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Standard Test Methods for Specific Gravity, Apparent, of Liquid Industrial Chemicals[1]

This standard is issued under the fixed designation D 891; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 These test methods cover the determination of the specific gravity, apparent, of liquid industrial chemicals. Two test methods are covered as follows:

1.1.1 *Test Method A*, specific gravity, apparent, by means of a hydrometer.

1.1.2 *Test Method B*, specific gravity, apparent, by means of a pycnometer.

NOTE 1—Test Method D 4052 describes an instrumental procedure.

1.2 In common usage the term specific gravity, apparent, is understood to mean specific gravity. Since this test method is to be in conformity with Terminology E 12, all terms reading specific gravity were changed to specific gravity, apparent, without altering the meaning of specific gravity and, the term apparent could be dropped in everyday operations after establishing the use term equivalency.

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.*

1.4 Review the current Materials Safety Data Sheets (MSDS) for detailed information concerning toxicity, first aid procedures, handling, and safety precautions.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1193 Specification for Reagent Water[2]

D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter[3]

E 1 Specification for ASTM Thermometers[4]

E 12 Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases[5]

E 100 Specification for ASTM Hydrometers[4]

E 202 Test Methods for Analysis of Ethylene Glycols and Propylene Glycols[5]

E 302 Test Methods for Monobasic Organic Acids[5]

E 346 Test Methods for Analysis of Methanol[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:* [6]

3.1.1 *specific gravity, apparent*—the ratio of the weight in air of a unit volume of a material at a stated temperature to the weight in air of equal density of an equal volume of gas-free distilled water (see Note 2) at a stated temperature. It shall be stated as follows:

$$\text{Specific gravity, apparent, } x/y°C \tag{1}$$

where x is the temperature of the material and y is the temperature of the water.

NOTE 2—Gas-free distilled water is distilled water that has been boiled to eliminate dissolved gases.

4. Significance and Use

4.1 Specific gravity, apparent, may be used as a qualitative test in establishing the identity of a chemical. It may be used to calculate the volume occupied by a product whose weight is known, or to calculate the weight of a product from its volume. It may be used to determine the composition of binary mixtures of pure chemicals. In the case of most refined industrial chemicals specific gravity, apparent, is of minimal value in defining quality, although it may detect gross contamination.

4.2 Of the two test methods described, the pycnometer method (Test Method B, 1.1.2) is the most accurate and precise. For this reason it is the preferred method in case of disputes. The hydrometer method (Test Method A, 1.1.1) is the least accurate and precise, but it is also the simplest and fastest to perform and is often entirely satisfactory for many purposes.

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[1] These test methods are under the jurisdiction of ASTM Committee E15 on Industrial Chemicals and are the direct responsibility of Subcommittee E15.01 on General Standards.

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[2] *Annual Book of ASTM Standards*, Vol 11.01.

[3] *Annual Book of ASTM Standards*, Vol 05.02.

[4] *Annual Book of ASTM Standards*, Vol 14.03.

[5] *Annual Book of ASTM Standards*, Vol 15.05.

[6] These definitions conform to those in Terminology E 12 with this explanation modified as follows: specific gravity corresponds to apparent specific gravity as defined in Terminology E 12 and absolute specific gravity corresponds to specific gravity as defined in Terminology E 12.

If the sample is too viscous to permit the hydrometer to float freely, the pycnometer test method should be used.

5. Test Temperatures

5.1 Specifications for industrial chemicals often specify different temperatures at which specific gravity, apparent, shall be measured, for example:

Specific gravity, apparent, at 15.56/15.56°C,
Specific gravity, apparent, at 20/20°C,
Specific gravity, apparent, at 25/25°C, or
Specific gravity, apparent, at 60/60°F

Where precision is desired, it is necessary to determine the specific gravity, apparent, at the temperature prescribed in the specifications for the material to be tested and to use instruments that have been calibrated and standardized at the specified temperature.

5.2 The expression "specific gravity, apparent, at 25.0/15.56°C," for example, means the ratio of the weight in air of a unit volume of a material at 25.0°C to the weight in air of equal density of an equal volume of gas-free distilled water at 15.56°C.

