



## Standard Test Methods for Relative Density of Gaseous Fuels<sup>1</sup>

This standard is issued under the fixed designation D1070; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 These test methods cover the determination of relative density of gaseous fuels, including liquefied petroleum gases, in the gaseous state at normal temperatures and pressures. The test methods specified are sufficiently varied in nature so that one or more may be used for laboratory, control, reference, gas measurement, or in fact, for any purpose in which it is desired to know the relative density of gas or gases as compared to the density of dry air at the same temperature and pressure.

1.2 The procedures appear in the following sections:

|                                                       |                  |
|-------------------------------------------------------|------------------|
| Method A, Ac-Me Gravity Balance                       | Section<br>7 – 9 |
| Method B, Ranarex Recording and Indicating Gravimeter | 10–11            |
| Method C, UGC Gravimeter                              | 12 – 14          |

NOTE 1—The test methods and apparatus described herein are representative of methods and apparatus used broadly in industry. Manufacturer's instructions for specific models should be consulted for further details and as supplements to the information presented here. In addition to instrumentation described below additional equally accurate and satisfactory instruments may be available.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

**D5503 Practice for Natural Gas Sample-Handling and Conditioning Systems for Pipeline Instrumentation<sup>2</sup>**

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee D03 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.03 on Determination of Heating Value and Relative Density of Gaseous Fuels.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *density*—mass per unit of volume of the fuel gas or air being considered.

3.1.2 *gaseous fuel*—material to be tested, as sampled, without change of composition by drying or otherwise.

3.1.3 *relative density*—ratio of the density of the gaseous fuel, under the observed conditions of temperature and pressure, to the density of dried air, of normal carbon dioxide content, at the same temperature and pressure.

3.1.3.1 *Discussion*—In these test methods the term “relative density” has replaced the term “specific gravity.” The term, specific gravity, as used in a previous edition of these test methods, was used incorrectly.

3.1.4 *relative humidity*—ratio of actual pressure of existing water vapor to maximum possible pressure of water vapor in the atmosphere at the same temperature, expressed as a percentage.

### 4. Summary of Test Methods

4.1 *Displacement Balances*—This test method is based on the balancing of the weight of a fixed volume of gas at atmospheric pressure against the weight of dry air across the center of gravity of a balance beam. The amount of this “deflection,” subject to correction, for humidity, high CO<sub>2</sub> content or other factor measures the relative density. Instruments of this class may be either visual or chart recording.

4.2 *Kinetic Energy*—This test method measures the ratio of the change in kinetic energy between an impeller and an impulse wheel operating in gas and a second impeller and impulse wheel operating in a reference gas (generally air). The relative torque of the impulse wheels is measured and provides a value for relative density since the relative torque is proportional to the gas and air densities.

### 5. Significance and Use

5.1 These test methods provide accurate and reliable methods to measure the relative density of gaseous fuels on an intermittent or continuous basis. These measurements are frequently used for regulatory or contract compliance custody transfer and process control.

## 6. Sampling

6.1 The sample shall be representative of the gas to be measured and shall be taken from its source without change in form or composition. Sampling of natural gases should be in accordance with Practice **D5503**.

### **METHOD A—Ac–Me GRAVITY BALANCE (Four-Spring Type)**

## 7. Apparatus

7.1 *Ac–Me Gravity Balance (Four-Spring Type)*, pressure-tight cylindrical container mounted on a base board. Inside the container is a balance beam with a sealed float at the back and graduated scale at the front. The beam is suspended at the center by thin flat springs. A window for viewing the scale is provided at the front of the container. The balance beam may be locked by a cam mechanism when the instrument is not in use. Valves for introducing gas and air samples are provided.

7.2 *Carrying Case*, for transportation or storage.

7.3 *Air Dryer*, to dehydrate air samples (silica gel).

7.4 *Tripod*, to support the balance firmly.

7.5 *Pressure-Vacuum Pump*, to transfer samples and adjust pressure in the balance.

7.6 *Mercury Manometer*, 760 mm, to measure pressure in the balance.

7.7 *Aneroid Barometer*, temperature compensated to convert balance pressure readings to absolute pressures. (Absolute pressure not corrected to sea level.)

