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Validation of Custody Transfer Metering Skid at Site After Laboratory Proving

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ABSTRACT.

Proving is a comparison of indicated volume of a custody transfer flow meter to calibrated prover volume. Meter factor of flow meter is determined after a series of calculations and corrections for temperature, pressure, and density.

The use of volumetric proving tank is not practical for proving large size flow meters used for custody transfer applications at site. Also there is a need to prove the custody transfer flow meters at normal operating conditions while metering is in progress.

The compact prover provides good accuracy and fast operation for proving of liquid flow meters in an operational line. Because of its compact size and piston design, which includes an internal poppet valve, the compact prover can be easily installed in most of the operation lines.

This paper describes about the determination of prover base volume (at FCRI), calibration of custody transfer flow meter against the prover at laboratory and at site conditions. The results of both proving are compared and discussed.

The base volume of the prover was determined at FCRI by water draw method as recommended in API. The density meter of prover skid was proved against a pycnometer. The base volume was certified at 101.325 kPa (absolute) and 15 deg.C reference temperature.

After the base volume determination of small volume prover, custody transfer mass flow meter was calibrated against the small volume prover and a pre calibrated density meter. The metering skid was transferred to site and the mass flow meter was proved at the operating conditions in methane propane (C2/C3) medium against the small volume prover.

Proving of small volume prover skid, flow meters and density calibration at site is a challenging as the temperature and pressure conditions may not be very stable. Ultimately all measurements are used to make fair decisions and poor quality measurement result in deprived quality decisions. By laboratory calibration we can ensure the reliability in proving with least uncertainty and the results obtained at site can be compared and validated against the laboratory results.

KEYWORDS:

Small volume prover, proving, pycnometer, water draw, field verification.

INTRODUCTION

Custody transfer flow measurement is to determine the quantity of a given fluid delivered so that ownership may be transferred. An essential element of a good business practice is the sense of confidence exhibited by both buyer and seller, when each believes that the price is right and the quality and quantity of goods exchanged are acceptable to both parties.

With the developments in modern electronics, "compact provers" are common in market, which needs much less space as compared to conventional provers. Instead of mechanical detector switches, small volume prover utilises optical techniques for measuring displacement of piston.

The flow passes through the meter pushes the displacer along a calibrated length of pipe. The displacers may be a piston that seals positively against the inside wall of the pipe so that no fluid leaks past the piston. As the displacer enters the calibrated length, its proximity is sensed by a detector and admits the flow meter pulses to an electronic counter and starts counting. As it leaves the calibrated length, a second detector sends a signal which stops counting. After correction for pressure and temperature effects, the precisely known volume of the prover is compared with the number of meter pulses counted, providing an accurate method for proving the flow meter.

In prover operation, standard density, i.e. density at standard conditions of pressure and temperature is required. A compact prover with a pre calibrated density meter was used for proving of custody transfer mass flow meters.

A small volume prover must be proved before being placed into service in order to determine its base volume (the calibrated volume corrected to standard conditions). In this case the base volume was determined at FCRI as per Manual of Petroleum Measurement Standards Chapter 4 - Proving systems, by water draw method. The mass flow meter was then assembled in series with the prover and proved against the prover and density meter.

After proving the mass flow meter, the whole unit was transferred to the site and reproved in the operating fluid at site conditions. The results are compared and presented in this paper.

CLASSIFICATION OF PROVERS

Pipe provers can be classified as conventional pipe provers and compact pipe provers. The conventional pipe provers are of large size due to the use of electro mechanical detectors. The positioning accuracy being ±1mm the calibrated length of conventional prover will be of the order 10 meters to 20 meters, to reduce the error to ± 0.01%. This was also to reduce the rounding off error of ± 1 pulse by employing large calibrated volume.

As the name implies the compact prover is used where saving of space is required. The length of calibrated portion is smaller than that of conventional pipe prover for same duty. Compact prover employs electronic detectors with greater accuracy than the electro mechanical detectors employed in conventional prover. Compact prover employs new methods of pulse interpolation so that rounding off error can be reduced with smaller number of pulses. This enables the calibrated volume to be reduced by a factor of ten.

