

THE ROLE OF THE WITNESS DURING NGL PROVING

Charles Woods
VP Special Projects
SPL Labs
1616 2nd Ave
Greeley, CO 80631

Introduction

This paper discusses the act of meter proving and the role that a witness to this act should play to ensure sound liquid measurement. The primary focus of this paper is on liquid proving in the gas processing space which includes both refined and unrefined products such as propane, butane, natural gas liquids “NGL”, Condensate, and Y-Grade among others. The discussion will primarily focus on mass and density meter proving while briefly mentioning volumetric meter proving as the three are related.

This paper will cover the topic of why meter proving is essential as a quantity measurement test and as an accounting assurance. In doing so, the topic of overall liquid measurement account will be covered briefly. As such, the basics of proving systems, what is a meter prover, and how is it used in the act of proving a meter, and how to interpret the result (a proving report) will also be covered.

Naturally in discussing inferred mass proving, some attention will be given to the contrast between traditional volumetric meter proving and mass/density meter proving. This topic will end with a brief discussion of why inferred mass proving occupies a prominent space within the realm of natural gas liquids (NGL) measurement and the gas processing space in general.

Accounting and settlement of liquid quantities are paramount to any company’s bottom line. This is true in all stages from operation and production, to transportation, to refining and delivery. At each stage of this process, there is a transfer of custody of the liquid product that must be settled and transparency within this transaction is critical. This is where the role of the witness is important. While the process and details of meter proving are often left to the prover operator, the witness must be knowledgeable about the overall process and what details might ultimately affect the outcome of the settlement. The aim of this paper is to inform an individual that may be tasked with witnessing meter proving operations about the basic, pertinent information needed to provide accountability to the process of meter proving and act as an advocate for good measurement on behalf of the entity they represent.

Liquid Measurement Accounting

Liquid measurement is comprised of a measure of the quality of a liquid product and the quantity of that same product. The quality component of liquid measurement accounts for things such as impurities in the product (i.e., sediment, water, methanol, etc.), the specifications of the product, and the sometimes the composition of the product. The quantity component accounts for things that are directly related to arriving at a standardized volume of liquid quantity. While quality measurements typically appear as contractual obligations (such as specifications) or simple volume subtractions (such as

water), quantity measurements are driven by physical parameters such as volumetric flow, temperature, and pressure. For sake of brevity, this paper will primarily focus on liquid quantity measurement.

Liquid quantity measurement is a two-part process: 1) the measurement and averaging of physical properties and 2) the correction of these physical properties to a standardized state. Within these corrections are also corrections for accuracy of the physical parameters such as volume. It is this correction for accuracy, specifically of the liquid volume quantity, where meter proving plays a role. Both steps in this process work together to arrive at a standardized net volume of liquid product delivered.

$$NSV = IV_m \cdot MF_{v o l} \cdot CTL \cdot CPL - V_{B S W}$$

In the above equation, an indicated quantity is recorded from a flow meter (Indicated Volume “IV” is shown but could be substituted with Indicated Mass “IM” by removing the temperature and pressure corrections). This indicated quantity is then corrected based on the potential inaccuracies of the flow meter through use of a Meter Factor “MF”. In the case of volume quantity, the value is also corrected to a standardized set of conditions of temperature and pressure through two correction factors, Correction for the Temperature of the Liquid “CTL” and Correction for the Pressure of the Liquid “CPL”. Finally impurities are subtracted (“V_{BSW}”) from the corrected quantity to arrive at a net quantity of merchantable product (shown as Net Standard Volume “NSV” but could be substituted with Net Standard Mass “NSM”).

