

# **Manual of Petroleum Measurement Standards Chapter 14—Natural Gas Fluids Measurement**

## **Section 4—Converting Mass of Natural Gas Liquids and Vapors to Equivalent Liquid Volumes**

GPA 8173-17

THIRD EDITION, XXXXX

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## Foreword

### Summary of Method

This standard provides methods that can be used to calculate equivalent liquid volumes, gas volumes, and energy from a measured mass and composition. This standard considers that different analytical methods may be used as starting points and provides methods for calculation from each potential starting point. It should be used by entities desiring more accurate balancing of systems utilizing mass measurement as well as entities wanting to report more accurate quantities.

### Committee Notes

This standard is maintained jointly by the GPA Midstream Measurement and Quantity Determination (MAQD) Committee and the API Committee on Gas Fluids Measurement (COGFM) in an effort to provide consistent methods for calculating volumes from mass. GPA 8173 was published as a tentative standard in 1973 and became a technical standard in 1976. It is published as part of the API Manual of Petroleum Measurement Standards (MPMS), Chapter 14, Section 4 (14.4).

### Summary of Changes

There were four significant changes to this revision: an unrounded method of calculation was added, the method for choosing which component value to adjust when the sum of values does not equal the expected total, and annexes for the calculation of energy and equivalent gas volume from mass.

The previous revision used an adjustment method to ensure reported component concentrations totaled exactly 100% and reported component mass quantities total the measured mass. This method remains and is labelled the Adjusted Method. This revision added a full numerical precision method that is labelled the Unrounded Method.

In the previous revision, the value to be adjusted was based on the component with the lowest number of carbon atoms. This revision adjusts the value of the component with the highest absolute density.

Two annexes were added to the standard. One annex provides the normative method to calculate gas equivalent energy from mass. The other annex provides guidance for calculating gas equivalent volumes.

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**Table of Contents**

To be completed during editorial review and publication process

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## Introduction

Measurement by mass is often preferred for chemical reactions and for various processes where the mass ratios of components are of primary interest in effecting control of the operation. Mass quantities may be converted to volumes at reference conditions to facilitate commercial transactions.

Since the 1970's, the gas processing industry has recognized the importance of measuring mixed natural gas liquid (NGL) streams using mass measurement techniques. Mass measurement is preferred because, unlike volumetric measurement, the mass measurement process is not sensitive to the effects that pressure, temperature, intermolecular adhesion, and solution mixing have upon the measured stream. Solution mixing / intermolecular adhesion occurs when smaller molecules fill the spaces between the larger molecules in the solution. Temperature and pressure also affect the change in volume caused by solution mixing / intermolecular adhesion. Due to these behaviors, the sum of the volumes of individual components in their pure state is greater than the volume of the mixture.

Measured mass, for NGL liquid or vapor mixtures, may be converted to units of liquid volume by determining each component's mass from the total measured mass via sample analysis, then dividing each component's mass by its absolute density at reference conditions. The component volumes are based on the pure component's equilibrium vapor pressures. The total liquid volume is not at the equilibrium vapor pressure of the mixture.

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This standard was developed jointly by the GPA Midstream Measurement and Quantity Determination Committee, and the API Committee on Gas Fluids Measurement (COGFM). It is referenced by API as Chapter 14, Section 4 (14.4) of the API Manual of Petroleum Measurement Standards (MPMS). The participation of COGFM in developing this standard is gratefully appreciated and acknowledged.

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# Converting Mass of Natural Gas Liquids or Vapors to Equivalent Liquid Volumes

## 1 Scope

This standard prescribes a method for calculating liquid volumes at equilibrium pressures and at temperatures of 60 °F, 15 °C, and 20 °C from the mass of a natural gas fluid (liquid or vapor) measured at operating conditions, in conjunction with a representative compositional analysis and published values for each component's molar mass and absolute density.

## 2 Normative References

- GPA 2145, *Table of Physical Properties for Hydrocarbons and Other Compounds of Interest to the Natural Gas Industry*

## 3 Terms, Definitions, Abbreviations, and Symbols

### 3.1 Definitions

#### 3.1.1

##### **absolute density**

The mass of a substance per unit of volume at a specified temperature and pressure.

#### 3.1.2

##### **Equilibrium Vapor Pressure (EVP)**

The pressure at which a liquid and its vapor are in equilibrium at a given temperature.

#### 3.1.3

##### **molar mass (*M*)**

The mass of a substance divided by its amount of substance.

#### 3.1.4

##### **mole**

The amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kilograms of carbon 12.

#### 3.1.5

##### **mole fraction**

The amount of a component divided by the total amount of all component in a mixture.

#### 3.1.6

##### **mole percent**

Mole fraction multiplied by 100.

#### 3.1.7

##### **natural gas liquids**

Those hydrocarbons liquefied at the surface in field facilities or in gas processing plants. Natural gas liquids include ethane, propane, butanes and natural gasoline.

## 3.2 Acronyms, Abbreviations, and Symbols

For the purposes of this document, the following abbreviations and symbols apply.