7.8 *Rubber Hose*, 6.35-mm (¼-in.) inside diameter, four lengths with brass swivel connections to join the balance to its operating accessories.

7.9 *Sampling Hose*, 6.35 mm (¼ in.) with swivel connections and two male 6.35-mm (¼-in.) pipe adapters.

7.10 *Additional Apparatus*—Refer to the manufacturer's literature for further information on sizes, assembly, and other details applicable to specific models.

## 8. Procedure

8.1 Assemble and set up the balance in accordance with the manufacturer's instructions, making certain that it is firmly supported, level, and is not disturbed during the entire test. Take and record the following four readings:

8.1.1 *Average Barometric Reading*—Read the aneroid barometer at the beginning and end of each test, and record the average of these two readings.

8.1.2 *Air Reading*:

8.1.2.1 Admit air through first valve and air dryer until atmospheric pressure is reached. Record temperature in the balance. Close first valve.

8.1.2.2 Open second valve and pull a vacuum of about 650 mm, then close second valve. Unlock the balance beam by turning locking level counterclockwise. The beam will then be in an unbalanced position with the zero above the hairline indicator.

8.1.2.3 Observe the scale from such a position that the reflection of your eye in the look glass is centered on the hairline. Admit air through first valve and air dryer until the beam begins to fall. Then pinch down the flow of air through first valve so that the air can be cut off at exactly the right instant to keep the beam in the balanced position. Observe the scale noting how far the zero swings above and below the hairline. The beam is balanced when the zero of the scale is swinging an equal amount above and below the hairline.

8.1.2.4 When balance is obtained, lock instrument and read and record the air vacuum shown on the manometer. Record the temperature within the balance.

8.1.3 *Gas Reading*:

8.1.3.1 Close the valve on the air dryer and close Valve 1. Then open Valve 2 and pull a vacuum of about 650 mm on the balance.

8.1.3.2 Open gas supply valve and admit gas to the balance until the pressure reads about 650 mm. (Do not exceed manometer maximum reading or the balance may be damaged.)

8.1.3.3 Repeat 8.1.3.1 and 8.1.3.2 three times. The third time will leave only about 0.05 % air in the balance. If the balance is purged by flowing gas through it, the purging should be continued until two successive readings (8.1.3.4) check.

8.1.3.4 Unlock the instrument and release gas pressure through Valve 2 until balanced position of beam is reached. Follow the same method as described for the air reading in 8.1.2.4. When balance is obtained, lock the instrument and record the gas pressure shown on the manometer. Record the temperature in the balance.

NOTE 2—When the gas supply is under a vacuum or has a high content of hydrocarbons heavier than ethane, keep the gas pressure within the balance below that in the source line or container to avoid condensation in the balance. If necessary, readjust instrument to balance on gas at a vacuum about 20 mm higher than that in the sampling source.

8.1.4 *Air Check Reading*:

8.1.4.1 Close gas supply valves. Open second valve and pull a vacuum of about 650 mm.

8.1.4.2 Admit air through the air dryer to the balance until atmospheric pressure is reached. Close first valve.

8.1.4.3 Repeat 8.1.4.1 and 8.1.4.2 at least three times or until two successive readings (8.1.4.4) will check.

8.1.4.4 Open second valve and pull a vacuum of about 650 mm, then close second valve. Unlock instrument; admit air through first valve to bring the beam to the balanced position as when taking the first air reading.

8.1.4.5 When balance is obtained, lock instrument; read and record the air vacuum shown on the manometer. Record the temperature in the balance. This reading must check with the first air reading if the two temperatures in the balance are the same. When test is complete close all valves on the balance. Close the cock on the air dryer to prevent moistening of silica gel.