PARAMETERS TO BE MONITORED

While proving, apart from the number of pulses and volume of the prover, pressure, temperature and density are to be monitored. Pressure is normally measured at inlet and outlet of the prover and near the meter to be proved. The accuracy of pressure measurement should be within ± 0.05% of full scale.

Temperatures have considerable effect on oil volume and accurate methods are therefore necessary. Temperature will also to be measured at three points mentioned for pressure. Pre calibrated thermometers are used for the calibration at the laboratory. Grade 1 platinum RTDs with an accuracy of ± 0.2% is acceptable for temperature measurement. RTDs are to be site in thermo wells of good design.

PROVING OF MASS FLOW METER

The purpose of proving a meter is to determine its meter factor, a number obtained by dividing the actual mass of liquid passed through a meter during proving by the mass registered by the flow meter. The purpose of a meter factor is to correct a meter's indicated mass as it pertains to a particular flow rate.

The calibrated base volume of the prover will be used to calculate the meter factor of the mass flow meter at the required flow rates. The meter to be calibrated was assembled in series with the prover and the liquid passing through the prover will be allowed to pass through the mass flow meter. The pulse output from the meter will be started/stopped by the signal from the optical switches of the prover. Density meter was calibrated against the pycnometer.

Flow is maintained through the flow meter and prover section until stable conditions of temperature are reached. Vent connections was checked to ensure that the meter and the prover sections are completely purged and that no air pockets in the system.

The essential step of proving consists of operating a valve or combination of valves that causes the metered stream to move the displacer through the calibrated section of the prover. Upon completion of each proving run, the data are recorded, the initial counter reading is again determined or reset to zero and additional proving runs are made as required.

In this case, ten passes are averaged into a 'proving run', consecutive five of these 'proving runs' are then compared for the repeatability requirement and, if ok, these 'proving runs' are then averaged to obtain a meter factor.

The mass flow meter was also proved against the gravimetric system of the laboratory.

WATER DRAW CALIBRATION

As per the standard API MPMS Chapter 4.3 – Proving systems, the calibration of small volume provers by the water draw method was conducted by placing the prover, field standards and test liquids in a stable temperature conditions. In the laboratory total environment is shaded from direct sunshine to allow the equipment and liquid to reach an equilibrium temperature. Test set-up for water draw calibration at FCRI is shown in fig 1 and fig 2.

The reservoir capacity of the laboratory is 320000 litres by volume and located underground. It was quite easy to achieve the temperature stability during proving at the laboratory conditions.

Water draw was conducted in the night. To achieve temperature stability, continuously water was pumped through the prover, field standard and associated pipe lines for a sufficiently long period. The displacers was moved through the small volume prover enough times to flush the prover and eliminate air that may have been caught in parts of the small volume prover system and to allow both the metal and liquid of the prover system to reach a common and steady temperature .

In addition to stabilizing the prover, it is necessary to verify that the valves, seals and displacer are secure and that there is no leakage from in or around the prover. This was achieved by conducting a leak test. Test measure was a 60 litre reference volume tank designed as per API MPMS chapter 4.7. High sensitivity test standards with a resolution 0.02 percent or better is recommended for calibrating small volume provers. Here a single field standard was used during a water draw calibration of small volume prover to reduce the uncertainty.

The prover was calibrated using small diameter water lines and temporary valves, automated fast responding valves actuated by the detector switches , commonly called solenoid valves, was used. Provisions were made to ensure that no water bypasses the field standard.

A visual inspection of field standard was made before use to ascertain that the capacity has not been altered by dents or corrosion. The test measure proving certificate, its validity and traceability to the national standard were verified. The drain valve of the seraphin test measure were checked for any leaks.

Failure to repeat may be due to the air in the system, leaking valves, seals or varying pressure. It is recognized that repeatability is only one component of accuracy and that with the test runs made at an equal rate can complete an erroneous calibration because of a consistent leak. This problem can be eliminated by making a second run at a different rate (typically 25% varied from the first run) after the initial runs have been made. With a changed flow rate, a different volume (after correction) that exceeds by 0.02 percent the average of the two initial runs (after correction) indicates the possibility of a leak in the prover which must be corrected before the calibration.