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EVP	equilibrium vapor pressure
lbm	pound mass; 1 lbm = 453.59237 grams (exact)
M	component molar mass; formerly molecular weight
$M_i$	component mass per mole of mixture
$M_{total}$	total mass per mole of mixture
m	total measured mass
$m_i$	component mass from total measured mass
$m_{vi}$	component mass of mixture
$m_{v total}$	total mass of mixture
NGL	natural gas liquid
$\rho_{abs}$	component absolute density
SI	international system of units (Système Internationale)
USC	U.S. customary units of measurement
$V_i$	component volume at base temperature and a reference base pressure of 14.696 psia (101.325 kPa). When the substance is not in the liquid phase at 14.696 psia (101.325 kPa), the reference base pressure is then the equilibrium vapor pressure at base temperature.
$v_i$	component volume fraction of mixture
$w_i$	component mass fraction of mixture; formerly weight fraction
$x_i$	component mole fraction of mixture
i	(subscript) ith component
n	number of components in the mixture

## 4 Summary of Method

### 4.1 General

The total mass of a natural gas liquid or natural gas vapor is determined at operating pressure and temperature using a mass measurement system. The total mass is converted to individual component volumes using a representative component analysis.

The physical properties of pure components as stated in GPA 2145 shall be used.

The physical properties of pure components at conditions not listed in GPA 2145 (e.g., 20 °C) should be generated from REFPROP, NIST Standard Reference Database 23. An exception is made for methane, which has a critical temperature of -82.59 °C (190.56 K). The absolute density of 270 kg/m<sup>3</sup> for methane at 20 °C has been extrapolated from GPA 2145-09 and should be used for methane at 20 °C until GPA

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2145 is updated to include a dataset of absolute densities at 20 °C. Physical properties obtained from sources other than GPA 2145 or REFPROP shall be documented with the source name and version or publication date, and shall be of equivalent or better uncertainty than REFPROP.

The examples in this publication illustrate typical components. In actual practice, all the components detected that are representative of the measured product stream should be included in the conversion to equivalent liquid volumes.

## 5 Limitations of the Standard

### 5.1 General

This standard is limited to the area of applicability of the standards governing the input data. Any input data outside of those limitations may result in erroneous calculations. In addition to the uncertainty of the component and pseudo-component physical properties, any error or uncertainty in the input analyses or mass is carried through to the result.

Methods for determining total measured mass are not covered by this standard. Methods for obtaining representative samples and subsequent compositional analyses are not covered by this standard.

## 6 Calculations

### 6.1 General

Two calculation methods are presented: Unrounded and Adjusted. The Unrounded Method uses all unrounded intermediate values. This method is preferred, especially for online calculations such as those in EGM (Electronic Gas Measurement) and ELM (Electronic Liquid Measurement) installations. The Adjusted Method uses rounded intermediate values, with some values adjusted so the reported sum of the component values matches the reported total value. The Adjusted Method was developed to work around precision limitations of reported values to force the sum of the reported component values to match the reported total. This method is useful for accounting systems that prefer precise sums for mass fraction and total measured mass.

For each calculation, calculation procedures are presented, one for each fluid composition unit of measure: mole percent, volume percent, and mass percent. The procedure to use shall correspond with the calibration basis of the instrument used to analyze the fluid. For example, if a chromatograph is calibrated based on volume percent, the procedure to calculate component volume from volume percent (8.2.2 or 8.3.2) shall be used.

In order to maintain consistent calculation results for accounting purposes, the arithmetic precision of calculations may imply an accuracy exceeding that of the analytical and measurement instruments. It should be noted that intermediate calculations may not represent the actual precision of the results.

Consistency of units and reference conditions shall be maintained throughout the calculation processes. For example, it would be inappropriate to multiply mass in kilograms by an absolute density in lbs/gal to determine a volume. It may be necessary to convert values to maintain consistency of units throughout the calculations.

### 6.2 Unrounded Method

This section describes the calculation process for calculating component and total volumes without rounding any intermediate values.

#### 7.2.1 Component Volume from Mole Percent, Unrounded Method

Given the fluid composition as mole percent and the fluid total measured mass, calculate the component volumes at base temperature and EVP.

**7.2.1.1** For each component, convert component mole percent values to component mole fraction of mixture ( $x_i$ ) values by multiplying each component mole percent value by 0.01.

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**7.2.1.2** For each component, calculate component mass per mole of mixture ( $M_i$ ) to six decimal places by multiplying each component mole fraction ( $x_i$ ) value by its molar mass ( $M$ ):

$$M_i = x_i \times M \quad \text{Eq. (1)}$$

**7.2.1.3** Calculate total mass per mole for the mixture ( $M_{total}$ ) by summing the component mass per mole ( $M_i$ ) values:

$$M_{total} = \sum_{i=1}^n M_i \quad \text{Eq. (2)}$$

**7.2.1.4** For each component, calculate component mass fraction of the mixture ( $w_i$ ) value rounded to six decimal places by dividing each component mass per mole ( $M_i$ ) value by the total mass per mole ( $M_{total}$ ):

$$w_i = \frac{M_i}{M_{total}} \quad \text{Eq. (3)}$$

**7.2.1.5** Calculate component mass from total measured mass ( $m_i$ ) values by multiplying each component mass fraction ( $w_i$ ) value by the total measured mass ( $m$ ):

$$m_i = w_i \times m \quad \text{Eq. (4)}$$

**7.2.1.6** Calculate component volume ( $V_i$ ) values for the mixture by dividing component mass ( $m_i$ ) values by component absolute density values ( $\rho_{abs_i}$ ):

$$V_i = \frac{m_i}{\rho_{abs_i}} \quad \text{Eq. (5)}$$

## **7.2.2 Component Volume from Volume Percent, Unrounded Method**

Given the fluid composition as volume percent and the fluid total measured mass, calculate the component volumes at base temperature and EVP.

**7.2.2.1** For each component, convert component volume percent values to component volume fraction of mixture ( $v_i$ ) values by multiplying each component volume percent value by 0.01.