## 9. Calculation

9.1 When an aneroid barometer is used in the field, it should be checked periodically with a mercury barometer. The barometer should be handled very carefully and be well packed for

transportation. If barometer reading is in inches and fractions, multiply reading by 25.4 to convert to millimetres. To convert to absolute pressure, add barometric pressure in millimetres to both air and gas pressure readings. (If air or gas reading is on vacuum, subtract it from barometric pressure.) Divide the absolute pressure for air by the absolute pressure for gas to obtain the relative density of the gases shown in the following example:

|                    | Manometer Reading |   | Barometer Reading |   | Absolute Pressure |
|--------------------|-------------------|---|-------------------|---|-------------------|
| Barometer reading: |                   |   |                   |   |                   |
| 753 mm             |                   |   |                   |   |                   |
| Air reading        | -127              | + | 753               | = | 626               |
| Gas reading        | 204               | + | 753               | = | 957               |
| Air check reading  | -127              |   |                   |   |                   |

$$\text{Relative density} = \frac{\text{absolute air pressure}}{\text{absolute gas pressure}} = \frac{626}{957} = 0.654 \quad (1)$$

9.2 When there is a difference between the temperature for the air reading and the temperature for the gas reading, these temperature readings should be converted to absolute temperature, by adding 460, and used in calculations as shown by the following example:

|                    | Manometer Reading | Absolute Pressure, P | Temperature °F | Absolute Temperature, T |
|--------------------|-------------------|----------------------|----------------|-------------------------|
| Barometer reading: |                   |                      |                |                         |
| 745 mm             |                   |                      |                |                         |
| Air reading        | -95               | 650                  | 66             | 526                     |
| Gas reading        | 197               | 942                  | 68             | 528                     |
| Air check reading  | -90               | 655                  | 70             | 530                     |

$$\text{Relative density} = (P_{\text{air}}/P_{\text{gas}}) \times (T_{\text{gas}}/T_{\text{air}}) \quad (2)$$

$$= (650/942) \times (528/526) = 0.693 \text{ (first air reading)}$$

$$\text{Relative density} = (655/942) \times (528/530) \quad (3)$$

$$= 0.693 \text{ (air check reading)}$$

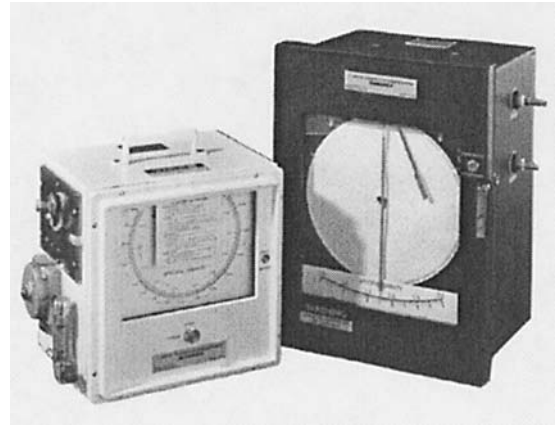
## METHOD B—RANAREX PORTABLE AND STATIONARY GRAVITOMETERS

### 10. Apparatus

10.1 *Ranarex Gravimeters* are typical of kinetic energy instruments designed for use as either portable or stationary instruments to determine and continuously record relative density. Fig. 1 shows examples of portable and recording Ranarex gravimeters.

10.1.1 Instrumentation based on the same operational principle contain common features to Ranarex models. The chassis, consisting of a main body and two chamber doors. Behind these doors are two cylindrical gas tight each having inlet and outlet connections. Each chamber contains an impeller and an impulse wheel, facing each other, in a manner similar to a torque converter. An electric motor and drive belt rotate the impellers at the same speed in opposite directions. Heavy aluminum covers enclose and protect the entire mechanism.

10.1.2 The impeller in the lower chamber draws in a continuous flow of the test gas and rotates it at high speed against the vanes of the companion impulse wheel. As the rotating gas impinges on the impulse wheel vanes, it undergoes a change in kinetic energy that creates on the lower impulse wheel a torque proportional to the density of the gas. Similarly,

