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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Methods for Relative Density of Gaseous Fuels[1]

This standard is issued under the fixed designation D 1070; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the determination of relative density (specific gravity) 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:

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Method A, Ac-Me Gravity Balance	7-9
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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 as supplements to the information practical to cover here. It is not intended to imply that there are not other equally accurate and satisfactory instruments commercially available or that others will not be developed in the future.

1.3 *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:*

D 1145 Test Method of Sampling Natural Gas[2]

D 1247 Method of Sampling Manufactured Gas[2]

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 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.

3.1.4 *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.

NOTE 2—In these test methods the term "relative density" has replaced the term "specific gravity." The term, specific gravity, as used in the previous edition of these test methods, was not technically correct usage.

4. Summary of Test Methods

4.1 *Method Using Pressure Balances*—In this test method, a beam carrying a bulb and counterweight is brought to balance, successively in air and in gas, by adjusting the pressure within the balance case. The absolute pressures are determined by means of a barometer and a mercury-filled manometer, and the relative density is computed from the ratio of absolute pressures. Pressure balance instruments vary in size, method of supporting the balance beam, sealing the balance case, and other minor details of construction. However, they are all subject to corrections and errors of the same kind, although not necessarily of the same magnitude.

4.2 *Method Using Displacement Balances*—This test method uses instruments that depend on the principle of balancing the weight of a given volume of gas at atmospheric pressure by displacement of the center of gravity of a balance beam. The amount of this" deflection," subject to correction, measures the relative density. Instruments of this class may be either of the indicating or recording type. Apparatus of this general classification varies even more widely in construction than the pressure balance covered in 4.1.

4.3 *Centrifugal Force Methods*—This test method measures the difference in centrifugal force between the gaseous fuel being tested and a reference gas (air), as both are accelerated by a specially designed wheel.

4.4 *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 another impeller and

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[2] *Discontinued*—See *1986 Annual Book of ASTM Standards*, Vol 05.05.

impulse wheel operating in a reference gas (air). These measurements are in terms of the torques of the impulse wheels that are proportional, respectively, 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, which may be used for regulatory or contract compliance custody transfer and process control.

6. Sampling

6.1 The sample shall represent the gas being sampled and shall be taken from its source without change of form or composition. Sample natural gases in accordance with Test Method D 1145. Sample manufactured gases in accordance with Method D 1247.

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 3—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 nm, 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				

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

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—Ac–Me RECORDING GRAVITOMETER

10. Apparatus

10.1 *Ac–Me Gravitometer* is a continuous balancing instrument which weighs the difference between the weight of a fixed volume of air and the weight of the same volume of gas under the same temperature and pressure conditions. The gas is contained within a float that is suspended from a balance beam by knife edges and hook bearings. The weight of the metal in the float is counterbalanced by a balancing weight; therefore, the force that moves the balance beam and the recording pen arm is the difference in the weight of the gas in the float and the buoyance of the air surrounding the float. The gas whose relative density is being measured is reduced in pressure at entrance to the instrument and flows continuously through the float after which it is exhausted to atmosphere at atmospheric pressure. In this way, a continuous sample and relative density record is obtained.

10.2 Since the weight of the gas sample in the float is compared to ambient air, it is necessary to compensate for barometer and temperature changes to obtain relative density at standard conditions. The automatic compensator consists of a mercury container positioned vertically above the balance point of the balance beam, a mercury gage, and a dry air-filled tube for sensing temperature changes. As variations in atmospheric temperature take place, the pressure in the closed tube will vary accordingly; for instance, an increase in pressure is indicated by a plus reading on the mercury gage scale. The mercury displaced out of the gage by the increase in pressure is moved into the mercury container. This adds weight above the balance point and changes the center of gravity of the balanced system the proper amount to correct the relative density record for the temperature rise which took place. Variations in barometric pressure are compensated in a similar manner since the mercury container is open to the atmosphere and changes in barometric pressure will also force mercury in or out of the container.

10.2.1 The Ac–Me gravitometer is housed in a heavy sheet metal case which protects the working parts. The case has access doors at the top and side for use when adjustment or cleaning is required. The gas sample enters the instrument and is immediately reduced in pressure by an internal regulator, then passes to a small flowmeter which indicates approximate sample rate. An inlet valve is incorporated in the flowmeter for adjustment of the sample rate. The gas then flows through the inlet tubing to the bottom of the instrument and up through the float. It is discharged at the bottom past a seal of mineral oil and exhausts through a large diameter pipe to the outlet.

