Title: Natural Gas Liquid Measurement-Direct & Inferred Mass

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Introduction

Natural Gas Liquid (NGL) streams consist of mixtures of hydrocarbons including ethane, propane, butane, pentane and natural gasoline. NGL is sometimes referred to as y-grade. The American Petroleum Institute (API) Manual of Petroleum Measurement Standards (MPMS) Chapter 14 Section 7 provides guidance on the mass measurement of NGL. Mass measurement techniques are applied to NGL measurement due to solution mixing of a variable fluid composition within the NGL stream.

Mass measurement can be achieved by direct measurement (Coriolis flow meter) or inferred by multiplying a volumetric flow rate times flowing density. This paper will discuss the relative advantages of direct mass measurement for NGL streams.

NGL stream components are bought and sold on a volumetric basis. Conversion of measured mass during a measurement interval to the volume of each NGL stream component will be discussed.

Hydrocarbon Mixing

NGL solution mixing results from different sized molecules flowing together in an NGL stream. Smaller molecules fit within voids in the structure of larger molecules. An analogy can be made to mixing sand and marbles. Mixing one barrel of sand and marbles yields less than two barrels of mixture (Figure 1.) because the sand fills in around the marbles. Simultaneously varying the NGL stream composition, temperature and pressure makes it impossible to predict the resulting volume of the hydrocarbon mixture. It is not possible to apply temperature and pressure volume correction factors from API MPMS Chapter 11 on NGL streams. An NGL stream's measured mass is independent of composition, temperature and pressure.

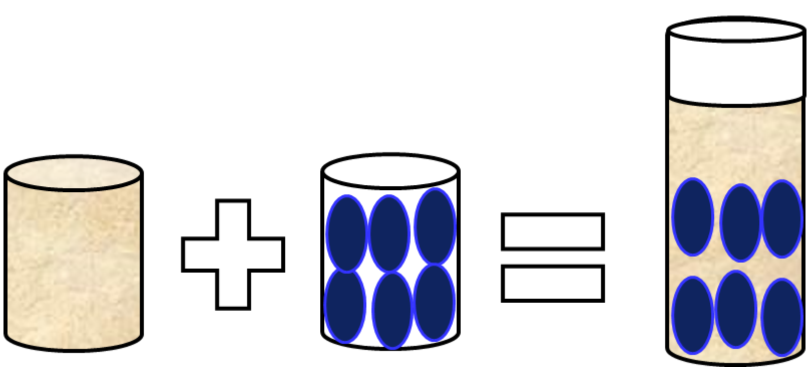

Figure 1.

Mass/Volume/Density Relationships

Mass, volume and density are related. Relationships are shown below:

Mass=Volume x Density

Volume=Mass / Density

Density=Mass / Volume

Mass can be measured directly using a Coriolis flow meter or inferred by measuring volume and density at flowing conditions.

Dividing mass by density at flowing conditions yields indicated volume. Volume at standard conditions can be determined by dividing mass by density at standard conditions. This topic will be discussed further in a converting mass to volume section below.

Direct Mass Measurement

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.

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

$Qm=Im_m x MF_m$

Where:

Qm=mass flow

Im_m=indicated Coriolis meter mass

MF_m=meter factor for Coriolis meter mass

The direct mass equation includes only two terms.

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).

Inferred Mass Measurement

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 (pulses per barrel).

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

$Qm=IVxMF_{v}x\rho_{f}xDMF$

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

The inferred mass measurement calculation has two additional terms for a flowing density and a density meter factor. Inferred mass density measurement guidance is provided by API MPMS Chapter 9 Section 4. Density meter loops (Figure 2.) 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 (pressure, temperature and composition) in the density bypass loop of the flow through the volumetric (duty) flow meter can be difficult. Differences in process conditions at the duty flow and density meters can provide additional mass measurement uncertainty versus a direct mass measurement.