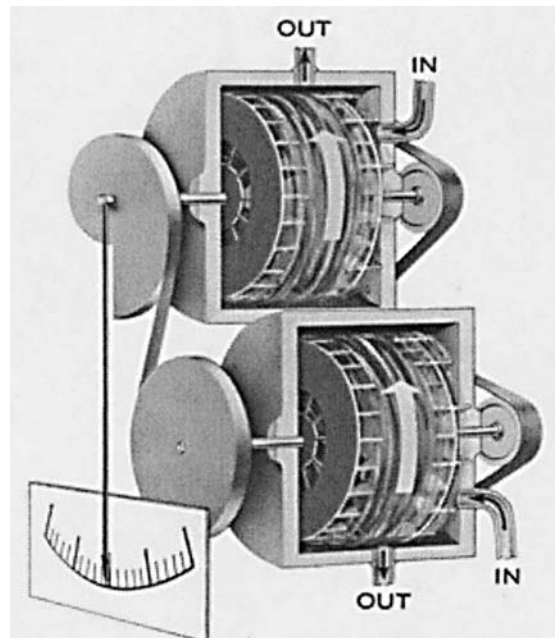


**FIG. 1 Examples of Portable and Recording Ranarex Gravimeters**

the impeller in the upper chamber draws in a continuous flow of outside air and rotates it at the same speed as the gas but in opposite direction. As the rotating air impinges on the impulse wheel vanes, it too undergoes a change in kinetic energy that creates on the upper impulse wheel, a torque proportional to the density of the air.

10.1.3 The impulse wheel torques are transmitted through pivot shafts to the external lever arms, connecting link, and indicator, which move as a system to an angular position at which the torques balance each other. The linkage system serves as a mechanical computer dividing one torque by the other. At each angular position of the linkage, there is a corresponding value for the ratio. However, since the torques are proportional to the density of the medium in each chamber, the ratio may be expressed as follows:

$$\text{density of lower chamber/density of upper chamber} \quad (4)$$



**FIG. 2 Examples of Portable and Recording Ranarex Gravimeters**

10.1.4 When the unknown gas is admitted to the lower chamber and air is admitted to the upper chamber, the ratio becomes as follows:

$$\text{density of gas/density of air} = \text{relative density} \quad (5)$$

10.1.5 The relation between the value of this fraction and angular position of the linkage and indicator is determined in the design of the instrument. The indicating scale and recording chart are graduated to read directly in relative density.

10.1.6 Refer to the manufacturer's literature for further information on sizes, assembly, and other options applicable to specific models.

## 11. Procedure

11.1 Ranarex gravimeters are direct-reading devices, and when operated in accordance with the instructions will deliver values consistent with ASTM definition for relative density (see 3.1.3). Compensation for factors, which if neglected would cause deviation from the basic definition, is provided as follows:

11.1.1 *Dried Air Standard*—Install a drier at the air inlet. The instrument must use air at normal CO<sub>2</sub> content as the reference standard.

11.1.2 *Temperature*—The air and the gas should be at the same temperature. The installation of a sample line of reasonable length relative to diameter, for example, the equivalent of 3 to 5 m (10 to 15 ft) of 9.5-mm (3/8-in.) tube or pipe, will allow sufficiently rapid heat transfer for the gas sample to reach ambient temperature before it is drawn into the reference chamber.

11.1.3 *Pressure*—Reduce the gas sample to atmospheric within 6- to 13-mm (1/4- to 1/2-in.) water column at the inlet to the apparatus. The reference air is also at atmospheric pressure. Therefore, measure both the gas and air at atmospheric pressure. Normal operating results have indicated that if the gas flow is between 0.28 to 0.71 m<sup>3</sup>/h (10 to 25 scfh), the gas pressure would be reduced to the prescribed pressure.

11.1.4 *Power Supply*—By maintaining the voltage and line frequency between the limits specified in the manufacturer's manual, the speed of the electric motor remains sufficiently constant that minor variations have no effect on measurement.

11.2 Prior to connecting the instrument to gas, turn on the motor and check the zero point on air.

NOTE 3—All instruments that include the reading 1.0 range are usually “zeroed” on air. Those that do not include 1.0 must be zeroed with a gas of known relative density such as hydrogen (H<sub>2</sub>, 0.07), helium (He, 0.14), or methane (CH<sub>4</sub>, 0.554). Turn on gas valve, allow to purge for 1 or 2 min, then record the measurement.

