may vary it would be good practice to follow the standard piping configurations shown in AGA Report No. 7 for any turbine meter run.

The use of a flow conditioner upstream of the Meter Run is recommended if there is the possibility the Master Meter piping might have an adverse effect on the Master Meter.
The Master Meter run must be complete with a Flow Computer, pressure and temperature transmitter and differential pressure (DP) transmitter.

When needed the pressure, temperature and differential pressure are available from one multivariable device. It is possible for some resolution to be lost by the method used to connect transmitters to the flow computer. Devices are available to convert the digital signal from transmitters directly to Flow Computers.

The Master Meter, its associated piping, and electronics must be calibrated as an assembly. Test at various pressures can be done and correction factors established for any shift in performance.

The field meter to be tested and the pressure, temperature, and DP transmitters associated with it are connected to the proving Flow Computer in such a way that the existing measurement is not affected.
Normally the signals from the meter come from a parallel connection and the analog signals from the pressure and temperature transmitters are connected in series. A device that can measure the gas density, either a Gas Chromatograph or a Correlative device also needed to determine the mass flow. With a Gas Chromatograph the density of the gas is determined by its composition. A Correlative device uses other means such as speed of sound, thermal conductivity etc. to determine the gas density.

High Pressure Proving with Inline Meters

High Pressure proving at various flow rates and pressures can be accomplished with a High Pressure Master Meter Proving system. This system is located where there is sufficient pressure and flow to check all the meters in the system individually. For example the best location for High Pressure Proving in a distribution system is where gas enters the distribution pipeline. The system here can serve two functions. It can measure the gas being purchased and it can be used to prove all the high pressure meters used downstream in the distribution system.
Routing the flow through the other meters in the system can vary the flow rates through the meter being tested.

The pressure in a High Pressure Proving System can be varied as long as the Master Meter System has been proved at that pressure and it does not affect the downstream system.

Connecting a Portable Master Meter Run to the Field Meter Skid

1. Connect the Master Meter Run to the three valve manifold using either new gaskets or gaskets that are suitable for multiple uses.
2. Connect the electrical cables from the Master Meter, Pressure Transmitter and Temperature Transmitter to either the existing Flow Computer or Connect the Field Meter, Field Pressure Transmitter, and Temperature Transmitter signals to the Flow Computer on the Master Meter Run.

3. Slowly fill the Master Meter Run with gas by opening a small valve usually a needle valve or small ball valve that connects the line pressure piping to the Master Meter. As a rule of thumb pressurization of the line should not exceed one PSI per Second. It is also a good practice to check for leaks with an approved leak detection method while the Master Meter Run is filling. Checking at a low pressure first before the line is completely filled and checked at line pressure can save time and gas if a leak is detected.

4. Open the upstream valve connected to the Master Meter Run.

5. Slowly open the downstream valve that connects the Master Meter Run to the Field Meter Run.

6. Slowly close the Block and Bleed valve downstream of the Field Meter on the three valve manifold putting the Field Meter and Master Meter in series with one another.

7. Follow the Master Meter Proving Procedures usually supplied by the Company for Proving a Master Meter.

8. When the Proving has been completed open the Block and Bleed Valve downstream of the Field Meter.

9. Close the valves connecting the Master Meter Run to the Field Meter and slowly bleed down the pressure on the Master Meter Run. One PSI drop per second is always a safe pressure drop rate.

10. Disconnect the Master Meter Run from the Field Prover Skid.

<u>Onsite Master Meter Proving Procedures</u>

1. After the Master Meter has been properly installed on the three-valve manifold, the system must be checked for leaks.
2. The precision of the Master Meter should be verified before each prove.

3. The manufacturer of the Master Meter will have a procedure on how to verify the meter is still in calibration. When the Master Meter condition is verified its condition should be recorded on the prove report.

4. Enter the tracking information from the Master Meter or select a Master Meter whose information has already been entered into an existing database.

5. Enter all the information for the Field Meter to be proved or enter the serial number for the information to be entered automatically if it already exists in a database.

6. Prove runs are normally done at 10%, 25%, 50%, 75% and 95% of the maximum rated flow rate of the meter to be proved. These are recommendations only. The test flow rates requested by the end user should be used wherever possible. If the required flow rates cannot be obtained the Field Meter must be proved at the available test flow rates.

Proves can be done based on time or on volume. Either method if performed properly, can produce a good prove. In this example we will use proof runs based on time.

7. Set the time and number of proves for the prove runs. The number of pulses generated by the meters will determine the time for each flow run. The time must be long enough for a statistically significant number of pulses to be generated by the lowest frequency output. If the Flow Computer is capable of Pulse Interpolation the time of each run can be shortened in accordance with the API Manual of Petroleum Measurement Standards Chapter 4, Section 6, Pulse Interpolation.

8. The number of proofs at a specific flow rate depend on the client. However, it is recommended that a minimum of three runs be made at each test flow rate to determine if the meter being proved is repeatable.

9. Start the prove. The Flow Computer will automatically stop and start each run, based on the time entered into the Flow Computer. On the first run allow time for stabilization of the flow rate through the meters before beginning the data acquisition.

10. When the prove runs for the specified time and the run is successful, the information is saved in the Flow Computer and/or can be printed out. If the flow rate of the station can be changed, it is recommended that the first test run be performed at maximum flow rate setting. If the meter repeats and is within specifications at the maximum flow it is an indication that it may prove at the lower flows. Proves at all flow rates and operating pressures specified must be done to insure the field meter is operating properly.

11. At any time during a prove run or cycle, the prove can be stopped (Aborted). Aborting the prove stops the proving run. An aborted prove report should be stored or printed.

12. When the prove for all flow rates is complete, the flow control valve closes to the meter run closes, the prove report is printed, and all information is saved electronically in a file for that prove.

Conclusion

Using available knowledge, products and equipment natural gas meter proving in the field and in the shop can be used to verify the accuracy and repeatability of natural gas measurement systems.

References

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