10.2.2 The balance beam is near the center, mounted on knife edges and bearings. It supports the float at one end and the balance weight with microweights at the other end. A vertical arm extending upward from the balance beam connects to a link, the pen arm assembly, and pen arm, transmitting the motion of the balance beam to the chart. The mercury container is vertical and at the balance point of the balance term. The sensitivity weight is vertically below the balance point. This combination is the mercury column. A rubber tube and steel tubing connect the mercury column to the compensator gage fastened to the rear of the case. The upper end of the compensator gage is attached to the rear of the case. The upper end of the compensator is attached to one end of the compensator tube, the compensator valve, and compensator dryer. An oil seal and a levomatic oiler are located at the lower end of the float. Adjustable legs are provided for leveling the instrument as well as a cross test level for checking its level.

11. Procedure

11.1 Allow the instrument time to reach temperature equilibrium with its surroundings. Set the mercury level in the compensator gage glass as follows:

11.1.1 Determine the barometric pressure then existing at the instrument. Read the thermometer. Refer to the compensator chart in the cover of the instrument and from the intersection of the temperature (vertical) and barometer (horizontal)

lines follow the diagonal lines to the corresponding compensator gage readings. Set this reading by connecting a pump or hand aspirator to the compensator dryer nipple and carefully applying enough pressure or vacuum to bring the mercury level to the proper scale reading.

11.1.2 Turn on the gas to the sample line and observe the flowmeter on the face of the instrument. Adjust the flow rate by means of the inlet valve at the top of the flowmeter inside the instrument. A rate of 0.17 m^3/h (6 ft^3/h) is suggested as normal; however, it may be varied between 0.11 m^3/h (4 ft^3/h) and 0.45 m^3/h (16 ft^3/h), if desired. Higher rates are not recommended.

11.1.3 The instrument is now in operation, and as soon as the gas sample has replaced the air in the float, it will continuously record the gas relative density.

11.2 To ensure that the instrument has not been disturbed, bumped, or otherwise dislocated and is operating properly, it may be desirable to recalibrate occasionally. Before such a recalibration, completely purge the instrument of gas since any gas remaining in the float will result in error in the calibration.

11.3 If it is desired to check the instrument reading without purging and recalibrating, this may be done by using a relative density balance for spot checks. Make such a check at a time when the relative density recording is constant so there will be no difference between the balance sample and the gas in the instrument. Draw the balance sample from the piping just ahead of the instrument. A minor adjustment of microweights may be used to bring the instrument chart reading into agreement with the balance check, if desired.

11.4 Check the reading of the compensator gage to see if it agrees with the scale reading obtained from the compensator chart; however, no change in the mercury setting should be made unless there has been no change in ambient temperature for at least 1 h. Failure on the mercury gage readings to check with the chart readings may be caused by one of the following items:

11.4.1 *Rapid Temperature Change*—During periods of rapid temperature change, the compensator may not have had time to reach ambient temperature and consequently the gage reading will not yet have come to the chart reading. In this case, do not reset the gage reading as it would introduce an error that would remain until the next check.

11.4.2 *Moist Air or Free Water in Compensator Tube*—The chart is computed on the basis of having dry air in the compensator tube, and since moist air has a different temperature-pressure-volume characteristic, it will not produce gage readings that agree with chart readings. When adjusting the compensator gage reading, connect the pump or aspirator to the hose nipple on the air dryer to prevent introducing moisture. When the drying agent (silica gel) has become saturated with moisture, as shown by its turning pink, bake it dry or replace with new material. In extreme cases, it may be necessary to purge the compensator tube with dry air.

12. Calculation

12.1 The Ac–Me recording gravitometer is direct reading and no calculations are required.

METHOD C—ARCCO-ANUBIS RECORDING GAS GRAVITOMETER

13. Apparatus

13.1 *Arcco-Anubis Recording Gas Gravitometer* is a direct-weighing instrument designed to produce a temperature, barometric pressure, and humidity-compensated record of the relative density of gases.