5.3 It is possible to convert the specific gravity, apparent, at x/T_1°C to the corresponding value at x/T_2°C by multiplying the value at T_1 by the factor given in Table 1. For example, a liquid has a specific gravity, apparent, of 0.9500 at 20/20°C and the value at 20/4°C is desired: 0.9500 × 0.9982336 = 0.9483, the value at 20/4°C. The values in Table 1 are the ratios of the density of water at the appropriate temperatures.

5.4 If the change in specific gravity, apparent, with temperature of the liquid is known, the specific gravity, apparent, at T_1/y may be converted to that at T_2/y by the following equation:

$$\text{Specific gravity, apparent, at } T_2/y = (T_1 - T_2)k + \text{specific gravity, apparent, at } T_1/y \quad (2)$$

where:
T_1 = original temperature, °C,
T_2 = the second temperature,° C, and
k = change in specific gravity, apparent, per °C.

Example: The specific gravity, apparent, of *n*-butanol at 20/20°C is 0.8108 and the change in specific gravity, apparent, is 0.00074/°C. What is the specific gravity, apparent, at 4/20°C?

$$\text{Specific gravity, apparent, at } 4/20°C = [(20 - 4)0.00074] + 0.8108 = 0.8226 \quad (3)$$

TEST METHOD A—SPECIFIC GRAVITY, APPARENT, BY MEANS OF A HYDROMETER

6. Summary of Test Method

6.1 The specific gravity, apparent, of the sample is determined by immersing a calibrated hydrometer in the sample at the test temperature. The displacement of the hydrometer is a function of the specific gravity, apparent, of the sample that is read on the hydrometer scale at the level of the meniscus of the sample.

7. Apparatus

7.1 *Hydrometer*—The hydrometers to be used shall be those specified in Specification E 100, as follows:

Nominal Apparent Specific Gravity Range	ASTM Hydrometer No.
0.650 to 0.700	82H-62
0.700 to 0.750	83H-62
0.750 to 0.800	84H-62
0.800 to 0.850	85H-62
0.850 to 0.900	86H-62
0.900 to 0.950	87H-62
0.950 to 1.000	88H-62
1.000 to 1.050	89H-62
1.050 to 1.100	90H-62
1.100 to 1.150	113H-62
1.150 to 1.200	114H-62
1.200 to 1.250	115H-62

NOTE 3—The ASTM hydrometers prescribed in Test Method A, 7.1, are calibrated as if all weights are in vacuum. Equivalent values at the same temperature for all weights in air may be approximated for ambient conditions as follows:

$$\text{apparent specific gravity} = 1.00120 \times (\text{sp gr}) - 0.00120$$

where:
sp gr = specific gravity determined by ASTM hydrometer.

7.2 *Hydrometer Cylinder*—The vessel in which the sample for the gravity test is confirmed shall be made of clear glass and shall be cylindrical in shape. For convenience in pouring, it may have a lip on the rim. The inside diameter shall be at least 25.4 mm (1.0 in.) greater than the outside diameter of the hydrometer used in it. The height of the cylinder shall be such that after equilibrium has been reached, the lowest point on the hydrometer will be at least 25 mm (1 in.) off the bottom of the cylinder.

7.3 *Thermometer*—The thermometers used shall be those specified in Specification E 1. Thermometer 90C, a 76-mm immersion thermometer, covering 0 to 30°C with 0.1°C graduations, is recommended for most work. Thermometer 63C is

TABLE 1 Conversion of Specific Gravities, Apparent, from Basis x/T_1 to Basis x/T_2°C

Specific Gravities, Apparent, on Basis x/T_1	Multiplied by This Factor Gives Specific Gravities, Apparent, on Basis x/T_2				
	t/4	t/15	t/15.56	t/20	t/25
t/4	1	1.0008722	1.0009586	1.0017695	1.0029335
t/15	0.9991286	1	1.0000864	1.0008966	1.0020595
t/15.56	0.9990423	0.9999136	1	1.0008101	1.0019730
t/20	0.9982336	0.9991042	0.9991905	1	1.0011619
t/25	0.9970751	0.9979447	0.9980309	0.9988395	1

similar except it is a total immersion type and covers − 8 to 30°C with 0.1°C graduations.

