

CGA G-1.2—2019

**STANDARD FOR ACETYLENE
METERING AND PIPING**

FIFTH EDITION

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NOTE—Technical changes from the previous edition are underlined.

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Contents	Page
1 Introduction.....	1
2 Scope	1
3 Definitions.....	1
Part 1: Properties of acetylene	3
4 Properties of acetylene.....	3
4.1 Physical properties	3
4.2 Chemical properties.....	7
4.3 Other properties—toxicity	7
5 Conversion of gas volume to base conditions.....	7
Part 2: Acetylene metering (for low and medium pressure service).....	9
6 Types of meters for acetylene service.....	9
6.1 Inferential-type meters.....	9
6.2 Volumetric-type meters.....	10
7 Meter accessories	11
7.1 Orifice and Venturi meters.....	11
7.2 Rotary positive displacement meters.....	12
7.3 Bellows meter	13
8 Materials of construction for meters and accessories	13
8.1 Metals.....	13
8.2 Nonmetals	14
9 Installation of meters	14
9.1 Location	14
9.2 Installation method	14
9.3 Electric grounding and bonding.....	15
10 Maintenance of meters.....	15
10.1 Meter accuracy inspection.....	15
10.2 Removing the meter from service.....	15
10.3 Repairing the meter	15
10.4 Returning the meter to service	15
Part 3: Acetylene piping	16
11 General design	16
11.1 Materials.....	16
11.2 Code construction.....	16
11.3 Grounding.....	16
11.4 Weather protection	16
11.5 Overheating protection	16
11.6 Maintenance	16
11.7 Regulations.....	16
12 Piping	17
12.1 Materials.....	17
12.2 Pipe	17
12.3 Pipe fittings and flanges	17
12.4 Valves—types.....	18
12.5 Packing.....	18

12.6	Bolts and nuts for flanges	18
12.7	Gaskets	18
12.8	Pipe joint compound	18
12.9	Design and construction	18
12.10	Proximity to other facilities	18
12.11	Crossings	18
12.12	Drains	19
12.13	Purging facilities	20
12.14	Expansion joints	20
12.15	Corrosion prevention	20
12.16	Cleaning and testing	20
12.17	Warnings	20
13	Storage (gasholder)	20
13.1	Type of equipment—gasholders	20
13.2	Design of equipment	21
13.3	Warnings	21
13.4	Material specifications	21
13.5	Location	21
14	Booster system	21
14.1	Type of equipment	21
14.2	Design of equipment	22
14.3	Controls	22
15	Protective devices	22
15.1	Types of devices	22
15.2	Flash arrestors	23
15.3	Pressure relief	26
15.4	Flow controls	28
15.5	Special valves (low and medium pressure systems only)	28
15.6	Emergency shutdown	29
15.7	Packed lines	29
16	General explosive behavior of acetylene	30
16.1	Deflagrations	30
16.2	Detonations	31
16.3	Application to design	37
17	References	38

Tables

Table 1—Physical constants of acetylene	3
Table 2—Temperature versus viscosity of acetylene	6
Table 3—Specific heats of acetylene at 1 atm (Btu/lb × °F)	6
Table 4—Least pressure for complete traverse of flame psia (kPa, abs) corrected to 59 °F (15.0 °C)	36

Figures

Figure 1—Compressibility factors for acetylene	5
Figure 2—Typical liquid drain for low pressure lines	19
Figure 3—Typical liquid drain for medium pressure lines	19
Figure 4—Typical packed tower flash arrestor	23
Figure 5—Hydraulic backpressure valve	25
Figure 6—Acetylene transmission piping—typical system (low pressure production)	27
Figure 7—Acetylene transmission piping—typical system (medium pressure production)	27
Figure 8—Typical flood valve (low pressure)	29
Figure 9—Steady rates of travel of deflagration flames through acetylene in long tubes of different diameters	30