13.1.1 This instrument consists of two inverted, thin wall cups or bells suspended on knife edge links and with the lower bell edges submerged in oil to form a gastight seal. They are equal distances from the fulcrum of a balance beam that drives the indicating and recording pen. One bell restrains the sample gas, while the other accommodates dry reference air. The difference in weight between the dry air and gas produces an unbalance in direct proportion to the relative density of the gas.

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

14. Procedure

14.1 The gas being inspected flows under the "working bell" and out through a vertical gas column or "stack." A column of equal height contains dry air which exerts its weight to the underside of its bell. The difference in weight exerted by the two columns on the underside of their equivalent bells tends to raise or lower them causing a movement of the balance beam and recording pen in direct ratio to the relative density of the gas flowing through the instrument.

15. Calculation

15.1 The Arcco-Anubis gas gravitometer is direct reading and no calculations are required.

METHOD D—ARCCO-ANUBIS PORTABLE GAS BALANCE

16. Apparatus

16.1 *Arcco-Anubis Portable Gas Balance* is an indirect weighing instrument. It is designed primarily to meet the conditions of field service, but is equally adapted to laboratory use.

16.2 This instrument consists of a balance-type beam that has a buoy or float on one end and a counterweight and pointer on the other end. This beam assembly is suspended in a closed tube that has a glass at one end to enable the operator to observe the position of the float and pointer with respect to a calibration scale.

17. Procedure

17.1 Make relative density determination by admitting air to the sealed chamber and pressurizing it sufficiently to cause the beam to balance in the horizontal position. Note the pressure reading on the manometer. Repeat this operation, using the gas under inspection.

17.2 Convert these two manometer readings to absolute pressure by adding each to the barometric pressure. The relative density then becomes absolute pressure air/absolute pressure gas. This basic method is normally reserved for the

laboratory determinations because of the need for a manometer and a pressure-vacuum pump. An important feature of the Arcco instrument for field and related applications is a movable scale that will calibrate at atmospheric pressures thereby requiring only a barometric reading plus the balance reading for the relative density determination.

18. Calculation

18.1 The Arcco-Anubis portable gas balance requires the usual application of Boyle's and Charles' laws unless a graph supplied with the instrument is used.

18.1.1 Calculate the relative density as follows:

$$\text{Relative density} = \text{density reading} \times \frac{50 - \text{in. Hg}}{\text{abs pressure sample in. Hg}} \times \frac{\text{sample temperature °F abs}}{520°\text{F abs}} \quad (4)$$

18.1.2 By use of graph:

$$\text{relative density} = \text{density reading} \times \text{factor from graph} \quad (5)$$

METHOD E—KIMRAY GRAVITOMETER

19. Apparatus

19.1 *Kimray Gas Gravitometer* is a manually operated instrument for determining the density or relative density of gases.

19.1.1 The basic principle of centrifugal force is used with the apparatus. Gas whose relative density is to be measured enters axially into one side of a specially designed wheel that is rotated by an external drive motor and is discharged at peripheral openings in the wheel. The centrifugal pressure head thus developed is differentially measured against a similar head developed by reference gas (air) introduced into the other side of the rotating wheel in a manner identical to the introduction of the gas being tested. The differential head pressure is measured by a manometer system. The relative density (air = 1) of the gas under test is directly related to the differential pressure, and by using a suitable scale for the two manometers, a direct reading of the relative density is obtained.

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

20. Calibration

20.1 This instrument can be calibrated against air and against a standard sample. These procedures are fully covered in the manufacturer's literature.

21. Procedure

21.1 The Kimray gravitometer is a precision instrument and should be carefully handled to obtain an accurate relative density reading.

21.2 The manufacturer's literature describing the instrument presents the theory of dynamic measurement of relative density of gases with the Kimray gas gravitometer and states the precautions necessary to obtain accurate readings. Detailed operating instructions for the instrument are given. The steps outlined should be carefully observed.

METHOD F—RANAREX RECORDING AND RANAREX INDICATING GRAVITOMETER

22. Apparatus

22.1 *Ranarex Recording Gravitometer* is a kinetic-type instrument designed for use in a stationary location to determine and record continuously relative density. The Ranarex indicating gravitometer is a model of the kinetic-type instrument designed for portable service and to indicate only. A special version of the portable model is designed for operation in test cars.

