



Designation: D4052 – 18a

Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter¹

This standard is issued under the fixed designation D4052; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

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

1. Scope*

1.1 This test method covers the determination of the density, relative density, and API Gravity of petroleum distillates and viscous oils that can be handled in a normal fashion as liquids at the temperature of test, utilizing either manual or automated sample injection equipment. Its application is restricted to liquids with total vapor pressures (see Test Method [D5191](#)) typically below 100 kPa and viscosities (see Test Method [D445](#) or [D7042](#)) typically below about 15 000 mm²/s at the temperature of test. The total vapor pressure limitation however can be extended to >100 kPa provided that it is first ascertained that no bubbles form in the U-tube, which can affect the density determination. Some examples of products that may be tested by this procedure include: gasoline and gasoline-oxygenate blends, diesel, jet, basestocks, waxes, and lubricating oils.

1.1.1 Waxes and highly viscous samples were not included in the 1999 interlaboratory study (ILS) sample set that was used to determine the current precision statements of the method, since all samples evaluated at the time were analyzed at a test temperature of 15 °C. Wax and highly viscous samples require a temperature cell operated at elevated temperatures necessary to ensure a liquid test specimen is introduced for analysis. Consult instrument manufacturer instructions for appropriate guidance and precautions when attempting to analyze wax or highly viscous samples. Refer to the Precision and Bias section of the method and [Note 9](#) for more detailed information about the 1999 ILS that was conducted.

1.2 In cases of dispute, the referee method is the one where samples are introduced manually as in [6.2](#) or [6.3](#), as appropriate for sample type.

1.3 When testing opaque samples, and when not using equipment that is capable of automatic bubble detection, proper procedure shall be established so that the absence of air

bubbles in the U-tube can be established with certainty. For the determination of density in crude oil samples use Test Method [D5002](#).

1.4 The values stated in SI units are regarded as the standard, unless stated otherwise. The accepted units of measure for density are grams per millilitre (g/mL) or kilograms per cubic metre (kg/m³).

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific warning statements, see [3.2.1](#), Section [7](#), [9.1](#), [10.2](#), and [Appendix X1](#).

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

[D287](#) Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)

[D445](#) Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

[D1193](#) Specification for Reagent Water

[D1250](#) Guide for Use of the Petroleum Measurement Tables

[D1298](#) Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

[D4057](#) Practice for Manual Sampling of Petroleum and Petroleum Products

¹ This test method is under the jurisdiction of ASTM Committee [D02](#) on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee [D02.04.0D](#) on Physical and Chemical Methods.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

- [D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products](#)
- [D4377 Test Method for Water in Crude Oils by Potentiometric Karl Fischer Titration](#)
- [D5002 Test Method for Density, Relative Density, and API Gravity of Crude Oils by Digital Density Analyzer](#)
- [D5191 Test Method for Vapor Pressure of Petroleum Products and Liquid Fuels \(Mini Method\)](#)
- [D7042 Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer \(and the Calculation of Kinematic Viscosity\)](#)

3. Terminology

3.1 Definitions:

3.1.1 *density, n*—mass per unit volume at a specified temperature.

3.1.1.1 *Discussion*—The SI unit of density is kg/m³; the unit of measure g/cm³ is commonly used in industry.

3.1.2 *relative density, n*—the ratio of the density of a material at a stated temperature to the density of water at a stated temperature.

3.1.2.1 *Discussion*—Relative density is also commonly known as specific gravity. Commonly used stated temperatures are 20 °C/20 °C, 15 °C/15 °C, 20 °C/4 °C and 60 °F/60 °F. “Relative density” was historically known as the deprecated term “specific gravity.”

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *adjustment, v*—the operation of bringing the instrument to a state of performance suitable for its use, by setting or adjusting the density meter constants.

3.2.1.1 *Discussion*—On some digital density analyzer instruments, an adjustment may be made rather than calibrating the instrument. The adjustment procedure uses air and freshly boiled reagent water (**Warning**—Handling water at boiling or near boiling temperature can present a safety hazard. Wear appropriate personal protective equipment.) as standards to establish the linearity of measurements over a range of operating temperatures.

3.2.2 *API gravity, n*—a special function of relative density 60 °F/60 °F, represented by:

$$^{\circ}\text{API} = \frac{141.5}{\text{relative density}} - 131.5 \quad (1)$$

3.2.2.1 *Discussion*—No statement of reference temperature is required since 60 °F is included in the definition.

3.2.3 *calibration, v*—set of operations that establishes the relationship between the reference density of standards and the corresponding density reading of the instrument.

3.2.4 *sample aliquot, n*—the fraction of the original laboratory sample dedicated for this test.

3.2.4.1 *Discussion*—The sample aliquot is typically residing in syringes, sample vials, beakers, or containers for the purpose of transferring a representative test specimen into the apparatus’ U-tube.

3.2.5 *test specimen, n*—the volume of the sample aliquot residing in the U-tube during the measurement cycle.

3.2.5.1 *Discussion*—Sample material residing in filling nozzles, tubing and valve manifolds is not considered “Test Specimen.” A test specimen can be measured only once.