Figure 10—Pressure required for deflagration and detonation of acetylene in long tubes at room temperature with nonshock thermal ignition	31
Figure 11—Pressure profile of reaction-zone region of ideal detonation in acetylene according to the models of (a) Zeldovich-von Neumann-Doering and (b) Cook and associates	32
Figure 12—Pressure profile of gas in tube (shown at top of diagram), originally containing acetylene, at an early stage (a) and a later stage (b) of travel of the detonation wave	33
Figure 13—Pressure profile of gas in the tube of Figure 12 shortly after the detonation front has struck the end of the tube and has given rise to reflected wave (a) and a little later (b)	34
Figure 14—Explosion pressure ratios developed by the cascading process in acetylene as a function of the predetonation length: tube length ratio, calculated for 40 psia (275 kPa, abs) initial pressure and applies approximately to any initial pressure	35
Figure 15—Predetonation distance chart for acetylene in tubes assuming nonshock thermal ignition near a closed end	36

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1 Introduction

In March 1956, the Board of Directors of the International Acetylene Association appointed a committee to study the metering of acetylene for the purpose of establishing recommendations. When the International Acetylene Association became affiliated with the Compressed Gas Association, the recommendations were issued as CGA G-1.2, *Recommendations for Chemical Acetylene Metering*, in November 1961. In a similar manner, the International Acetylene Association also developed a guide for the safe handling of acetylene in transmission piping systems. This information was adopted by the Acetylene Committee of the Compressed Gas Association, and CGA G-1.3, *Acetylene Transmission for Chemical Synthesis* was published in 1984.

While reviewing the information contained in these publications, CGA realized there were points of common interest in each, and the public would best be served by joining the two previous publications in an edition of CGA G-1.2, *Acetylene Metering and Pipeline Transmission*. Further study has indicated the benefits of addressing high pressure information in this publication, which has been renamed *Acetylene Metering and Piping*.

This publication is composed of three parts. The first part deals with properties of acetylene, the second part deals with pipeline acetylene transmission, and the third part deals with acetylene piping. In each part the included data are a compilation of practices, which have evolved through the years and have been demonstrated experimentally by test to be pertinent to the safe metering and transmission of acetylene.

2 Scope

The scope of this publication is limited to a maximum working pressure of 400 psi (2760 kPa).^{1,2} The data also covers acetylene of purity greater than 99.5% on a dry basis; no attempt has been made to include the use of mixtures of acetylene and other gases.

Section 6 through Section 10 covers recommendations for acetylene metering. While the primary consideration is concerned with large-volume meters, information is also included on small-volume meters. A complete tabulation of the pertinent physical and chemical properties of the gas is included in Section 4. For more information, see CGA G-1, *Acetylene* [2]. It is recommended that standard conditions be based on clean, water-saturated acetylene at 14.73 psia and 60 °F (102 kPa, abs and 15.6 °C), although the data in this report are applicable to other base conditions [3, 4].

Sections 11 through 15 are a review of the various components of an acetylene piping system. Section 16 discusses the general explosive behavior of acetylene in piping systems on the basis of numerous tests and observations that have been made over many years. Primary consideration was given to those properties peculiar to acetylene and requiring special handling techniques and protective measures. In addition to those special techniques required by the unstable nature of acetylene, precautions in construction and operation formally applicable to flammable gases shall be observed.

3 Definitions

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

¹ kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry* [1].

² References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.1.4 Will

Used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions**3.2.1 Boiling point**

Temperature at which a substance vaporizes. If the surrounding pressure is 0.1013 MPa (1.013 bar, 14.7 psi), this temperature is described as the normal boiling point.

3.2.2 Critical pressure

Pressure that must be exerted to produce liquefaction at the critical temperature.

3.2.3 Critical temperature

Temperature above which a pure gas cannot be liquefied, regardless of the degree of compression.

3.2.4 Deflagration

Exothermic reaction such as extremely rapid oxidation or decomposition in which the reaction progresses through the unburned material at a rate less than the velocity of sound. For more information, see 16.1.

NOTE—A deflagration will have an explosive effect.

3.2.5 Density

Ratio of the mass of a specimen of a substance to its volume

3.2.6 Detonation

Exothermic reaction characterized by the pressure of a shock wave in material that establishes and maintains the reaction. For more information, see 16.2.

NOTE—The reaction zone progresses through the material at a rate greater than the velocity of sound. The principal heating mechanism is one of shock compression. A detonation will have an explosive effect.