7.4 *Water Bath*—A water bath capable of maintaining the selected test temperature ±0.05°C. The depth of the bath must be sufficient to immerse the hydrometer cylinder so that the contained liquid is completely below the surface of the liquid in the bath.

8. Procedure

8.1 Cool the sample in the original container to about 2°C below the temperature at which the specific gravity, apparent, is to be determined. Rinse each piece of equipment with a portion of the sample and discard the rinse liquid. Pour the sample into the clean hydrometer cylinder without splashing, so as to avoid formation of air bubbles. Remove any air bubbles adhering to the surface by touching them with a piece of clean filter paper. Select a location that is free from air currents. Place the cylinder vertically in the waterbath and let the temperature of the sample reach the temperature of the bath ±0.05°C as follows: Stir the contents of the cylinder, being careful to avoid formation of air bubbles. When the temperature of the sample is about 0.2°C below that of the bath, slowly and carefully lower the hydrometer into the sample to a level two smallest scale divisions below that at which it will float and then release the hydrometer. After it has come to rest and floats freely away from the walls of the cylinder, read the gravity as the point at which the surface of the sample apparently cuts the hydrometer scale. When the temperature of the sample matches that of the bath, make this observation by placing the eye slightly below the level of the liquid and slowly raise the eye until the surface of the sample first seen as a distorted ellipse seems to become a straight line cutting the hydrometer scale. Determine the temperature of the sample just before and also, for referee tests, just after reading the hydrometer.

9. Report

9.1 Report the reading obtained in 8.1 plus any calibration correction as the specific gravity, apparent, of the sample to the nearest 0.0001 unit.

10. Precision and Bias

10.1 *Precision*:

10.1.1 The precision of this test method should be determined for each chemical to provide criteria for judging the acceptability of results. The following precision data reported in Test Method E 302 for monobasic organic acids are typical.

10.1.2 *Repeatability* (*Single Analyst*)—The standard deviation for a single determination has been estimated to be 0.00020 unit at 24 DF. The 95 % limit for the difference between two such runs is 0.0005 unit.

10.1.3 *Within-Laboratory, Between-Days Variability (formerly called repeatability)*—The standard deviation of results (each the average of duplicates), obtained by the same analyst on different days, has been estimated to be 0.00016 unit at 12 DF. The 95 % limits for the difference between two such averages is 0.005 unit.

10.1.4 *Reproducibility (Multilaboratory)*—The standard deviation of results (each the average of duplicates), obtained by analysts in different laboratories, has been estimated to be 0.00057 unit at 5 DF. The 95 % limit for the difference between two such averages is 0.0015 unit.

10.2 *Bias*—The bias of this test method has not been determined due to the unavailability of suitable reference materials. However, the bias is dependent upon the calibration of the hydrometer and the degree of control of the temperature of the hydrometer bath.

TEST METHOD B—SPECIFIC GRAVITY, APPARENT, BY MEANS OF A PYCNOMETER[7]

11. Summary of Test Method

11.1 A tared pycnometer is filled with freshly boiled water that has been cooled to the specified test temperature and weighed to determine the weight of water in the filled pycnometer. The same pycnometer is filled with the sample at the test temperature and weighed. The ratio of the weight of sample to water in air is the specific gravity, apparent.

12. Apparatus

12.1 *Pycnometer*—A pycnometer of 25-mL capacity with a ground-glass stopper having a capillary opening, a chamber to provide for expansion up to room temperature, and a cap to prevent evaporation.

12.2 *Water Bath*—A water bath capable of maintaining the test temperature at ±0.05°C during the test.

12.3 *Thermometer*—An ASTM thermometer conforming to the requirements of Specification E 1 and covering the required temperature shall be used. Thermometer 90C, a 76-mm immersion thermometer, covers from 0 to 30°C in 0.1°C graduations, is suitable for most purposes. Thermometer 63C is similar, but is a total immersion type covering − 8 to 32°C.

12.4 *Analytical Balance*—A balance capable of weighing 150 g with a precision of 0.1 mg.

12.5 *Analytical Weights*—Class S weights, as certified by the National Institute of Standards and Technology, or equivalent weights, if required by the balance.