## METHOD C—UGC GRAVITOMETER

### 12. Apparatus

12.1 The UGC gravimeter operates on the principles of equal and opposite force. On the ends of a mechanical beam

balance, and at equal distance from the pivot point, are two identical floats. One float is specific and contains a gas sample with a known relative density. The other float is the sample float through which is passed a sample of the gas that is being measured. The pressure in the two floats is kept equal by a pressure loaded regulator. This equalization of pressure prevents error as a result of environmental conditions such as atmospheric pressure variations. A variation in the mass of the gas passing through the sample float in relation to the known sample in the balanced float will cause the beam balance to be displaced. A change in the position of the beam balance is transcribed onto a recording chart and translated to relative density.

12.2 Because of the volumes of the floats and the necessary piping, there is a lag in response time, both on increasing and decreasing densities. This lag is dependent on flow rate through the equipment and is illustrated by the manufacturer's curves.

12.3 A more detailed explanation of the theory of operation of this instrument may be found in the UGC gas gravimeter manual.

### 13. Procedure

13.1 Once the UGC gravimeter has been installed, calibrated using a certified reference gas, and placed in operation, the relative density of the gas being measured is recorded on a circular chart or using a data acquisition system.

### 14. Calculation

14.1 The UGC gravimeter is direct reading and there are no calculations to make when a relative density reading is desired.

### 15. Precision and Bias

15.1 No precision data is available for these test methods.

15.2 The apparatus described in these test methods for the determination of the relative densities of gaseous fuels may be expected to give results with an accuracy of  $\pm 1\%$  provided standard reference gases are used for calibration, good maintenance practices are followed, and extremes in operating conditions are avoided. The degree of accuracy can be proved by comparing the readings of the apparatus with standard samples that are commercially obtainable.

15.3 An error of 1 % in the determination of relative density affects by 0.5 % (less at higher pressures) the measurement of fuel gas flow by a meter employing an orifice, a pitot, or venturi tube.