3.2.7 Ignition temperature

Lowest temperature at which a flammable gas or vapor-air mixture ignites from its own heat source or a contacted heated surface without spark or flame. Vapors and gases spontaneously ignite at a lower temperature in oxygen than in air, and their ignition temperature may be influenced by the presence of catalytic substances.

3.2.8 Lower explosive limit (LEL)

Lower limit of flammability of a gas or vapor at ordinary ambient temperatures and pressures expressed in percent of the gas or vapor in air by volume. The LEL will vary with temperature and pressure.

NOTE—LEL is sometimes referred to as lower flammability limit (LFL).

3.2.9 Melting point

Temperature at which a substance transitions from the solid to the liquid phase. If the surrounding pressure is 0.1013 MPa (1.013 bar, 14.7 psi), this temperature is described as the normal melting point.

3.2.10 Molecular formula

Chemical formula that gives the total number of atoms of each element in each molecule of a substance [5].

3.2.11 Molecular weight

Average mass of a molecule of a compound compared to 1/12th of the mass of carbon 12 and calculated as the sum of the atomic weights of the constituent atoms [5].

3.2.12 Solubility in Water

Maximum amount of a gas that will dissolve in water, expressed as a ratio (gas to water) at a given temperature and pressure.

3.2.13 Sublimation point

Temperature at which a substance transitions directly from the solid to the gas phase without passing through the intermediate liquid phase.

3.2.14 Triple point

Only temperature and pressure at which three phases (gas, liquid, and solid) in a one-component system can exist in equilibrium.

Part 1: Properties of acetylene**4 Properties of acetylene**

Acetylene is a colorless, flammable gas and ordinarily has some type of odor due to the impurities introduced by the method of production. See CGA G-1 [2].

4.1 Physical properties**Table 1—Physical constants of acetylene**

	U.S. Units	SI Units
Molecular formula	C ₂ H ₂	C ₂ H ₂
Molecular weight	26.04	26.04
Vapor pressure at 70 °F (21.1 °C)	635 psi	4378 kPa
Density of the gas at 32 °F (0 °C) and 1 atm	0.07314 lb/ft ³	1.1716 kg/m ³
Specific gravity of the gas at 32 °F and 1 atm (air = 1)	0.906	0.906
Specific volume of the gas at 70 °F (21.1 °C) and 1 atm ¹⁾	14.7 ft ³ /lb	0.918 m ³ /kg
Specific gravity of liquid at −112 °F (−80 °C)	0.613	0.613
Density of liquid at 70 °F (21.1 °C)	24.0 lb/ft ³	384 kg/m ³
Boiling point at 10 psi ²⁾ (69 kPa)	−103.4 °F	−75.2 °C
Melting point at 10 psi ²⁾ (69 kPa)	−116 °F	−82.2 °C
Critical temperature	96.8 °F	36.0 °C
Critical pressure	907 psia	6254 kPa, abs
Critical density	14.4 lb/ft ³	231 kg/m ³
Triple point	−116 °F at 17.7 psia	−82.2 °C at 122 kPa, abs
Latent heat of vaporization at triple point	264 Btu/lb	614 kJ/kg
Latent heat of fusion at −114.7 °F (−81.5 °C)	41.56 Btu/lb	96.67 kJ/kg
Specific heat of gas at 60 °F (15.5 °C) and 1 atm		
C _p	0.383 Btu/(lb)(°F)	1.60 kJ/(kg)(°C)
C _v	0.304 Btu/(lb)(°F)	1.27 kJ/(kg)(°C)
Ratio of specific heats	1.26	1.26
Solubility in water, vol/vol at 32 °F (0 °C) and 1 atm	1.7	1.7
Solubility in water, vol/vol at 60 °F (15.6 °C)	1.1	1.1
Sublimation point, at atmospheric pressure [6]	−118 °F	−83.3 °C
¹⁾ Based on 1.171 g/L 32 °F (0 °C) and 1 atm (14.696 psia; 101.325 kPa, abs). ²⁾ Reported at 10 psi (69 kPa) instead of at 1 atm because at 1 atm acetylene sublimates directly from the solid to the gaseous state without entering the liquid state. Its sublimation point at 1 atm (14.696 psia; 101.325 kPa) is −118 °F (−83.3 °C).		