**7.2.2.2** For each component, calculate the component mass of the mixture ( $m_{vi}$ ) rounded to six decimal places by multiplying each component volume fraction ( $v_i$ ) value by its absolute density ( $\rho_{abs_i}$ ):

$$m_{vi} = v_i \times \rho_{abs_i} \quad \text{Eq. (6)}$$

**7.2.2.3** Calculate the total mass of the mixture ( $m_{v_{total}}$ ) by summing the component mass of mixture ( $m_{vi}$ ) values:

$$m_{v_{total}} = \sum_{i=1}^n m_{vi} \quad \text{Eq. (7)}$$

**7.2.2.4** For each component, calculate the component mass fraction of the mixture ( $w_i$ ) value rounded to six decimal places by dividing each component mass ( $m_{vi}$ ) value by the total mass of the mixture ( $m_{v_{total}}$ ):

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$$w_i = \frac{m_{vi}}{m_{v\_total}} \quad \text{Eq. (8)}$$

**7.2.2.5** Calculate component mass from total measured mass ( $m_i$ ) values by multiplying each component mass fraction ( $w_i$ ) value by the total measured mass ( $m$ ):

$$m_i = w_i \times m \quad \text{Eq. (9)}$$

**7.2.2.6** Calculate component volume ( $V$ ) values for the mixture by dividing component mass ( $m_i$ ) values by component absolute density values ( $\rho_{abs_i}$ ):

$$V_i = \frac{m_i}{\rho_{abs_i}} \quad \text{Eq. (10)}$$

### 7.2.3 Component Volume from Mass Percent, Unrounded Method

Given the fluid composition as mass percent and the fluid total measured mass, calculate the component volumes at base temperature and EVP.

**7.2.3.1** For each component, convert component mass percent values to component mass fraction ( $w_i$ ) values by multiplying each component mole percent value by 0.01.

**7.2.3.2** For each component, calculate component mass from total measured mass ( $m_i$ ) values by multiplying each component mass fraction ( $w_i$ ) value by the total measured mass ( $m$ ):

$$m_i = w_i \times m \quad \text{Eq. (11)}$$

**7.2.3.3** Calculate component volume ( $V_i$ ) values for the mixture by dividing component mass ( $m_i$ ) values by component absolute density values ( $\rho_{abs_i}$ ):

$$V_i = \frac{m_i}{\rho_{abs_i}} \quad \text{Eq. (12)}$$

### 7.3 Adjusted Method

This method uses an adjustment procedure with rounded values where adjustments are applied to certain calculations when the sum of the values differs from the expected sum for the displayed precision.

After rounding has occurred, the process is as follows:

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$$N = i: \rho_{abs_{\max}(var_i)} = \max(\rho_{abs_{\max}(var_i)}) \quad \text{Eq. (13)}$$

$$\delta = \sum Expected - \sum_{i=1}^n Var_i \quad \text{Eq. (14)}$$

$$Var_{N,new} = Var_{N,old} + \delta \quad \text{Eq. (15)}$$

Where:

$Var$	–	is the data set
$Var_i$	–	is the value of the $i^{\text{th}}$ variable
$Var_{N,old}$	–	is the value of the $i^{\text{th}}$ variable before adjustment, where $i = N$
$Var_{N,new}$	–	is the value of the $i^{\text{th}}$ variable after adjustment, where $i = N$
$N$	–	is the component with the highest density that also has the maximum value
$n$	–	is the number of data points in the data set $Var$
$\delta$	–	is the difference between the expected sum and the actual sum of the data set
$\rho_{abs_{\max}(var_i)}$	–	is the absolute density of the maximum $Var_i$

For example: If ethane and propane were both 0.4 liquid volume fraction, any difference between the sum of the component liquid volume fractions and the total of 1.0 volume fractions would be applied to the propane liquid volume fraction because propane has a higher absolute density than ethane.

### 7.3.1 Component Volume from Mole Percent, Adjusted Method

Calculate the component mass fractions using the procedures in sections 7.2.1.1 through 7.2.1.4, rounding each mass fraction to six decimal places.

If the sum of the rounded component mass fractions does not equal 1.000000 exactly, apply the adjustment procedure in section 7.3 using 1.000000 as the expected sum.

Using the rounded component mass fractions, calculate the component mass values using the procedure in section 7.2.1.5.

Round the component mass values to the same number of decimal places as the measured mass ( $m$ ).

If the sum of the rounded component mass values does not equal the measured mass ( $m$ ) exactly, apply the adjustment procedure in section 7.3 using  $m$  as the expected sum.

Calculate the component volume ( $V_i$ ) values for the mixture using the procedure in section 7.2.1.6.

### 7.3.2 Component Volume from Volume Percent, Adjusted Method

Given the fluid composition as volume percent and the fluid total measured mass, calculate the component volumes at base temperature and EVP using the Adjusted Method.

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Calculate the component mass fractions using the procedures in sections 7.2.2.1 through 7.2.2.4, rounding each component's mass fraction to six decimal places.

If the sum of the rounded component mass fractions does not equal 1.000000 exactly, apply the adjustment procedure in section 7.3 using 1.000000 as the expected sum.

Using the rounded component mass fractions, calculate the component mass values using the procedure in section 7.2.2.5.

Round the component mass values to the same number of decimal places as the measured mass ( $m$ ).

If the sum of the rounded mass values does not equal the measured mass ( $m$ ) exactly, apply the adjustment procedure in section 7.3 using  $m$  as the expected sum.