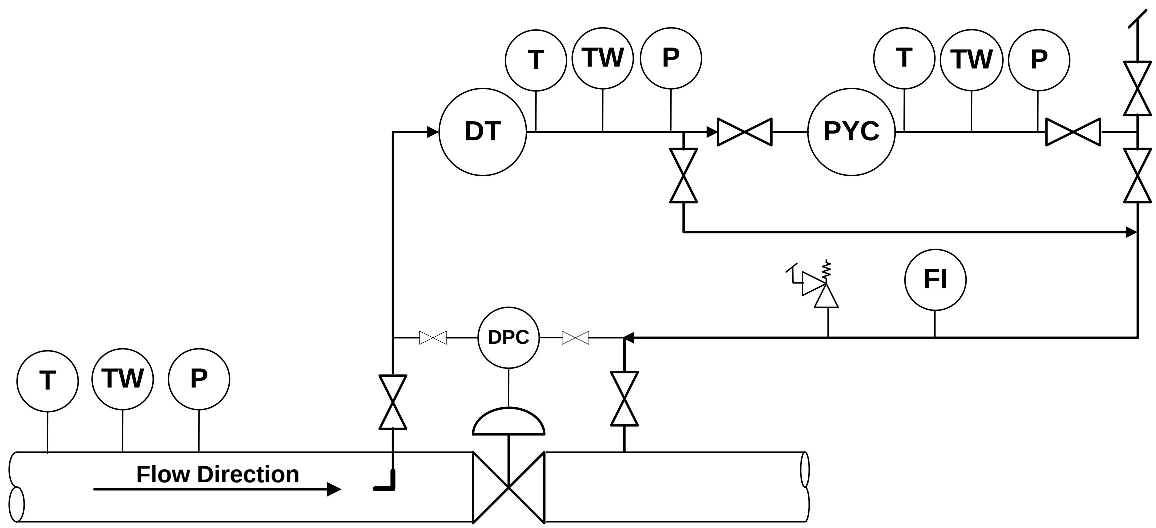

Figure 2.

Density Measurement

Density measurement is required on a meter prover for direct 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. Inferred mass measurement systems have a continuous density measurement loop as described in a section above. Density loops should include pressure and temperature measurements at the density meter and pycnometer outlets in order to ensure equal process conditions when a pycnometer sample is pulled. Regardless of where a density loop is located, a density meter factor is required. API MPMS Chapter 9 Section 4 provides guidance on calibrating density meters against a pycnometer.

Sampling

A flow weighted proportional fluid sample is taken during the measurement interval. The sample pressure must be maintained above the fluid vapor pressure in order to prevent liquid-vapor separation from occurring in the sample container. Fluid samples are analyzed by gas chromatography in order to determine the weight fraction of each component in the fluid stream during the measurement interval.

On-line Analysis

Many operating companies have adopted online fluid analysis using gas chromatographs installed near the mass measurement system. A gas chromatograph (GC) measures the flowing fluid composition and provides compositional data to a flow computer. On-line analysis is used to eliminate a need for handling and processing manual samples. Gas Processors Association Standards GPA 2261 and GPA 2177 provide some guidance on GC NGL measurement applications.

Converting Mass to Volume

The API MPMS Chapter 14 Section 4 provides guidance for converting NGL mass quantities to equivalent volumes. NGL samples obtained during the measurement period are analyzed to determine the weight fraction of each stream component or measured in real time via an online GC. Weight fraction is multiplied by total NGL mass which yields the mass of each component. Dividing the component mass by its density at standard conditions provides the volume of each NGL stream component. Table 1. below shows an example mass to volume conversion of an NGL stream.

ENGLISH UNITS

COMP	MOL %		MOL WT		MOL % x MW	WT FRAC		TOTAL LB MASS		COMP LB MASS		DENSITY LB/GAL		GALLON
CO_2	0.11	x	44.010	=	4.84	.001107	x	825300	=	914	÷	6.8199	=	134
C_1	2.14		16.043		34.33	.007852		825300		6480		2.5		2592
C_2	38.97		30.070		1171.83	.268014		825300		221192		2.9696		74485
C_3	36.48		44.097		1608.66	.367923		825300		303647		4.2268		71839
IC_4	2.94		58.123		170.88	.039083		825300		32255		4.6927		6873
NC_4	8.77		58.123		509.74	.116585		825300		96218		4.8691		19761
IC_5	1.71		72.150		123.38	.028219		825300		23289		5.2058		4474
NC_5	1.82		72.150		131.31	.030032		825300		24785		5.2614		4711
C_{6+}	7.06		87.436		617.30	.141185		825300		116520		5.951*		19580
Total	100.00				4372.27	1.000000				825300				204449

*Extended Analysis

NOTE – Calculation procedures for Appendix X1 are the same as used in GPA Standard 8173 "Converting Mass Natural Gas Liquids and Vapors to Equivalent Liquid Volumes".

Table 1.

Conclusion

Mass measurement techniques are used to measure NGL. Solution mixing makes predicting NGL volumes impossible under varying composition, pressure and temperature. Several sections of the API MPMS provide guidance for the mass measurement of NGL.

NGL mass can be measured directly with Coriolis flow meters. Inferred mass can be determined by multiplying a volumetric flow meter volume times density. Direct mass measurement systems have an advantage of no need for online density measurement during the measurement interval.

NGL mass is converted to volume by determining the mass of each component and dividing by density at standard conditions.