4.1.1 Density

Based on investigations by Kiyama, Holemann and Hasselmann, Legarde and Cambon, and Bottomley and Reeves, it is CGA's judgment that the most accurate value for the density of acetylene is 1.171 g/L at 760 mm of mercury and at 0° C [7, 8, 9, 10].

This value for the density of acetylene has been used in constructing the compressibility values for acetylene.

Density at 32 °F (0 °C), 760 mm Hg, dry:

- 1.171 g/L;
- 0.07310 lb/ft³; and
- 13.68 ft³/lb.

Density at 60 °F (15.6 °C), 30 in Hg, water saturated:

- 1.090 g/L;
- 0.0680 lb/ft³; and
- 14.69 ft³/lb.

4.1.2 Compressibility

The pressure-volume relation of acetylene deviates from Boyle's Law, which is applicable only to perfect gases. If V_1 equals the volume of a specified weight of acetylene that is at a low pressure of P_1 , and if V_h is the volume at high pressure, P_h , then according to Boyle's Law [11]:

$$\frac{P_1 V_1}{P_h V_h} = 1.0$$

Acetylene is super compressible so that it will occupy a smaller volume after an increase in pressure than Boyle's Law states, and, consequently, the previous ratio will be greater than unity.

The curves shown in Figure 1 present the compressibility factor, Z , for acetylene at various temperatures and pressures in which $PV = ZNRT$ [11]. The super-compressibility factor, s , (used frequently in flow computations) is the reciprocal of the compressibility factor and therefore can be calculated from the compressibility factors on curves shown in Figure 1.

The compressibility data have not been determined experimentally but are calculated from the PVT data of P. H. Holemann. To the knowledge of the authors of this report, no experimental work has been done to determine the compressibility in the ranges of pressures and temperatures presented here. Until further data are available, the use of these data is recommended.

4.1.3 Viscosity

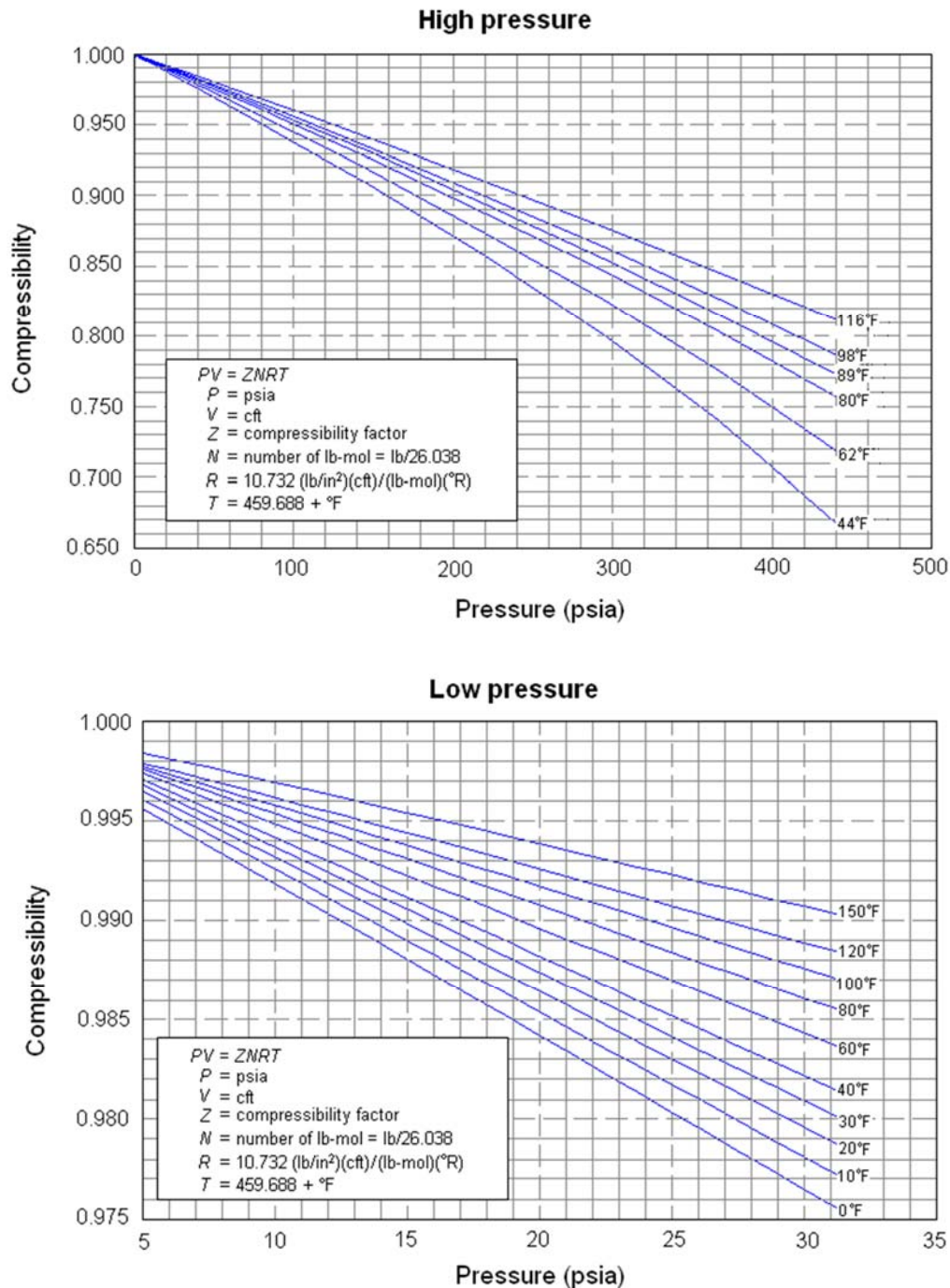
For the viscosity values, see Table 2.