### 16. Keywords

16.1 gaseous fuels; natural gas; relative density

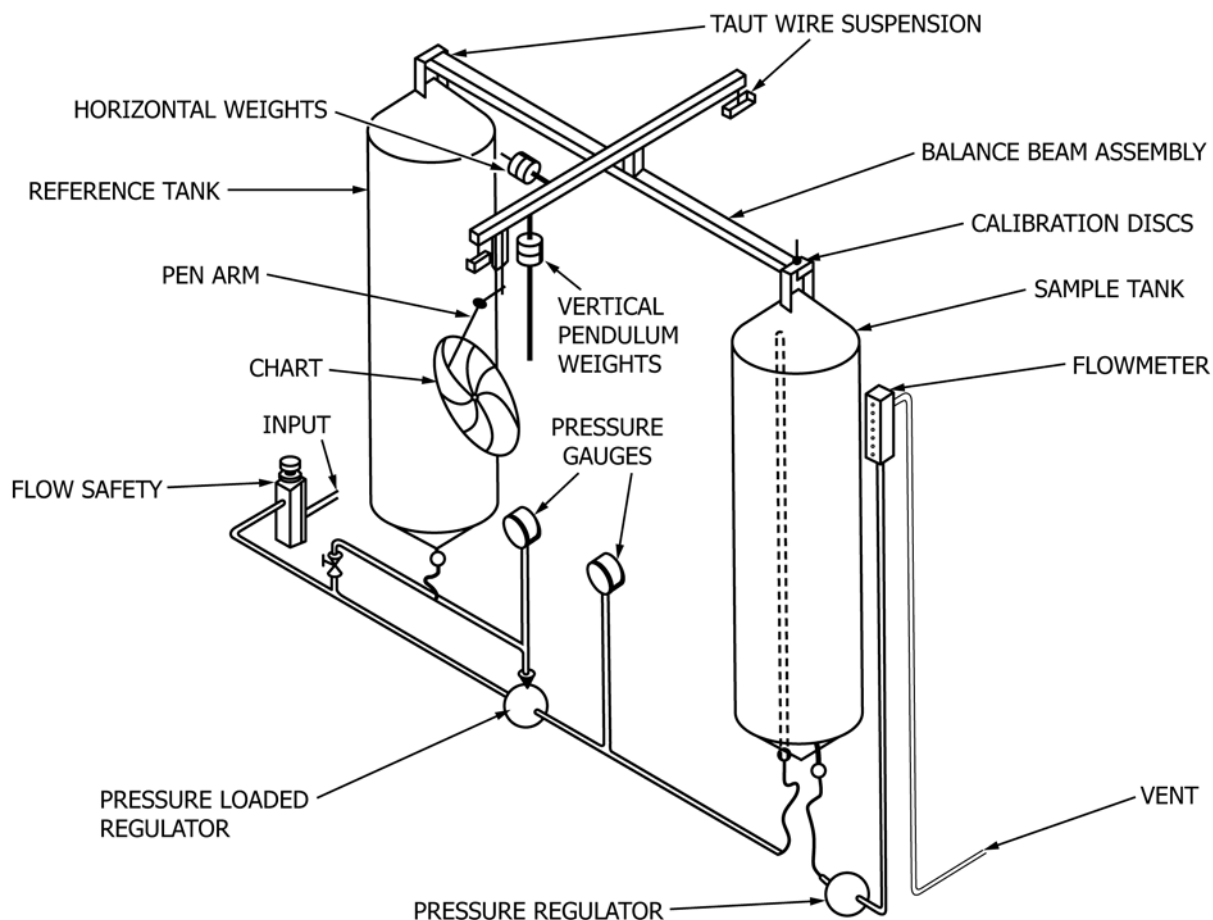


FIG. 3 UGC Gravitometer

## APPENDIXES

### (Nonmandatory Information)

#### X1. OPERATING PRECAUTIONS FOR MORE THAN ONE OF THE METHODS LISTED

##### X1.1 Wet Gas

X1.1.1 When the relative density of a “wet” fuel gas is being determined, it is imperative that the pressure in the measuring devices be maintained somewhat lower than the pressure at the source of the sample. This procedure should ensure against condensation in the device. If condensate does appear, the test should be eliminated, the unit purged of all liquids, and the tests repeated.

##### X1.2 Propane and Gasoline Vapors

X1.2.1 A source of error, which becomes appreciable with propane and may be large when the gas contains much gasoline vapors or even butane, is absorption in the connection hoses if rubber tubing or rubber gasket material is used. The exposed surface of rubber materials should be kept at a minimum, and whenever practicable, the rubber tubing should be replaced with metal. If rubber tubing must be used, it should be pre-saturated with the gas to be tested by permitting a slow flow of gas through it, overnight if practicable. The tube used

for gas should never be used for air. If gases of approximately the same composition are to be tested in succession, it will be desirable to keep air out of the gas tubing by closing the ends when not in use.

##### X1.3 Temperature of Units

X1.3.1 Special care must be taken to avoid extreme temperature changes in the units during the running of tests of recording of relative densities. Personal contact, drafts, direct sunlight, cycling heating, or air conditioning units should be avoided.

##### X1.4 Corrections for Carbon Dioxide

X1.4.1 In these standards, the relative density of gaseous fuels has been designated as the ratio of the density of the gas to that of dry air of normal CO<sub>2</sub> content, (0.03 %) at the same temperature and pressure. The composition of the outdoor air, unmodified by products of combustion from nearby equipment, is so constant with respect to all constituents except water

vapor that its density when dried does not vary sufficiently to affect the limits of accuracy prescribed in these test methods. It is possible, however, in a laboratory or compressor station to encounter CO<sub>2</sub> concentrations far in excess of normal. Under such circumstances a correction for excessive CO<sub>2</sub> becomes necessary if the maximum attainable accuracy is desired. When CO<sub>2</sub> is entirely removed its effects on observed relative density results are negligible. In the event CO<sub>2</sub> is not removed, however, corrections for carbon dioxide applicable to results obtained with the balance type instruments may be calculated as follows:

$$RD_c = R(0.9998/0.529C_c) \quad (X1.1)$$

where:

- $RD_c$  = relative density with respect to dry air with normal CO<sub>2</sub> content,
- $R$  = observed value uncorrected for carbon dioxide in the reference air,
- 0.9998 = relative density of dry air minus normal CO<sub>2</sub> content,
- $C_c$  = concentration of CO<sub>2</sub> in reference air expressed as a fraction of the total, and
- 0.529 = difference between relative density of CO<sub>2</sub> and that of air.