Calculate the component volume ( $V_i$ ) values for the mixture using the procedure in section 7.2.2.6.

### **7.3.3 Component Volume from Mass Percent, Adjusted Method**

Given the fluid composition as mass percent and the fluid total measured mass, calculate the component volumes at base temperature and EVP using the Adjusted Method.

Calculate the component mass values using the procedures in section 7.2.3.1 and 7.2.3.2.

Round the component mass values to the same number of decimal places as the measured mass ( $m$ ).

If the sum of the rounded mass values does not equal the measured mass ( $m$ ) exactly, apply the adjustment procedure in section 7.3 using  $m$  as the expected sum.

Calculate the component volume ( $V_i$ ) values for the mixture using the procedure in section 7.2.3.3.

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## Annex A (Informative)

### Example Calculations—Component Volume from Mole Percent (USC) 60 °F

Given the fluid composition as volume percent and total measured mass, calculate the mixture’s component volumes ( $V_i$ ) at 60 °F and at EVP according to the equations in Section 7.2.2 (Eqs. 6-10) and using pure component properties from the latest edition of GPA 2145 for absolute density.

#### A.1 Unrounded Method

Table A.1 – Unrounded Method – XXX

Calculate component mass of mixture				Calculate component mass fraction of mixture			
	$V_i$	$\rho_{abs}$	$m_{vi}$	$m_{v\_total}$	$w_i$		
Component	Component Volume % of Mixture from Sample Analysis	Percent Conversion Factor	Component Volume Fraction of Mixture gal	Component Absolute Density GPA-2145 lbm/gal	Component Contribution to Mixture Absolute Density lbm/gal	Mixture Absolute Density lbm/gal	Component Mass Fraction of Mixture
CO <sub>2</sub>	0.07	x 0.01	= 0.0007	x 6.8129	= 0.004769	/ 3.968499 =	0.001202
C <sub>1</sub>	1.27		0.0127	x 2.5000	= 0.031750		0.008001
C <sub>2</sub>	37.92		0.3792	x 2.9704	= 1.126376		0.283829
C <sub>3</sub>	35.13		0.3513	x 4.2285	= 1.485472		0.374316
iC <sub>4</sub>	3.36		0.0336	x 4.6925	= 0.157668		0.039730
nC <sub>4</sub>	9.67		0.0967	x 4.8706	= 0.470987		0.118681
iC <sub>5</sub>	2.19		0.0219	x 5.2120	= 0.114143		0.028762
nC <sub>5</sub>	2.31		0.0231	x 5.2584	= 0.121469		0.030608
C <sub>6+</sub>	8.08		0.0808	x 5.6419 *	= 0.455866		0.114871
Totals	100.00		1.0000		3.968499		1.000000

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**Table A.1.2 – Unrounded Method – XXX**

Component	Calculate component mass			Calculate volume		
	$w_i$	$M$	$m_i$	$\rho_{abs}$	$V$	$V$
	Component Mass Fraction of Mixture <sup>1</sup>	Total Measured Mass lbm	Component Mass from Total Measured Mass lbm <sup>1</sup>	Component Absolute Density GPA-2145 lbm/gal	Component Volume at 60 °F & EVP gal <sup>1</sup>	Component Volume at 60 °F & EVP Bbl <sup>1</sup>
CO <sub>2</sub>	0.001202	× 825,300 =	991.7806 /	6.8129 =	145.6	3.5
C <sub>1</sub>	0.008001		6,602.8174	2.5000	2,641.1	62.9
C <sub>2</sub>	0.283829		234,244.1855	2.9704	78,859.5	1,877.6
C <sub>3</sub>	0.374316		308,922.8546	4.2285	73,057.3	1,739.5
iC <sub>4</sub>	0.039730		32,789.0711	4.6925	6,987.5	166.4
nC <sub>4</sub>	0.118681		97,947.7565	4.8706	20,110.0	478.8
iC <sub>5</sub>	0.028762		23,737.4507	5.2120	4,554.4	108.4
nC <sub>5</sub>	0.030608		25,261.0358	5.2584	4,803.9	114.4
C <sub>6+</sub>	0.114871		94,803.0478	5.6419 *	16,803.4	400.1
Totals	1.000000		825,300.0000		207,962.8 <sup>a</sup>	4,951.5 <sup>a</sup>

\* For example purposes only, the absolute density of C6+ is calculated from a 60-30-10 split of nC6, nC7, and nC8.

<sup>1</sup> Displayed values do not reflect the full precision of the values

<sup>a</sup> Each component liquid volume is calculated at its equilibrium vapor pressure and equilibrium vapor pressures vary by component. Therefore, the calculated total liquid volume is not representative of the volume of the mixture and should not be used to represent a liquid volume at any one set of pressure and temperature conditions.