4.1.4 Specific heats

For specific heats, see Table 3.

4.1.5 Explosive limits in air

The explosive limits in air are 2.5% to 81% of acetylene by volume [6, 14]. Mixtures from 81% to 100% acetylene are flammable under certain conditions. Acetylene can spontaneously decompose at elevated temperatures and pressures. Section 16 includes further information and references to the explosive properties of acetylene and acetylene-air mixtures.



NOTE—Based upon data from Air Liquide *Gas Encyclopedia* [12].

Figure 1—Compressibility factors for acetylene

Table 2—Temperature versus viscosity of acetylene [13]

Temperature °F	Temperature (°C)	Viscosity at 1 atm Centipoises
40	(4.4)	0.0095
50	(10.0)	0.0096
60	(15.6)	0.0097
65	(18.3)	0.0098
70	(21.1)	0.0100
80	(26.7)	0.0102
90	(32.2)	0.0104
100	(37.8)	0.0106
110	(43.3)	0.0108
120	(48.9)	0.0109
130	(54.4)	0.0110
140	(60.0)	0.0111
NOTE—To convert centipoise (cP) to pascal second (SI units) multiply cP × 10 ⁻³ .		

Table 3—Specific heats of acetylene at 1 atm (Btu/lb × °F) [13]

Temperature °F	Temperature (°C)	Specific heat at constant pressure	Specific heat at constant volume	Ratio C _p /C _v
40	(4.4)	0.379	0.299	1.27
50	(10.0)	0.381	0.302	1.26
60	(15.6)	0.383	0.304	1.26
65	(18.3)	0.384	0.305	1.26
70	(21.1)	0.385	0.306	1.26
80	(26.7)	0.387	0.309	1.25
90	(32.2)	0.389	0.311	1.25
100	(37.8)	0.392	0.314	1.25
110	(43.3)	0.394	0.317	1.24
120	(48.9)	0.397	0.319	1.24
130	(54.4)	0.400	0.322	1.24
140	(60.0)	0.403	0.325	1.24
NOTE—To convert Btu/(lb × °F) to kJ/(kg × °C) (SI units) multiply Btu/(lb × °F) by 4.1868.				

4.1.6 Ignition temperature

The ignition temperature of acetylene will vary depending upon the initial temperature, water vapor content, and mixture composition. The minimum ignition temperature for acetylene-air mixtures is approximately 571 °F (299 °C) and applies to mixtures in the range from 30% to 70% acetylene. The ignition temperature for pure acetylene at atmospheric pressure is approximately 1190 °F (643 °C) [6].