- **Prover volume calculation at base condition 15°C and 0 kPa**

V_{TP} - Net volume corrected for 15 deg.C and 0 kPa pressure

$= V_M * T_{MP} * C_{SS} * C_{PL} * C_{PS}$

T_{MP} - Temperature differential factor for water from API ch. 11.2.3M

C_{SS} - Correction factor for stainless steel measuring can, 17-4PH Stainless steel, Invar Rod

C_{PL} - Compressibility reduction factor for water

C_{PS} - Pressure correction factor for stainless steel prover

V_{tm} - Corrected prover volume at 15 deg.C , 0 kPa

Css =

$$\frac{\{1+(Tm-15)\times 0.0000477\}}{\{1+(Tp-15)\times 0.0000216\}\times\{1+(Td-15)\times 0.00000144\}}$$

T_m is the measure temperature in deg.C

T_p is the prover temperature deg.C

T_d is the Invar Rod temperature deg.C

C_{pl}= $\{1-(0.000000464\times P)\}$

P is the Prover pressure in kPa

C_{ps}= $\dfrac{1}{1+\dfrac{(P\times D)}{(E\times t)}}$

P is the prover pressure in kPa

D is the Diameter of the prover in mm

E is the modulus of elasticity of the prover in kPa

t is the thickness of the prover in mm

RESULTS AND DISCUSSIONS

The term's repeatability and linearity are commonly used to define meter accuracy. Repeatability is the variation in the meter's performance under constant operating conditions, i.e. constant flow rate, temperature, density, etc. where-as linearity is the variation in the meter's performance over a range of flow, commonly referred to as turndown ratio.

Sl. No	**Q** tph	**MF** site	**MF at lab**	
			prover	gravimetric
1	90.0	0.998544	0.999931	1.000113
2	125.0	0.997783	0.999445	0.999695
3	170.0	0.997368	0.999514	0.999969

Table 1. Meter factor at site and at lab.

During field proving, a variation in meter factor with laboratory proving was observed in the order of 0.2%.The repeatability obtained at laboratory calibration and field proving was within 0.05%. However the linearity obtained were 0.025% and 0.06% respectively for lab proving and field proving.

To ascertain the calibration results at laboratory, mass flow meters were calibrated against the primary gravimetric method. The meter factor determined by prover and gravimetric method is agreeing within 0.05%, ie within the uncertainty of mass flow meter. The characteristic curve of prover is given in fig 3.

CONCLUSION

A custody transfer flow measurement system consists of different components which interact to provide the measurement data. The quality of those individual components, their installation and calibration has a direct bearing on the accuracy of measurement. In the present scenario with more automation, sophisticated electronics and instrumentation; there is a substantial requirement of increase in quality of measurement. Like any other flow meter, operating conditions may affect a mass flow meter's accuracy and repeatability. Conditions that might affect the in-situ meter proving are

a. Mechanical stress on the meter.
b. Flow variations.
c. Piping configurations.
d. Fluid pressure and extreme temperatures
e. Ambient temperature changes.
f. Fluid type and composition.

At laboratory, proving is conducted under ideal conditions without any stress on the meter. The fluid is water and is very stable due to large capacity and under shade. Dedicated constant head tanks, VFD driven pumps are used to obtain a steady flow rate through the prover and flow meters. This minimizes the effects of outside influences on the meter's accuracy and repeatability.

Any issues with performance of the prover or flow meter can be easily identified and tracked during laboratory proving. Accredited calibration laboratories have more control on data and processing with least uncertainty.