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## A.2 Adjusted Method

**Table A.2 Adjusted Method**

Calculate component mass of mixture					Calculate component mass fraction of mixture		
Component	Component Volume % of Mixture from Sample Analysis	Percent Conversion Factor	$V_i$ Component Volume Fraction of Mixture gal	$\rho_{abs}$ Component Absolute Density GPA-2145 lbm/gal	$m_{vi}$ Component Contribution to Mixture Absolute Density <sup>1</sup> lbm/gal	$m_{v\_total}$ Mixture Absolute Density lbm/gal	$w_i$ Component Mass Fraction of Mixture <sup>1</sup>
CO <sub>2</sub>	0.07	x 0.01	= 0.0007	x 6.8129	= 0.004769	/ 3.968500	= 0.001202
C <sub>1</sub>	1.27		0.0127	2.5000	0.031750		0.008001
C <sub>2</sub>	37.92		0.3792	2.9704	1.126376		0.283829
C <sub>3</sub>	35.13		0.3513	4.2285	1.485472		0.374316
iC <sub>4</sub>	3.36		0.0336	4.6925	0.157668		0.039730
nC <sub>4</sub>	9.67		0.0967	4.8706	0.470987		0.118681
iC <sub>5</sub>	2.19		0.0219	5.2120	0.114143		0.028762
nC <sub>5</sub>	2.31		0.0231	5.2584	0.121469		0.030608
C <sub>6+</sub>	8.08		0.0808	5.6419 *	0.455866		0.114871
Totals	100.00		1.0000		3.968500		1.000000

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**Table A.2.1 Adjusted Method**

Component	Calculate component mass			Calculate volume		
	$w_i$	$M$	$m_i$	$\rho_{abs}$	$V$	$V$
	Component Mass Fraction of Mixture <sup>1</sup>	Total Measured Mass lbm	Component Mass from Total Measured Mass lbm	Component Absolute Density GPA-2145 lbm/gal	Component Volume at 60 °F & EVP gal	Component Volume at 60 °F & EVP Bbl
CO <sub>2</sub>	0.001202	825,300	992	6.8129	145.6	3.5
C <sub>1</sub>	0.008001		6,603	2.5000	2,641.2	62.9
C <sub>2</sub>	0.283829		234,244	2.9704	78,859.4	1,877.6
C <sub>3</sub>	0.374316		308,924	4.2285	73,057.6	1,739.5
iC <sub>4</sub>	0.039730		32,789	4.6925	6,987.5	166.4
nC <sub>4</sub>	0.118681		97,947	4.8706	20,109.8	478.8
iC <sub>5</sub>	0.028762		23,737	5.2120	4,554.3	108.4
nC <sub>5</sub>	0.030608		25,261	5.2584	4,803.9	114.4
C <sub>6+</sub>	0.114871		94,803	5.6419 *	16,803.4	400.1
Totals	1.000000		825,300		207,962.8 <sup>a</sup>	4,951.5 <sup>a</sup>

\* For example purposes only, the absolute density of C6+ is calculated from a 60-30-10 split of nC6, nC7, and nC8.

<sup>1</sup> Displayed values reflect the full precision of the values.

<sup>a</sup> Each component liquid volume is calculated at its equilibrium vapor pressure and equilibrium vapor pressures vary by component. Therefore, the calculated total liquid volume is not representative of the volume of the mixture and should not be used to represent a liquid volume at any one set of pressure and temperature conditions.

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## Annex B (informative)

### Example Calculations—Component Volume from Mass Percent (USC) 60 °F

Given the fluid composition as mass percent and total measured mass, calculate the mixture's component volume ( $V_i$ ) at 60 °F and at EVP according to the equations in 7.2.3 (Eqs.11 and12) and using pure component properties from the latest edition of GPA 2145 for absolute density.

#### B.1 Unrounded Method

**Table B.1 Unrounded Method**

Component	Calculate component mass			Calculate volume				
	$w_i$	$m$	$m_i$	$\rho_{abs}$	$V$	$V$		
	Component Mass % of Mixture from Sample Analysis	Percent Conversion Factor	Component Mass Fraction of Mixture	Component Absolute Density GPA-2145 lbm/gal	Component Volume at 60 °F & EVP gal <sup>2</sup>	Component Volume at 60 °F & EVP Bbl <sup>2</sup>		
CO <sub>2</sub>	0.12	x 0.01	= 0.0012	x 825,300	= 990.36	/ 6.8129	= 145.4	3.5
C <sub>1</sub>	0.80		0.0080		6,602.40	2.5000	2,641.0	62.9
C <sub>2</sub>	28.38		0.2838		234,220.14	2.9704	78,851.4	1,877.4
C <sub>3</sub>	37.43		0.3743		308,909.79	4.2285	73,054.2	1,739.4
iC <sub>4</sub>	3.97		0.0397		32,764.41	4.6925	6,982.3	166.2
nC <sub>4</sub>	11.87		0.1187		97,963.11	4.8706	20,113.2	478.9
iC <sub>5</sub>	2.88		0.0288		23,768.64	5.2120	4,560.4	108.6
nC <sub>5</sub>	3.06		0.0306		25,254.18	5.2584	4,802.6	114.3
C <sub>6+</sub>	11.49		0.1149		94,826.97	5.6419 *	16,807.6	400.2
Totals	<u>100.00</u>		<u>1.0000</u>		<u>825,300.00</u>		<u>207,958.0</u>	<u>4,951.4</u> <sup>a</sup>

\* For example purposes only, the absolute density of C6+ is calculated from a 60-30-10 split of nC6, nC7, and nC8.

<sup>1</sup> Displayed values reflect the full precision of the values.

<sup>2</sup> Displayed values do not reflect the full precision of the values.

<sup>a</sup> Each component liquid volume is calculated at its equilibrium vapor pressure and equilibrium vapor pressures vary by component. Therefore, the calculated total liquid volume is not representative of the volume of the mixture and should not be used to represent a liquid volume at any one set of pressure and temperature conditions.