4.1.7 Solubility in water

In view of the solubility of acetylene in water and other liquids, the disposal of liquids containing dissolved or entrained acetylene shall be drained in a safe manner.

4.2 Chemical properties

4.2.1 Impurities

The primary impurities in acetylene generated from calcium carbide are nitrogen, phosphine, hydrogen sulfide, ammonia, oxygen, and water vapor. In some cases, small amounts of carbon dioxide, hydrogen, methane, carbon monoxide, organic sulfur compounds, silicon hydrides, and arsine can be present. The primary impurities in acetylene derived from hydrocarbons are dependent upon the method of production. Some of these impurities are carbon dioxide, ethylene, methyl acetylene, diacetylene, hydrogen, ethane, and butanes [2].

4.2.2 Hazardous reactivity

Under certain conditions, acetylene reacts with copper, silver, and mercury to form acetylides that will explode when subjected to sufficient shock or temperature. See Bramfield, Clark, and Seyfang, "Copper Acetylides," *Journal of The Society of Chemical Industry* (British), for a more complete discussion on the formation of acetylides [6]. Acetylene can react explosively with fluorine or chlorine on exposure to sunlight [6].

4.2.3 Decomposition

Acetylene can decompose with explosive violence under certain pressure conditions when subjected to sufficient temperatures. For a more complete discussion of the explosive characteristics of acetylene, see Section 11 through Section 16.

4.3 Other properties—toxicity

Acetylene is classified as a simple asphyxiant. Pure acetylene is harmful if concentrations are sufficiently high to cause asphyxiation. Commercial grade acetylene may contain harmful quantities of impurities such as phosphine and hydrogen sulfide [6, 2].

5 Conversion of gas volume to base conditions

Because accessory instruments provided with various types of meters correct the metered gas volume from meter conditions to base conditions according to the perfect gas laws and without corrections for water vapor in the case of gases containing water vapor, their use is not acceptable where utmost accuracy is required. Therefore, it is recommended that in such cases the volume at base conditions be calculated using the data provided in this publication. The following information is a guide to perform the necessary computations.

The equation representing the pressure-volume-temperature relationship of gases is:

$$PV = ZNRT$$

Where:

P = absolute pressure, psia (barometric pressure + gauge pressure);

V = volume, ft³;

Z = compressibility;

N = number of pound-moles;

R = gas constant;

T = absolute temperature, °R.

If the subscript "c" is used to denote base conditions, we may write:

$$P_c V_c = Z_c N R T_c$$

Dividing by the general equation and using subscript “m” to denote metered conditions, we obtain:

$$\frac{P_c V_c}{P_m V_m} = \frac{Z_c N R T_c}{Z_m N R T_m}$$

or

$$V_c = V_m \times \frac{P_m}{P_c} \times \frac{T_c}{T_m} \times \frac{Z_c}{Z_m}$$

Rewriting this equation in terms of the quantities measured at metered conditions and in terms of selected base conditions of 14.73 psia (101.6 kPa, abs) and 60 °F (15.6 °C), we obtain:

$$V_c = V_m \times \frac{P_b + P_r}{P_c} \times \frac{60 + 460}{460 + T_r} \times \frac{Z_c}{Z_m}$$

or

$$V_c = V_m \times \frac{P_b + P_r}{14.73} \times \frac{520}{460 + T_r} \times \frac{Z_c}{Z_m}$$

Where:

V_m = volume of gas at meter conditions;

P_b = barometric pressure, psi;

P_r = gauge pressure at meter conditions, psi;

P_c = base pressure (14.73 psia);

T_r = gas temperature at meter conditions, °F;

Z_c = compressibility at base conditions (from 4.1.2);

Z_m = compressibility at meter conditions (from 4.1.2).

The previous equation for determining the gas volume at base conditions applies for a dry gas, but in the case where acetylene is saturated with water vapor at meter and base conditions, it is necessary to correct for the water vapor. At a base temperature of 60 °F (15.6 °C), the water vapor pressure is 0.2563 psia (1.767 kPa, abs), which when subtracted from the base pressure of 14.73 psia (101.6 kPa, abs) gives a base acetylene pressure of 14.4737 psia (99.796 kPa, abs) [15]. In the same manner, the partial pressure of the acetylene meter conditions is obtained by subtracting the water vapor pressure corresponding to the meter temperature from the meter pressure.