22.1.1 Apparatus using the same principle is common to the various models of these kinetic-type instruments. The chassis, consisting of a main body section and two chamber doors, forms two cylindrical chambers that are gastight to each other and to outside air and have inlet and outlet connections. Each chamber contains an impeller and an impulse wheel, facing each other but not touching, similar to the arrangement used in automotive" fluid drives." An electric motor and drive belt rotate the impellers at the same speed but in opposite directions. Heavy aluminum covers enclose and protect the entire mechanism.

22.1.2 The impeller in the lower chamber draws in a continuous flow of the gas being tested 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, 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.

22.1.3 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 of the ratio. However, since the torques are proportional to the density of the medium in each chamber, the ratio may be expressed as follows:

$$\text{density of lower chamber/density of upper chamber} \quad (6)$$

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

$$\text{density of gas/density of air} = \text{relative density} \quad (7)$$

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

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

23. Procedure

23.1 Ranarex gravitometer models are direct-reading units, and when operated in accordance with the instructions will follow the ASTM definition of relative density (see 3.1.4). Compensation for factors, which if neglected would cause deviation from the basic definition, is provided as follows:

23.1.1 *Dried Air Standard*—Install a drier at the air inlet. The instrument must use air at normal CO_2 content as the reference standard.

23.1.2 *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 (⅜-in.) tube or pipe, will allow sufficiently rapid heat transfer for the gas sample to reach the temperature of the ambient before it is drawn into the reference chamber.

23.1.3 *Pressure*—Reduce the gas sample to atmospheric within 6- to 13-mm (¼- to ½-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^3/h (10 to 25 scfh), the gas pressure would be reduced to the prescribed pressure.

23.1.4 *Electric Supply*—By maintaining the voltage 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.

23.2 When the above conditions have been met and the apparatus is satisfactorily set up to receive gas, turn on the motor and check the zero point on air.

NOTE 4—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_2, 0.07), helium (He, 0.14), or methane (CH_4, 0.554). Turn on gas valve, allow to purge for 1 or 2 min, and the readings can be recorded.

METHOD G—UGC GRAVITOMETER

24. Apparatus

24.1 The UGC gravitometer 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 equilization of pressure prevents error as a result of environmental conditions such as atmospheric pressure, dew, dust, and so forth. A variation in the mass of the gas passing through the sample float in relation to the known sample in the dualed 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.

24.2 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.

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

25. Procedure

25.1 Once the UGC gravitometer has been installed, calibrated, and placed in operation, the obtaining of the relative density of the gas being measured is a matter of reading the recording chart.

26. Calculation

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

27. Precision and Bias

27.1 No precision data is available for these test methods; however, the Committee is interested in conducting an interlaboratory test program and encourages interested parties to contact the staff manager, Committee D-3, ASTM Headquarters.

27.2 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 ±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.

27.3 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.

28. Keywords

28.1 gaseous fuels; natural gas; relative density; specific gravity

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 presaturated 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 stoppering 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_2 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_2 concentrations far in excess of normal. Under such circumstances a correction for excessive CO_2 becomes necessary if the maximum attainable accuracy is desired. When CO_2 is entirely removed its effects on observed specific gravity results are negligible. In the event CO_2 is not removed, however, corrections for carbon dioxide applicable to results obtained with the balance type instruments may be calculated as follows:

$$RD_c = R\,(0.9998/0.529C_c) \quad \text{(X1.1)}$$

where:

RD_c = relative density with respect to dry air with normal CO_2 content,
R = observed value uncorrected for carbon dioxide in the reference air,
0.9998 = relative density of dry air minus normal CO_2 content,
C_c = concentration of CO_2 in reference air expressed as a fraction of the total, and
0.529 = difference between relative density of CO_2 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^3 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, $\alpha = w$, 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, α, of the water vapor is:

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

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:

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

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:

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

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,

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

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_2 content in the surrounding air. Effects of the CO_2 content can be neglected only if the atmosphere is unquestionably fresh air or if an analysis shows the CO_2 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_2 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:

