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Application of Density Meters to Liquid Hydrocarbon Measurement

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1 Introduction

The American Petroleum Institute (API) Manual of Petroleum Measurement Standards (MPMS) Chapter 9 Section 4 provides guidance for online density meter selection/operation, sampling system design and field proving methods. Continuous density measurement may be accomplished with a device located in the main flowing stream or in a slipstream. Density measurement is utilized in both volumetric and mass measurement systems. Volumetric measurement requires the use of density to determine correction factors for temperature and pressure on a flowing liquid. Inferred mass measurement systems require density measurement at meter conditions to determine mass flow. Direct mass measurement systems require online density measurement at a meter prover to determine prover mass and calculate a mass meter factor.

2 Density Meter Selection

Proper density meter selection is determined by how a meter will be applied. Density uncertainty requirements for inferred mass measurement system applications is lower than volumetric measurement system applications. This is due to a fact that in inferred mass measurement a density term multiplies by volume to calculate mass. Density is used in volumetric applications with flowing temperature & pressure to compute a combined correction factor that corrects indicated volume to standard conditions. API MPMS Chapter 9 Section 4 provides density measurement uncertainty requirements based on a meter application and the following sections of this document explain how density is used for mass or volumetric measurement of hydrocarbon liquids.

3 Density Meter Installation

Density meters can be installed inline (full flow through), directly inserted into a pipeline or in a density by pass loop. Care must be taken to provide a representative sample of the flowing fluid where a density measurement is made. API MPMS Chapter 9 Section 4 provides guidance on how a density meter should be installed depending on an application.

Density meters may be installed upstream or downstream of a volumetric flow meter. The recommended installation is downstream of an inferred mass volumetric flow meter.

4 Field Proving Density Meters

API MPMS Chapter 9 Section 4 provides guidance on proving density meters against a pycnometer or hydrometer depending on an application. New pycnometer proving guidance requires three consecutive runs (+/- 0.05% repeatability) which represents a change from former API MPMS Chapter 14 Section 6 requirements.

Hydrometer proving guidance is new to API MPMS Chapter 9 Section 4 and allows for the use of either a batch proportional composite sample or spot sample. Liquid applications following this proving guidance must be stable at atmospheric pressure and measured volumetrically (e.g. crude oil or refined products).

5 Density Measurement in Net Standard Volume (NSV) Measurement System Calculations

NSV is the basis by which liquid volume of crude oils, refined products and some purity LPG is measured. NSV calculations are standardized by API MPMS Chapter 12 Section 2. Density measurement is required to calculate volume correction factors based on RHOb which is defined below. Continuous density meters are applied to volumetric measurement systems. Observed density (RHOobs) is measured online at flowing temperature and pressure. Observed density is corrected to standard conditions (RHOb) which is used to calculate volume correction factors for pressure and temperature.

$$NSV = GSV \times CSW$$

Where:

NSV - gross standard volume adjusted for S&W (sediment and water).

GSV - total fluid measured at standard conditions, including both merchantable crude oil and non-merchantable components such as sediment and water. Volume at standard conditions indicates volume that is adjusted for temperature and pressure effects (e.g. 60 Degrees F/0 psig).

CSW - correction factor for S&W (where present) reducing the gross standard volume for non-merchantable content which is equivalent to the merchantable fraction of fluid.

$$GSV = IV \times CCF$$

Where:

IV - uncompensated indicated volume registered by a volumetric flow meter.

$$CCF = MF \times CTL \times CPL$$

Where:

MF - meter factor that compensates an indicated volume for meter inaccuracy determined by meter proving.

CTL - correction for temperature on liquid-density dependent factor to compensate for the temperature of the measured liquid.

CPL - correction for pressure on liquid-density dependent factor to compensate for the pressure of the measured liquid.

CTL&CPL - calculations based on API MPMS Chapter 11.1/11.2 or applicable standards using:

TWA, PWA & RHOb

Where:

TWA/PWA - temperature/pressure flow weighted average

RHOb - density of liquid at 60 degrees F/0 psig or other standard conditions; calculated from RHOobs (API MPMS Chapter 12 Section 2, Part 1, Appendix B-Liquid Density Correlation)

RHOobs - density of liquid at observed temperature/ pressure

$$CSW = 1-(S\&W\%/100)$$

Where:

CSW - value representing the merchantable fraction of the gross standard volume.

S&W% - percentage of S&W.