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## B.2 Adjusted Method

**Table B.2 Adjusted Method**

Component	Component Mass % of Mixture from Sample Analysis	Percent Conversion Factor	Calculate component mass			Calculate volume		
			$w_i$	$m$	$m_i$	$\rho_{abs}$	$V$	$V$
			Component Mass Fraction of Mixture	Total Measured Mass lbm	Component Mass from Total Measured Mass lbm	Component Absolute Density GPA-2145 lbm/gal	Component Volume at 60 °F & EVP gal	Component Volume at 60 °F & EVP Bbl
CO <sub>2</sub>	0.12	x 0.01	= 0.0012	x 825,300	= 990	/ 6.8129	= 145.3	3.5
C <sub>1</sub>	0.80		0.0080		6,602	2.5000	2,640.8	62.9
C <sub>2</sub>	28.38		0.2838		234,220	2.9704	78,851.3	1,877.4
C <sub>3</sub>	37.43		0.3743		308,911	4.2285	73,054.5	1,739.4
iC <sub>4</sub>	3.97		0.0397		32,764	4.6925	6,982.2	166.2
nC <sub>4</sub>	11.87		0.1187		97,963	4.8706	20,113.1	478.9
iC <sub>5</sub>	2.88		0.0288		23,769	5.2120	4,560.4	108.6
nC <sub>5</sub>	3.06		0.0306		25,254	5.2584	4,802.6	114.3
C <sub>6+</sub>	11.49		0.1149		94,827	5.6419 *	16,807.6	400.2
Totals	100.00		1.0000		825,300		207,958.0	4,951.4 <sup>a</sup>

\* For example purposes only, the absolute density of C<sub>6+</sub> is calculated from a 60-30-10 split of nC<sub>6</sub>, nC<sub>7</sub>, and nC<sub>8</sub>.

<sup>a</sup> Each component liquid volume is calculated at its equilibrium vapor pressure and equilibrium vapor pressures vary by component. Therefore, the calculated total liquid volume is not representative of the volume of the mixture and should not be used to represent a liquid volume at any one set of pressure and temperature conditions.

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## Annex C (informative)

### Example Calculations—Component Volume from Mole Percent (Metric) 20 °C

Given the fluid composition as mole percent and total measured mass, calculate the mixture's component volumes ( $V_i$ ) at 20 °C and at EVP according to the equations in 8.2.3 (Eqs. 11 and 12) and using pure component properties from the latest edition of REFPROP for absolute density.

#### C.1 Unrounded Method

**Table C.1 Unrounded Method**

Calculate component mass fraction													
Component	Component Mol % of Mixture from Sample Analysis	Percent Conversion Factor	$x_i$	$M$	$M_i$	$M_{total}$	$w_i$						
			Component Mol Fraction of Mixture	Component Molar Mass REFPROP kg/kgmol	Component Mass per Mol of Mixture kg <sup>1</sup>	Total Mass per Mol of Mixture kg <sup>1</sup>	Component Mass Fraction of Mixture <sup>1</sup>						
CO <sub>2</sub>	0.11	x	0.01	=	0.0011	x	44.0095	=	0.048410	/	44.127769	=	0.001097
C <sub>1</sub>	2.14				0.0214		16.0425		0.343310				0.007780
C <sub>2</sub>	38.97				0.3897		30.0690		11.717889				0.265545
C <sub>3</sub>	36.48				0.3648		44.0956		16.086075				0.364534
iC <sub>4</sub>	2.94				0.0294		58.1222		1.708793				0.038724
nC <sub>4</sub>	8.77				0.0877		58.1222		5.097317				0.115513
iC <sub>5</sub>	1.71				0.0171		72.1488		1.233744				0.027958
nC <sub>5</sub>	1.82				0.0182		72.1488		1.313108				0.029757
C <sub>6+</sub>	7.06				0.0706		93.1887	*	6.579122				0.149093
Totals	100.00				1.0000				44.127769				1.000000

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**Table C.1.2 Unrounded Method**

Component	Calculate component mass			Calculate volume		
	$w_i$ Component Mass Fraction of Mixture <sup>1</sup>	$m$ Total Measured Mass kg	$m_i$ Component Mass from Total Measured Mass kg <sup>2</sup>	$\rho_{abs}$ Component Absolute Density REFPROP kg/m <sup>3</sup>	$V$ Component Volume at 20 °C & EVP m <sup>3</sup> <sup>2</sup>	$V$ Component Volume at 20 °C & EVP l <sup>2</sup>
CO <sub>2</sub>	0.001097	374,350	= 410.6814 /	773.39 =	0.531	531
C <sub>1</sub>	0.007780		2,912.4045	270.00	10.787	10,787
C <sub>2</sub>	0.265545		99,406.6094	339.04	293.200	293,200
C <sub>3</sub>	0.364534		136,463.3273	500.06	272.894	272,894
iC <sub>4</sub>	0.038724		14,496.2358	556.86	26.032	26,032
nC <sub>4</sub>	0.115513		43,242.1728	578.59	74.737	74,737
iC <sub>5</sub>	0.027958		10,466.2497	620.03	16.880	16,880
nC <sub>5</sub>	0.029757		11,139.5173	625.70	17.803	17,803
C <sub>6+</sub>	0.149093		55,812.8018	702.63 *	79.434	79,434
Totals	1.000000		374,350.0000		792.298 <sup>a</sup>	792,298 <sup>a</sup>

\* For example purposes only, the absolute density of C6+ is calculated from a 60-30-10 split of nC6, nC7, and nC8.

<sup>1</sup> Displayed values reflect the full precision of the values.

<sup>2</sup> Displayed values do not reflect the full precision of the values.