Meter Proving

Meter proving is a statistical test of a flow meter or densitometer that aims to compare the indicated quantity of the meter to a known standard. In the case of liquid volume measurement, this comparison is done against a meter prover, a device that displaces a fixed volume of high accuracy and precision. In the case of liquid density measurement, this comparison is done against a pycnometer of an accurate and precise known mass and known volume. By comparing these known quantities against the unknown quantity of a meter, meter proving gives a multiplicative adjustment factor that, when applied to the meter, corrects for any inaccuracies that may be present in the meter due to wear, damage, coating, installation effects, configurational issues, etc. This adjustment factor is commonly known as the meter factor “MF”.

$$MF_{v o l} = \frac{\text{Volume of Known Standard (Prover)}}{\text{Standardized Volume from the Meter}}$$

$$DMF = \frac{\frac{\text{Mass of Known Fluid in Pyc}}{\text{Volume of Known Standard (Pyc)}}}{\text{Unknown Density from the Densitometer}}$$

In the case of liquid mass measurement, it is very difficult to arrive at a direct mass measurement comparison under flowing conditions. As such, meter proving in mass is done by inference. Inferred mass proving takes the values of a known volume and a known density simultaneously to calculate a known, inferred mass quantity by utilizing a volumetric prover and a densitometer that has been proven with a pycnometer. Thus, an inferred mass meter factor has elements of both a volumetric meter factor and a density meter factor.

$$MF_{mass}$$

$$= \frac{\text{Volume of Prover} \times \text{Unknown Density from Prover Densitometer} \times DMF_{prover}}{\text{Unknown Mass from the Meter}}$$

In the gas processing sector, especially when NGL is the product, mass measurement is preferred over volumetric measurement when attempting to balance inlets and outlets to a system. There are a few reasons for this. 1) Some commodities are sold or transferred in BTU content and not in volumetrics terms, and as such a mass quantity of this product is needed to determine the heat value. 2) Calculating excess volume properties is difficult when the composition of the product might be changing or when the product is being mixed with other product streams. This uncertainty of excess volume often leads to imbalances in volume. 3) Most volumetric correction factors are generalized, not by composition, but by specific gravity. This generalization leads to much uncertainty in the final determination of a standardized volume which would be needed for a material balance.

By working with mass balances, much of the complexities that arise from trying to balance liquid volume disappear making mass liquid measurement the oft preferred strategy in this space. As a result, mass measurement (direct or inferred) and inferred mass meter proving have an outsized role to play.

Proving Systems and Equipment

Meter provers come in many types and sizes. While it's not the focus of this paper to exhaustively discuss all the different types, suffice it to say that meter provers are precisely calibrated volumetric measurement devices that are designed to capture and measure flowing liquid volume without the cessation of flow. These devices are most often traceable to a physical standard through organizations such as NIST or ISO and are a known standard by which to calibrate other devices.

In the gas processing space, the types of provers most often used are displacement provers. Displacement provers operate by allowing the flow coming from a meter stream to move a displacer (such as a spherical pipeline pig or a piston) along a path between two gate switches. The amount of volume that the displacer displaces while moving between these switches is the calibrated volume of the prover. When the meter prover is placed in series with the meter, the liquid mass or volume registered by the meter must also be displaced and measured in the prover.

The meter prover receives a frequency signal generated from the meter that is translated from either volume or mass measured by the meter. This frequency is generated through a conversion in

terms of pulse per unit (i.e., barrels or pounds of product). The meter prover then captures this signal through a counter, beginning when the prover displacer contacts a “start” switch and ending when the prover contacts a “stop” switch. Then by using this pulse per unit conversion factor, the meter prover has a measure of the quantity of product that was registered by the meter at the exact same time that the known prover volume was displaced. This is the basis for the meter factor calculation.

Meter provers by design can only accurately represent a displaced volume. For inferred mass meter proving however, an accurate measurement of the density of the product being displaced in the prover must also be made. For this reason, proving systems designed for inferred mass measurement also require a densitometer that measures a slip stream of fluid being displaced in the prover. If the density of the product displaced is both stable and representative, then the density of the product can be multiplied by the displaced volume in the prover to arrive at a displaced mass within the prover.

Densitometers, however, suffer from many of the same maladies that other operational meters do such as installation effects, wear and tear, changing operating conditions, etc. As such, a meter prover densitometer must first be proved against a pycnometer before being used for inferred mass meter proving purposes. A meter proving pycnometer is a spherical stainless steel pressure vessel equipped with an inlet and outlet with valves on each. Pycnometers are designed to capture a pressurized fluid for comparison against a densitometer’s measurement of density. Like meter provers, pycnometers have a precisely calibrated volume that predictably changes with temperature and pressure. Unlike meter provers, pycnometers also have a precisely calibrated evacuated weight which is translatable to mass.