## X1.5 Corrections for Humidity

X1.5.1 Where the balance methods compare the sample of fuel gas directly with dry air, there is normally no correction to be made for humidity. There are special cases, however, for example in the manufactured gas industry, in which it is sometimes desired to express relative density results under some other humidity condition of gas or air than that prevailing at the time of the observation. In this particular case, standards for measurement designate a cubic foot of fuel gas as the quantity that will fill a space of 1 ft<sup>3</sup> at a pressure of 30-in. Hg and a temperature of 60°F and in equilibrium with liquid water. It is inconvenient with the test methods listed to change the humidity of either gas or air. Consequently, the relative density determined by direct observation on a fuel gas may be the ratio of a gas of one humidity to air of another, in neither of which the observer is directly interested.

X1.5.2 Miscellaneous Publication M-177 of the National Bureau of Standards provides several formulas that permit ready calculation of the relative densities of gas and air under any condition of humidity in terms of their densities when dry, the density of water vapor and the partial pressure of each component of the mixtures. In other words, they permit the calculation of the relative densities of gas or air for any condition of either from observations made under any other conditions. Symbols used in these formulas are as follows:

- $R$  = ratio of density of gas to density of air under any definite conditions of humidity in each;
- $R_s$  = particular value of  $R$  when both gas and air are saturated;
- $RD$  = relative density of dry gas, that is, it is the particular value of  $R$  when both gas and air are free from water vapor;

- $RD_g$  = relative density of gas containing a partial pressure,  $g$ , of water vapor, that is, it is a value of  $R$  when the air is dry and the gas is not;
- $a$  = partial pressure of water vapor in the air;
- $g$  = partial pressure of water vapor in the gas;
- $w$  = pressure of water vapor at saturation (when air is saturated,  $a = w$ , when the gas is saturated,  $g = w$ );
- $b$  = barometric pressure;
- $h$  = average head of water during a determination, mm Hg;
- $P$  = total pressure at which gas or air is saturated ( $b + h$ ); and
- 0.622 = relative density of water vapor; that is, the ratio of the density of pure water vapor to the density of dry air at the same temperature and pressure.

X1.5.3 The relative density,  $RD$ , of a dry gas in terms of the ratio,  $R$ , of the density of gas containing a partial pressure,  $g$ , of water vapor to the density of air containing a partial pressure,  $a$ , of the water vapor is:

$$RD = R[(p - a)/(p - g)] + [0.622(Ra - g)/(p - g)] \quad (X1.2)$$

X1.5.4 The relative density,  $RD$ , of a dry gas in terms of the ratio,  $R_s$ , of the density of saturated gas to that of saturated air is:

$$RD = R_s + [0.622w(R_s - 1)/(P - W)] \quad (X1.3)$$

X1.5.5 Another special case of equation would be the relative density,  $RD_g$ , of a gas containing a partial pressure of water vapor,  $g$ , expressed in terms of the relative density,  $RD$ , of the dry gas as follows:

$$RD_g = RD[(P - g)/P] + (0.622g/g) \quad (X1.4)$$

X1.5.6 Still another special case of equation involves a method for expressing the relative density,  $RD_g$ , under the conventional standard conditions used for designating the heating value of fuel gas in the manufactured gas industry. Here  $P = 30$ -in. Hg and  $g$  = the vapor pressure of water at 60°F. In this case,

$$RD_g = 0.9826S + 0.0108 \quad (X1.5)$$

## X1.6 Corrections for the Effect of Water Vapor and Carbon Dioxide on the Density of the Gas in the Direct Weighing Methods

X1.6.1 Because the instruments are not tightly enclosed, their readings are affected by the water vapor and CO<sub>2</sub> content in the surrounding air. Effects of the CO<sub>2</sub> content can be neglected only if the atmosphere is unquestionably fresh air or if an analysis shows the CO<sub>2</sub> content of the air to be negligibly small.