<sup>a</sup> Each component liquid volume is calculated at its equilibrium vapor pressure and equilibrium vapor pressures vary by component. Therefore, the calculated total liquid volume is not representative of the volume of the mixture and should not be used to represent a liquid volume at any one set of pressure and temperature conditions.

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## C.2 Adjusted Method

Table C.2 Adjusted Method

Calculate component mass fraction													
			$x_i$		$M$		$M_i$		$M_{total}$		$w_i$		
Component	Component Mol % of Mixture from Sample Analysis		Percent Conversion Factor	=	Component Mol Fraction of Mixture	x	Component Molar Mass GPA-2145 kg/kgmol	=	Component Mass per Mol of Mixture kg <sup>1</sup>	/	Total Mass per Mol of Mixture kg	=	Component Mass Fraction of Mixture <sup>1</sup>
CO <sub>2</sub>	0.1100	x	0.01	=	0.0011	x	44.0095	=	0.048410	/	44.127768	=	0.001401
C <sub>1</sub>	2.1400				0.0214		16.0425		0.343310				0.008977
C <sub>2</sub>	38.9700				0.3897		30.0690		11.717889				0.305504
C <sub>3</sub>	36.4800				0.3648		44.0956		16.086075				0.020088
iC <sub>4</sub>	2.9400				0.0294		58.1222		1.708793				0.419713
nC <sub>4</sub>	8.7700				0.0877		58.1222		5.097317				0.044548
iC <sub>5</sub>	1.7100				0.0171		72.1488		1.233744				0.133181
nC <sub>5</sub>	1.8200				0.0182		72.1488		1.313108				0.032337
C <sub>6+</sub>	7.0600				0.0706		93.1887	*	6.579122				0.034251
Totals	100.00				1.0000				44.127768				1.000000

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**Table C.2.1 Adjusted Method**

	Calculate component mass			Calculate volume		
	$w_i$	$m$	$m_i$	$\rho_{abs}$	$V$	$V$
Component	Component Mass Fraction of Mixture <sup>1</sup>	Total Measured Mass kg	Component Mass from Total Measured Mass kg <sup>1</sup>	Component Absolute Density REFPROP kg/m <sup>3</sup>	Component Volume at 20 °C & EVP m <sup>3</sup> <sup>1</sup>	Component Volume at 20 °C & EVP l <sup>1</sup>
CO <sub>2</sub>	0.001401	374,350	= 524	/ 773.39	= 0.678	678
C <sub>1</sub>	0.008977		3,361	270.00	12.448	12,448
C <sub>2</sub>	0.305504		114,365	339.04	337.320	337,320
C <sub>3</sub>	0.020088		7,520	500.06	15.038	15,038
iC <sub>4</sub>	0.419713		157,121	556.86	282.155	282,155
nC <sub>4</sub>	0.044548		16,676	578.59	28.822	28,822
iC <sub>5</sub>	0.133181		49,856	620.03	80.409	80,409
nC <sub>5</sub>	0.032337		12,105	625.70	19.346	19,346
C <sub>6+</sub>	<u>0.034251</u>		<u>12,822</u>	702.63 *	<u>18.248</u>	<u>18,248</u>
Totals	<u>1.0000</u>		<u>374,350</u>		<u>794.465</u>	<u>794,465</u> <sup>a</sup>

\* For example purposes only, the absolute density of C6+ is calculated from a 60-30-10 split of nC6, nC7, and nC8.

<sup>1</sup> Displayed values reflect the full precision of the values.

<sup>a</sup> Each component liquid volume is calculated at its equilibrium vapor pressure and equilibrium vapor pressures vary by component. Therefore, the calculated total liquid volume is not representative of the volume of the mixture and should not be used to represent a liquid volume at any one set of pressure and temperature conditions.

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## Annex D (informative)

### Calculating Gas Equivalent Energy from Mass

Measured mass is often converted to gas equivalent energy to form part of the natural gas measurement and accounting processes. This annex provides the calculation method to convert mass to gas equivalent energy.

Calculate the energy contribution of each component by multiplying the mass quantity of each component by its fuel as idea gas heating value per unit mass. The mass quantity and per mass values shall have corresponding units of measure. A conversion factor may be applied to one or both values to convert to corresponding units of measure.

Calculate the total energy by summing all of the component energies.

Example for USC 60 °F:

Component	Component Mass lbm	Gas Energy BTU/lbm	Component Energy BTU	Component Energy MMBTU <sup>1</sup>
CO2	990.3600	0	0	0
C1	6,602.4000	23,892	157,744,540.8000	57.7445
C2	234,220.1400	22,334	5,231,072,606.7600	5,231.0726
C3	308,909.7900	21,654	6,689,132,592.6600	6,689.1326
iC4	32,764.4100	21,232	695,653,953.1200	695.6540
nC4	97,963.1100	21,300	2,086,614,243.0000	2,086.6142
iC5	23,768.6400	21,044	500,187,260.1600	500.1873
nC5	25,254.1800	21,085	532,484,385.3000	532.4844
C6+	<u>94,826.9700</u>	20,887 *	<u>1,980,650,922.3900</u>	<u>1,980.6509</u>
	<u>825,300.0000</u>		<u>17,873,540,504.1900</u>	<u>17,873.5405</u>

\* For example purposes only, the absolute density of C6+ is calculated from a 60-30-10 split of nC6, nC7, and nC8.

<sup>1</sup> Displayed values do not reflect the full precision of the values.