As order of operation, a meter prover and densitometer are connected in series with a meter of interest through a temporary connection known as a proving loop. Once flow is established through these devices, a pycnometer is connected to the prover densitometer through a slip stream referred to as a pyc loop. Once flow is also established and stabilized through the pyc loop, a statistical test is conducted where simultaneous snapshots of fluid density from the densitometer are compared to captured and measured samples of the fluid density through within the pycnometer. At the conclusion of this test, a density meter factor for the prover densitometer is determined and applied for the remainder of the mass meter proving.

Secondly, a statistical test is conducted where simultaneous snapshots are collected of the mass registered by the meter, the volume displaced by the meter prover, and the density measured by the prover densitometer. The average of these snapshots is taken, and the precision of the snapshots is compared for precision. The resulting average of these snapshots is used to calculate a mass meter factor which can then be applied to the mass meter to correct for inaccuracies.

The Role of a Witness During the Meter Proving Process

The determination of a meter factor through proving is an indication of the accuracy of a meter and ultimately a calibration or verification of the cash register of a given custody transfer transaction. Naturally this garners some attention from both parties involved, seller and buyer. For this reason, very often meter proving is done by a third-party service company or is conducted by a meter proving technician, the idea here being that there is an unbiased arbiter in this transaction. Even so, it is often a

contractual stipulation that this proving happens in a transparent way in which both parties are allowed to witness the process for any issues or inconsistencies.

This places a very important burden on the witness of this statistical test. A witness must be knowledgeable of the proving process and have a basic understanding of what may affect the outcome of this process. A witness must have a basic to detailed understanding of 1) general prover operation, 2) general LACT or meter operation, and 3) general accounting processes.

A witness needs to understand in general how the type of prover being used works, the fundamental principles by which it measures, and how the prover interplays with the LACT. These principles will answer questions as to why certain equipment may perform better than others in certain situations. Some examples include of these principles include 1) why sphere provers tend to repeat better on truck LACTs, 2) why piston provers are preferred for NGL and high vapor pressure liquid provings, 3) why density stability in the product is so important during pyc proving, and 4) why piston provers tend to perform better at low flow rates. These questions and more come from an understanding of the proving equipment and the statistical test it is seeking to perform.

A witness must also understand how a LACT/meter operates. Very often, the success of a given proving test relies not just on the prover or the meter, but on the entire system supporting the meter. While a meter proving attempts to test a meter at “normal operating conditions”, there is nothing normal about a prover being connected to a meter. The prover changes pressure drop calculations which in turn can change pump operations. The cycling of the displacer can alter the function of PID control loops which may sometimes have to be disabled. All these differences must be considered to provide the most stable operation possible in terms of flow rate, temperature, pressure, and density to allow the best opportunity for a successful test.

Finally, a witness must understand the basics of liquid mass or volume accounting to understand what impact the test is having on the end measurement. A reliable meter proving test can answer such questions as 1) is the meter over or under registering and by how much, 2) is the inaccuracy of my temperature averaging device causing inaccuracies in my volume measurement and by how much, and 3) are pressure effects on the meter causing inaccuracies in mass, density, or both? The answers to these questions require a basic understanding of general measurement accounting.

Conclusion

The role of a witness during meter proving is an important one and requires an active participant. Meter proving, in the best of situations, is a routine task that simply provides an adjustment to be made to the general accounting. However, the true value of meter proving doesn't lie in what goes right, it often lies in what goes wrong. Meter proving can be thought of as insurance in this way, primarily paying off in the worst-case scenarios instead of the best.

For this reason, a witness must be diligent and open to the idea that the proving may encounter issues. It is important to work through these issues with the prover technician and arrive at a satisfactory solution. Only in the achievement of a reliable test and a reliable meter can good measurement be obtained.