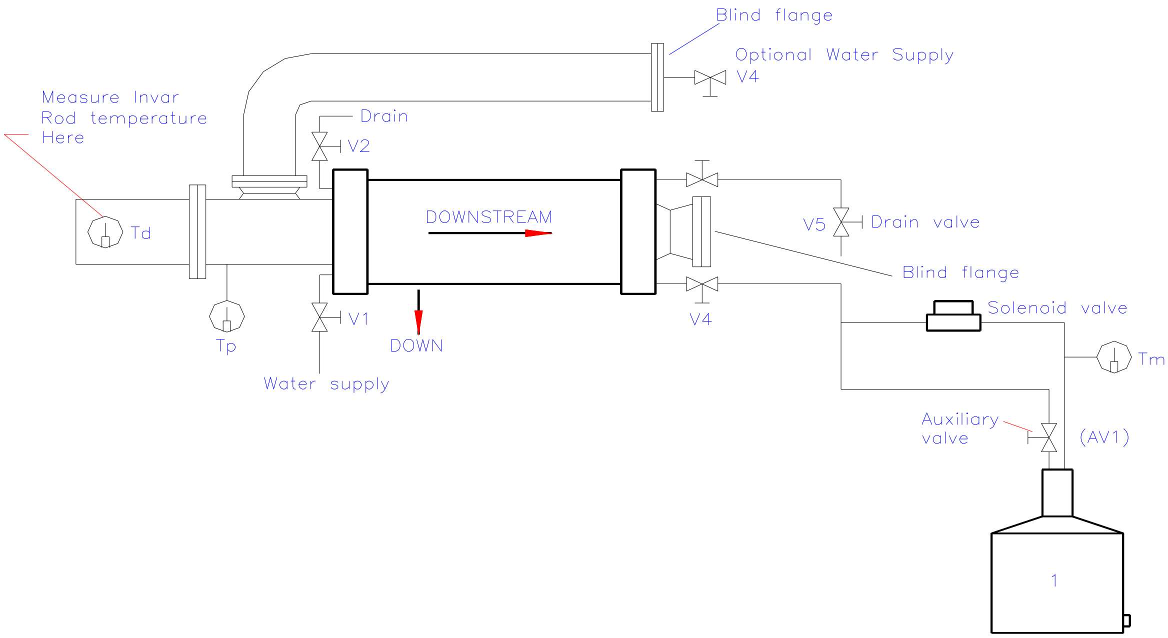

Fig.1 Test setup for water draw calibration

Fig 2. Laboratory proving at FCRI.

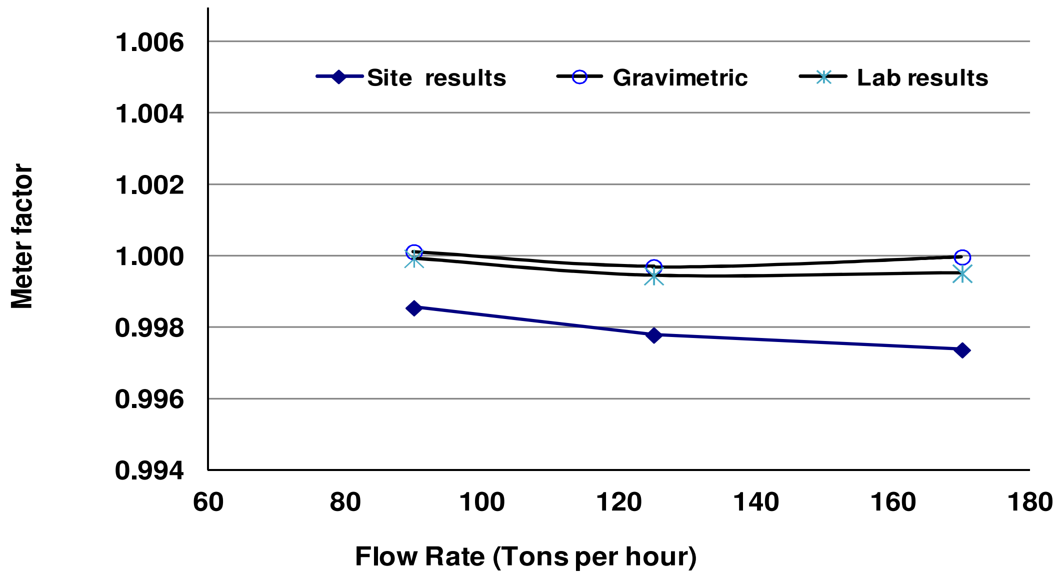

Fig. 3 Validation results at site and lab.

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