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

where:
Q = correction to be added to the reading to the apparatus,
RD_0 = true relative density of the calibration gas,
R = reading in contaminated air,
R_0 = scale reading at time of calibration,
W = fraction of water vapor by volume in the reference air,
W_0 = fraction of water vapor by volume in the air at time of calibration,
C = fraction of CO_2 by volume in reference air,
C_0 = 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:

$$K = [dx(r - r_1) + (y - x)(r - r_0) \sin \alpha] \quad \text{(X1.7)}$$

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;
α = 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_0 = 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 Ac-Me Gravity Balance

X2.1.1 When the Ac-Me gravity balance is used as the standard instrument for establishing relative density of reference gases, the greater degree of accuracy necessary for this purpose requires that:

X2.1.1.1 Room temperature must be held very constant,

X2.1.1.2 There should be no pressure variation in the room such as might be caused by the cycling of an air conditioner,

X2.1.1.3 A very accurate mercurial barometer must be used,

X2.1.1.4 Manometer mercury must be clean,

X2.1.1.5 Correction factors for mercury expansion and scale material expansion should be used for both the barometer and the mercury manometer,

X2.1.1.6 The balance should be insulated for additional temperature stability,

X2.1.1.7 Dry and pure reference air or nitrogen should be used,

X2.1.1.8 Temperature stability of the gas sample must be maintained, and

X2.1.1.9 The entire system must have a periodic check against a reference gas of certified value.

X2.2 Ac-Me Recording Gravitometer

X2.2.1 It is recommended for most accurate relative densities that the gravitometer be installed in a temperature-controlled housing unit that is free from drafts and contaminated atmosphere. It should be insulated against vibration and shock to protect the knife edges.

X2.3 Arcco-Anubis Recording Gas Gravitometer

X2.3.1 The manufacturer's procedures for calibration are recommended and are covered in detail in Bulletin No. 105-D-R2. This bulletin offers a choice of standard gas check or air check, or both, as well as an alternate dead weight check of range.

X2.4 Arcco-Anubis Portable Gas Balance

X2.4.1 The manufacturer's procedures for calibration are recommended and are covered in detail in Bulletin No. 106-R1.

X2.5 Kimray Gravitometer

X2.5.1 Manufacturer's recommendations should be read and followed to assure correct use of the Kimray instrument. In addition to these instructions, the following precautions should be observed. (Some of these instructions are listed by the manufacturer but are repeated here for emphasis.)

X2.5.2 *Dirty Sample*—This instrument should be protected against contaminated samples that tend to clog the tubing or collect on the rotor. Continued instability of the instrument may indicate that a buildup of dirt may be in the lines or on the rotor. To correct this, the instrument should be broken down and cleaned up. The plastic tubing has been found to deteriorate in time in some areas, and it should be periodically checked for leaks.

X2.5.3 *Proper Oil Level*—The oil level should be checked frequently. If the air manometer pot is less than half full, the air check reading will not be correct even if the static manometer levels are okay.

X2.5.4 *Electrical Problems*—A constant voltage regulator may be desirable where voltage sources vary such as units operating from a car battery since stable voltage is a requirement for rapid testing. Corrosion on the batteries or the head controller will cause faulty operation and should be checked frequently and cleaned when necessary.

X2.6 Ranarex Recording and Indicating Gravitometer

X2.6.1 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.

X2.6.1.1 Adequate flow of gas through sampling system.

X2.6.1.2 Free flow of gas and reference air through the instrument.

X2.6.1.3 Indicator free to respond, not "sluggish."

X2.6.1.4 No leakage between air and gas in sampling system or instrument.

X2.6.1.5 Indicator in static balance with motor stopped.

X2.6.1.6 Indicator "zeroed" or standardized accurately.

X2.6.1.7 Gas inlet flow adjusted to:

Test car gravitometer	0.22 to 0.28 m^3/h (8 to 10 scfh)
Precision recording gravitometer	0.42 to 0.57 m^3/h (15 to 20 scfh)

X2.6.1.8 Silica gel of air drier in activated condition.

X2.6.1.9 Correct electric supply:

Test car gravitometer	
6 V dc	6.0 to 6.3 V
12 V dc	12.0 to 12.6 V
Precision recorder	
Voltage I, 5 %	Frequency I, 2 %

X2.6.2 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.

X2.7 Recording UGC Gravitometer

X2.7.1 The calibration of this instrument should be done following instructions as listed in the manufacturer's bulletins.

X2.7.2 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.