13. Reagents

13.1 *Water*—References to water shall be understood to mean Type II or Type III reagent water conforming to Specification D 1193.

14. Procedure

14.1 Clean the pycnometer by filling it with a saturated solution of chromic acid in sulfuric acid (H_2SO_4, sp gr 1.84), allowing it to stand for a few hours, emptying, and rinsing well with water. Fill the pycnometer with freshly boiled water that has been cooled to about 2°C below the test temperature. Place it in the water bath maintained at the test temperature ±0.05°C until the pycnometer and its contents are at a constant volume at the test temperature. After immersion in the bath for at least 30 min, adjust the level of liquid to the proper point on the

[7] For a high degree of accuracy, the following paper discusses an apparatus and method of much merit: Lipkin and Associates, "Pycnometer for Volatile Liquids," *Industrial and Engineering Chemistry*, Analytical Edition, Vol 36, Jan. 15, 1944, pp. 55–58.

TABLE 2 Precision for Specific Gravity, Apparent, by Means of a Pycnometer

	Repeatability			Within-Laboratory, Between Days Variability			Reproducibility		
	Standard Deviation, ppm	Degrees of Freedom	95 % Limit, ppm	Standard Deviation, ppm	Degrees of Freedom	95 % Limit, ppm	Standard Deviation, ppm	Degrees of Freedom	95 % Limit, ppm
Methanol	0.000028	36	0.00008	0.000026	18	0.00007	0.00017	8	0.00048
Ethylene and Propylene Glycols	0.000071	96	0.0002	0.0001	48	0.0003	0.0002	5	0.0006

pycnometer, put the stopper in place, remove from the bath, wipe dry, and weigh. Empty the pycnometer, rinse successively with alcohol and ether, remove the ether vapor, immerse in the bath, and bring to the test temperature as was done before. After immersion at the test temperature for at least 30 min, put the stopper in place, remove from the bath, wipe dry, and weigh. Subtract the weight of the empty pycnometer from the weight when filled with water in order to get the weight of the contained water at the test temperature in air. Call this difference *W*. Cool the sample about 2°C below the test temperature, fill the pycnometer with it, immerse in the bath, and bring to the test temperature as was done before. After immersion at the test temperature for at least 30 min, adjust the liquid level, put the stopper in place, remove from the bath, wipe dry, and weigh. Subtract the weight of the empty pycnometer from the weight when filled with sample in order to obtain the weight of the contained sample at the test temperature. Call this difference *S*.

15. Calculation

15.1 Calculate the specific gravity, apparent, of the sample at *x/y*°C (in air) as follows:

$$\text{Specific gravity, apparent, at } x/y°C = S/W \quad (4)$$

where:
x = temperature of the sample, °C, and
y = temperature of the water, °C.

16. Report

16.1 Report the specific gravity, apparent, value to the nearest 0.0001 unit.

17. Precision and Bias

17.1 *Precision*:

17.1.1 The precision of this test method should be determined for each chemical. The following precision data reported in Test Methods E 346 for methanol and Test Method E 202 for ethylene and propylene glycols are typical.

17.1.2 *Repeatability (Single Analyst)*—The standard deviation for a single determination has been estimated to be the value shown in Table 2at the indicated degrees of freedom. The 95 % limit for the difference between two such runs is the value shown in Table 2.

17.1.3 *Within-Laboratory, Between-Days Variability (formerly called repeatability)*—The standard deviation of results (each the average of duplicates), obtained by the same analyst on different days, has been estimated to be the value shown in Table 2. The 95 % limit for the difference between two such averages is the value shown in Table 2.

17.1.4 *Reproducibility (Multilaboratory)*—The standard deviation of results (each the average of duplicates), obtained by analysis in different laboratories, has been estimated to be the value shown in Table 2. The 95 % limit for the difference between two such averages is the value shown in Table 2.

17.2 *Bias*—The bias of this test method has not been determined due to the unavailability of suitable reference materials. However, the bias is dependent upon the calibration of the pycnometer, the degree of control of the temperature of the water bath, and the effects of humidity and static electricity during the weighing of the pycnometer.

18. Keywords

18.1 analysis; apparent; hydrometer; pycnometer; specific gravity