X1.6.2 If the apparatus is set to record the true relative density,  $RD$ , when in dry air of normal CO<sub>2</sub> content, the following correction which is based on the difference between the reading with the test gas and that with a calibrating gas of known relative density will apply:

$$Q = RD - R - (RD_0 - R_0) = -0.387(W - W_0) + 0.529(C - C_0) \quad (X1.6)$$

where:

- $Q$  = correction to be added to the reading to the apparatus,  
 $RD_o$  = true relative density of the calibration gas,  
 $R$  = reading in contaminated air,  
 $R_o$  = scale reading at time of calibration,  
 $W$  = fraction of water vapor by volume in the reference air,  
 $W_o$  = fraction of water vapor by volume in the air at time of calibration,  
 $C$  = fraction of  $CO_2$  by volume in reference air,  
 $C_o$  = fraction of  $CO_2$  by volume in air at time of calibration, and  
 0.529 = difference between the relative density of  $CO_2$  and that of air.

X1.6.3 In case the apparatus has been set to record relative density correctly when not surrounded by dry air but by air of assumed water content, there must also be added to the relative density the difference between 1.000, the density of dry air and the density of the surrounding atmosphere assumed in calibration.

## X1.7 Correction for the Effect of Humidity on the Chart

X1.7.1 In very precise work, especially when unusual conditions of humidity exist, the difference of reading caused by the change of dimensions of the chart should be determined and applied if it is large enough to be significant. Before this

correction can be made, however, it is necessary to measure the expansion of the chart paper at two humidities in two directions (parallel to and at right angles to the length of roll) as it comes from the paper making machine. Charts are usually printed with the “6 o’clock axis” in the direction of the minimum and the “12 o’clock axis” in the direction of the maximum expansion. Here the correction to be added algebraically is:

$$K = [dx(r - r_1) + (y - x)(r - r_o)\sin\alpha] \quad (X1.7)$$

where:

- $x$  = expansion in the direction of “6 o’clock axis,” is percent per 1 % change of relative humidity;  
 $y$  = expansion in the direction of the “12 o’clock axis;”  
 $d$  = distance from the center of the chart to the pen terms of the unit of relative density on the scale of chart;  
 $\alpha$  = angle between the line from pen to center of the chart and the “6 o’clock axis;”  
 $r$  = percent relative humidity at the time of observation;  
 $r_o$  = percent relative humidity when the chart was printed; and  
 $r_1$  = percent relative humidity when the instrument reads correctly (after correction has been made as previously described for the buoyant effect of water vapor) on the “6 o’clock axis.”

NOTE X1.1—When integrating the chart,  $r$  should be taken as the percent of average relative humidity during the time represented by the chart and  $\sin = 0.5$ .

## X2. SPECIAL INSTRUCTIONS FOR APPARATUS

### X2.1 Ranarex Recording and Indicating Gravitometer

X2.1.1 Manufacturer’s instructions should be followed in making adjustments to maintain satisfactory operation. In instances in which the calibration is consistently in error after repeated checks, the following outline of requirements should be checked in the sequence listed and the proper adjustments made.

- X2.1.1.1 Adequate flow of gas through sampling system.
- X2.1.1.2 Free flow of gas and reference air through the instrument.
- X2.1.1.3 Indicator free to respond, not “sluggish.”
- X2.1.1.4 No leakage between air and gas in sampling system or instrument.
- X2.1.1.5 Indicator in static balance with motor stopped.
- X2.1.1.6 Indicator “zeroed” or standardized accurately.
- X2.1.1.7 Gas inlet flow adjusted to:

|                                  |                                                |
|----------------------------------|------------------------------------------------|
| Portable gravitometer            | 0.22 to 0.28 m <sup>3</sup> /h (8 to 10 scfh)  |
| Precision recording gravitometer | 0.42 to 0.57 m <sup>3</sup> /h (15 to 20 scfh) |

X2.1.1.8 Silica gel of air drier in activated condition.

X2.1.1.9 Correct power supply. Refer to technical documentation provided by the manufacturer.

X2.1.2 If readings are not accurate within ½ % of known standard gases, the user is encouraged to perform these nine tests. If the error persists the calibration is listed in the manufacturer’s instructions may be adjusted, but should be attempted only as a last resort.

### X2.2 Recording UGC Gravitometer

X2.2.1 The calibration of this instrument should be done following instructions as listed in the manufacturer’s bulletins.

X2.2.2 The instrument should be checked for leakage in the floats, tanks, pressure regulator, and connecting tubing if erratic readings are obtained. Particular care should be used to install this instrument where there is no vibration.

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