Making this correction for water vapor and using P_w to denote the water-vapor partial pressure at meter temperature, we obtain:

$$V_c = V_m \times \frac{P_b + P_r - P_w}{14.73 - 0.2563} \times \frac{520}{460 + T_r} \times \frac{Z_c}{Z_m}$$

In the case of positive displacement meters for which a proof curve has been provided by the manufacturer, the metered volume is further corrected based on the data of the proof curve.

To obtain the metered volume of orifice-type meters, it is recommended that calculation of flow rate be in accordance with the American Society of Mechanical Engineer's (ASME) *Performance Test Codes* or the American Gas Association's (AGA) *Orifice Metering of Natural Gas*, Parts 1-4 [16, 17]. The conversion of metered volume to base conditions is then performed.

Part 2: Acetylene metering (for low and medium pressure service)

6 Types of meters for acetylene service

The selection of an acetylene meter for a specific application will depend primarily upon the required accuracy, the condition of the acetylene to be metered, and the volume of flow. Secondary considerations include the cost of the metering installation, the available space for location of the meter, and steadiness of the flow rate. The recommendations of this section are limited to low and medium pressure service. Quantity meters are generally more accurate than rate meters, especially for lower rates of flow and for nonsteady flow conditions. Quantity meters include rotary meters, bellows or diaphragm meters, and wet gas meters. Rate meters are usually less expensive than quantity meters and are accurate for steady rates of flow. Fixed-orifice meters and variable-orifice meters are typical examples of rate meters. While other types of meters may be used for the metering of acetylene, the following types of meters are most commonly used.

6.1 Inferential-type meters

6.1.1 Orifice meter

The orifice meter is classed as a rate or rate-of-flow meter not a quantity meter such as a rotary, bellows, or liquid-sealed drum meter. Unlike a quantity meter in which the gas flows through the meter in multiple counted quantities or volumes, orifice meters pass the gas in a continuous stream. The volume of gas in quantity meters is determined by counting the number of fixed volumes passing through the meter; but in the case of orifice meters, the volume of gas passing through the meter is estimated from the physical reactions of the gas upon a measuring element as the gas flows through the orifice. Based upon empirical knowledge and the physical laws of fluid mechanics, calculations can be made from these physical reactions to determine the volume of gas passing through an orifice meter.

In addition to being classed as a rate meter, the orifice meter is further classified as a head meter to differentiate it from other types of rate meters such as a force, velocity, or thermal meter. The primary measuring element in orifice meters may be an orifice plate or a Venturi tube. The gas in passing through the primary element creates a difference in pressure, or head, depending upon the velocity and density of the gas. A secondary element such as a differential pressure indicator or recorder provides a record of this pressure. By calculation or by mechanical means, this pressure can be translated into rate of flow of gas from the known characteristics of the primary measuring element. An integrating mechanism can also be included to convert the rate of flow into total volume of gas.

The accuracy of a standard commercial orifice metering system is in the range of $\pm 2\%$. In the event of calibration of the orifice and pipeline section, greater accuracy can be expected. The accuracy as a result of this calibration may approach an ultimate limit of better than $\pm 1\%$. These values of accuracy are presented here to indicate values that can be expected, but this does not imply that commercial acetylene metering installations should meet these limits.

Head or orifice-type meters have several advantages such as low cost, small space requirements, easy installation, and ready interchangeability. Their disadvantages include uncertain accuracy under pulsating flow conditions and their relatively high pressure drop [3]. The advantages and disadvantages of primary measuring elements used in head meters are important in the selection of a head meter. The following factors are presented to assist in the initial selection of the primary element.

6.1.1.1 Orifice

The advantages are it has the lowest cost, is easily installed or replaced, may be used with flange taps or pipe taps, and has well-established coefficients of discharge. Disadvantages include high nonrecoverable head loss, narrow flow range, and suspended matter will build up on upstream side.

The last condition may be improved in some cases by using eccentric or segmental types of orifices with the hole flush with the bottom of the pipe.