6 Density Measurement in Direct Mass Measurement System Calculations

Mass measurement techniques (direct or inferred mass) are typically applied to light hydrocarbons (0.350-0.689 relative density at 60 Degrees F.). Direct mass measurement is achieved by using a Coriolis flow meter and programming the transmitter to output pulses per unit mass (pulses per pound). Coriolis flow meter installations should follow the guidance provided in API MPMS Chapter 5 Section 6. Direct mass meters require that a meter factor be derived by mass proving. This requires the addition of an online density measurement at prover conditions (prover volume x density = mass). An Inferred Mass Prover Density Measurement section of this paper (below) provides more details on requirements for proper prover density measurement.

API MPMS Chapter 14 Section 7 provides an equation for direct mass measurement:

$$Qm = Im_m \times MF_m$$

Where:

Qm = mass flow

Im_m = indicated Coriolis meter mass

MF_m = meter factor for Coriolis meter mass

7 Density Measurement in Inferred Mass Measurement System Calculations

Inferred mass measurement is achieved by using a volumetric flow meter in conjunction with an online density measurement at flowing conditions. Volumetric flow meters should be installed with guidance from an appropriate section of the API MPMS Chapter 5 depending on the meter technology selected (e.g. API MPMS Chapter 5 Section 3 for turbines). Coriolis flow meters are sometimes used for volumetric flow measurement in inferred mass measurement systems by configuring the flow meter transmitter to output pulses per unit volume (e.g. pulses per barrel) and measuring online density with a separate density meter installed in a bypass loop.

API MPMS Chapter 14 Section 7 provides an equation for inferred mass measurement:

$$Qm = IV \times MF_v \times \rho_f \times DMF$$

Where:

Qm = mass flow

IV = indicated meter volume at operating conditions

MF_V = volumetric meter factor

ρ_f = indicated density at operating conditions

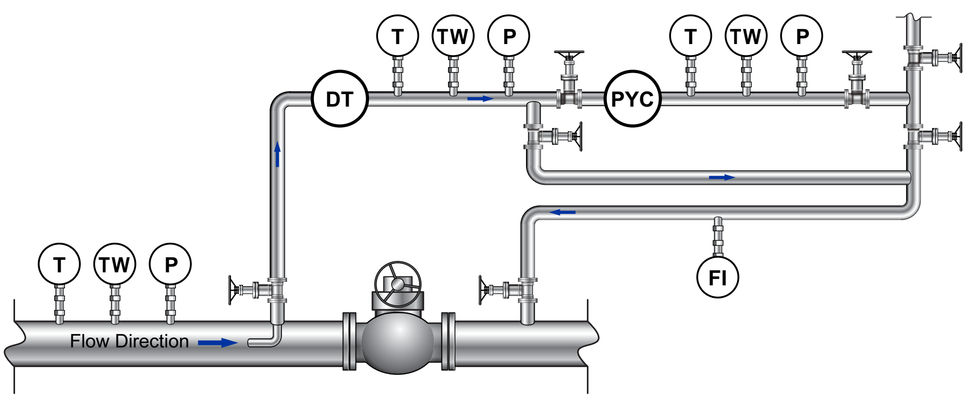
DMF = density meter factor

Inferred mass density measurement guidance is provided by API MPMS Chapter 9 Section 4. Density meter loops (Figure 1.) are generally one-inch pipe work or smaller which means the density meter is installed in a bypass loop from the main flow line. Maintaining a representative sample (composition, temperature and pressure) in the density bypass loop of the flow through the volumetric flow meter can be difficult. Insulation should be applied to density meter bypass loop piping.

Differences in process conditions at the flow and density meters can provide additional mass measurement uncertainty versus a direct mass measurement.

8 Inferred Mass Prover Density Measurement

Density measurement is required on a displacement meter prover for mass proving. Density meters are often placed on a piston prover's outlet across a valve or other restriction to create flow through the density loop. Density loops should include pressure and temperature measurements at the density meter and pycnometer outlets to ensure equal process conditions when a pycnometer sample is pulled. Regardless of where a density loop is located, a density meter factor (DMF) is required.



T = Temperature Measurement
TW = Test Thermowell
P = Pressure Measurement
DT = Density Transmitter
PYC = Pycnometer
FI = Flow Indicator

Figure 1.-Typical Inferred Mass Measurement Density

9 Conclusion

Density meter selection, installation, operation and maintenance guidance is provided in the API MPMS Chapter 9 Section 4. Density meter uncertainty requirements and installation requirements are determined by a meter's application. Inferred mass measurement density uncertainty requirements are lower than volumetric measurement applications.

Density meter factors are calculated based on field proving procedures outlined in API MPMS Chapter 9 Section 4 for pycnometer or hydrometer methods.

Density measurement is necessary for input to volumetric and mass measurement system calculations as outlined above and impacts the overall measurement uncertainty.

Emerson has application expertise and a range of density measurement solutions to address volumetric and mass measurement application requirements.

Please contact a local Emerson Automation Solutions sales office for more information.

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