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Example for Metric 20 °C:

Component	Component Mass kg	Gas Energy MJ/kg <sup>1</sup>	Component Energy MJ <sup>1</sup>	Component Energy GJ <sup>1</sup>
CO <sub>2</sub>	458 /	0 =	0 / 1,000.0000 =	0
C <sub>1</sub>	2,936	55.5415	163,069.9905	163.0700
C <sub>2</sub>	99,898	51.9276	5,187,467.2086	5,187.4672
C <sub>3</sub>	137,242	50.3482	6,909,887.6697	6,909.8877
iC <sub>4</sub>	14,567	49.3683	719,147.3431	719.1473
nC <sub>4</sub>	43,549	49.5264	2,156,824.2330	2,156.8242
iC <sub>5</sub>	10,574	48.9302	517,387.7642	517.3878
nC <sub>5</sub>	11,200	49.0263	549,094.3656	549.0944
C <sub>6+</sub>	<u>47,357</u>	48.5826 *	<u>2,300,726.7698</u>	<u>2,300.7268</u>
	<u>374,350</u>		<u>18,503,605.3445</u>	<u>18,503.6053</u>

\* For example purposes only, the absolute density of C6+ is calculated from a 60-30-10 split of nC6, nC7, and nC8.

<sup>1</sup> Displayed values do not reflect the full precision of the values.

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## **Annex E (informative)**

### **Calculating Equivalent Gas Volumes from Mass**

Measured mass is often converted to gas equivalent volume to form part of the natural gas measurement and accounting processes. This annex provides guidance on converting mass to equivalent gas volume.

Calculate the ideal equivalent gas volume of each component by multiplying the component mass by the absolute density.

Calculate the total ideal equivalent gas volume by summing the ideal equivalent gas volumes of all components.

Calculate the mole fraction of each component by dividing the component ideal gas equivalent volume by the total ideal equivalent gas volume.

Calculate the compressibility ( $z$ ), using the procedure in the latest version of GPA 2172 or AGA8, Part 2.

Calculate the real gas volume by multiplying the ideal equivalent gas volume by the compressibility ( $z$ ).

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Example for USC, 14.696 psia and 60 °F:

Component	Component Mass lbm	Gas Absolute Density lbm/Mcf	Component Ideal Gas Volume Mcf <sup>1</sup>	Total Ideal Gas Equivalent Volume Mcf <sup>1</sup>	Compressibility <sup>1</sup>	Total Real Gas Equivalent Volume Mcf <sup>1</sup>
CO <sub>2</sub>	990.3600 /	115.9700 =	8.5398	7,275.5341 *	0.9823	7,146.7571
C <sub>1</sub>	6,602.4000	42.2700	156.1959			
C <sub>2</sub>	234,220.1400	79.2400	2,955.8322			
C <sub>3</sub>	308,909.7900	116.2000	2,658.4319			
iC <sub>4</sub>	32,764.4100	153.1600	213.9228			
nC <sub>4</sub>	97,963.1100	153.1600	639.6129			
iC <sub>5</sub>	23,768.6400	190.1200	125.0191			
nC <sub>5</sub>	25,254.1800	190.1200	132.8328			
C <sub>6+</sub>	94,826.9700	246.2100 <sup>2</sup>	385.1467			
	<u>825,300.0000</u>		<u>7,275.5341</u>			

<sup>1</sup> Displayed values do not reflect the full precision of the values.

<sup>2</sup> For example purposes only, the absolute density of C6+ is calculated from a 60-30-10 split of nC6, nC7, and nC8.

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Example for Metric, 101.325 kPa and 20 °C:

Component	Component Mass kg	Gas Absolute Density <sup>1</sup> kg/m <sup>3</sup>	Component Ideal Gas Volume <sup>1</sup> m <sup>3</sup>	Total Ideal Gas Equivalent Volume <sup>1</sup> m <sup>3</sup>	Compressibility <sup>1</sup>	Total Real Gas Equivalent Volume <sup>1</sup> m <sup>3</sup>
CO <sub>2</sub>	458	1.829540	250.3361	202,975.8193 *	0.9824	199,393.7020
C <sub>1</sub>	2,936	0.666918	4,402.3377			
C <sub>2</sub>	99,898	1.250006	79,918.0175			
C <sub>3</sub>	137,242	1.833108	74,868.4869			
iC <sub>4</sub>	14,567	2.416209	6,028.8648			
nC <sub>4</sub>	43,549	2.416209	18,023.6860			
iC <sub>5</sub>	10,574	2.999311	3,525.4762			
nC <sub>5</sub>	11,200	2.999311	3,734.1908			
C <sub>6+</sub>	47,357	3.873966 <sup>2</sup>	12,224.4232			
	367,781		202,975.8193			

<sup>1</sup> Displayed values do not reflect the full precision of the values.

<sup>2</sup> For example purposes only, the absolute density of C<sub>6+</sub> is calculated from a 60-30-10 split of nC<sub>6</sub>, nC<sub>7</sub>, and nC<sub>8</sub>.

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## Bibliography

- REFPROP, *Reference Fluid Thermodynamic and Transport Properties*, NIST Standard Reference Database 23

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## **GPA Midstream Standard 8173**

### **History**

#### **(Adoption and Revisions)**

**1973:** Adopted as a tentative standard

**1974, 1975:** Revised

**1976:** Revised and adopted as a standard

**1983:** Revised

**1988:** Reaffirmed

**1989:** Reaffirmed

**1990:** Revised

**1994:** Reaffirmed

**1996:** Reaffirmed

**1998:** Reaffirmed

**1999:** Reaffirmed

**2017:** Revised