4. Summary of Test Method

4.1 A volume of approximately 1 mL to 2 mL of liquid sample is introduced into an oscillating U-tube and the change in oscillating frequency caused by the change in the mass of the U-tube is used in conjunction with calibration data to determine the density, relative density, or API Gravity of the sample. Both manual and automated injection techniques are described.

5. Significance and Use

5.1 Density is a fundamental physical property that can be used in conjunction with other properties to characterize both the light and heavy fractions of petroleum and petroleum products.

5.2 Determination of the density or relative density of petroleum and its products is necessary for the conversion of measured volumes to volumes at the standard temperature of 15 °C.

6. Apparatus

6.1 *Digital Density Analyzer*—A digital analyzer consisting of a U-shaped, oscillating tube, U-tube, and a system for electronic excitation, frequency counting, and display. The analyzer shall accommodate the accurate measurement of the sample temperature during measurement or shall control and keep the sample temperature constant to ± 0.05 °C. The instrument shall be capable of meeting the precision requirements described in this test method.

6.2 *Syringes*, for use primarily in manual injections, at least 2 mL in volume with a tip or an adapter tip that will fit the opening of the U-tube.

6.3 *Flow-Through or Pressure Adapter*, for use as an alternative means of introducing the sample into the density analyzer either by a pump, by pressure, or by vacuum.

NOTE 1—It is highly recommended that a vacuum not be applied to samples prone to light-end loss, as it can easily lead to the formation of bubbles in the U-tube. It is recommended to fabricate a special cap or stopper for sample containers so that air, such as from a squeeze pump, is used to displace a test specimen to the U-tube measuring cell by the flow-through method.

6.4 *Autosampler*, required for use in automated injection analyses. The autosampler shall be designed to ensure the integrity of the test specimen prior to and during the analysis and be equipped to transfer a representative portion of sample aliquot to the digital density analyzer.

6.5 *Ultrasonic Bath, Unheated*, (optional), of suitable dimensions to hold container(s) placed inside of bath, for use in effectively dissipating and removing air or gas bubbles that may be entrained in viscous sample types prior to analysis.

7. Reagents and Materials

7.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society,

where such specifications are available.³ Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water as defined by Type II of Specification **D1193** or higher.

7.3 *Water*, reagent water, freshly boiled to remove dissolved gasses, for use as primary calibration standard. (**Warning**—Handling water at boiling or near boiling temperature can present a safety hazard. Wear appropriate personal protective equipment.)

7.4 *Cleaning Solvent*, such as petroleum naphtha⁴ (**Warning**—Petroleum naphtha is extremely flammable), or other materials that are capable of flushing and removing samples entirely from the U-tube.

7.5 *Acetone*, for flushing and drying the U-tube. (**Warning**—Extremely flammable.)

7.6 *Dry Air*, for drying the U-tube.

8. Sampling, Test Specimens, and Test Units

8.1 Sampling is defined as all the steps required to obtain an aliquot of the contents of any pipe, tank, or other system, and to place the sample into the laboratory test container. The laboratory test container and sample volume shall be of sufficient capacity to mix the sample and obtain a homogeneous sample for analysis.

8.2 *Laboratory Sample*—Use only representative samples obtained as specified in Practices **D4057** or **D4177** for this test method.

8.3 *Test Specimen*—A portion or volume of sample aliquot obtained from the laboratory sample and delivered to the density analyzer U-tube. The test specimen is obtained as follows:

8.3.1 Mix the sample if required to homogenize, taking care to avoid the introduction of air bubbles. The mixing may be accomplished as described in Practice **D4177** or Test Method **D4377**. Mixing at room temperature in an open container can result in the loss of volatile material from certain sample types (for example, gasoline samples), so mixing in closed, pressurized containers or at least 10 °C below ambient temperature is required for such sample types where loss of volatile material is a potential concern. For some sample types, such as viscous lube oils that are prone to having entrained air or gas bubbles present in the sample, the use of an ultrasonic bath (see 6.5) without the heater turned on (if so equipped), has been found effective in dissipating bubbles typically within 10 min.

NOTE 2—When mixing samples with volatile components, consider the

³ *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

⁴ Suitable solvent naphthas are marketed under various designations such as “Petroleum Ether,” “Ligroine,” or “Precipitation Naphtha.”

sample properties in relation to both ambient temperature and pressure.

8.3.2 For manual injections, draw the test specimen from a properly mixed laboratory sample using an appropriate syringe. If the proper density analyzer attachments and connecting tubes are used, as described in 6.3, then the test specimen can be delivered directly to the analyzer’s U-tube from the mixing container. For automated injections, it is necessary to first transfer a portion of sample by appropriate means from a properly mixed laboratory sample to the autosampler vials, and take the necessary steps to ensure the integrity of the test specimen prior to and during the analysis. Sample vials for the autosampler shall be sealed immediately after filling up to 80 % ± 5 % and shall be kept closed until the auto sampler transfers the test specimen into the measuring cell. For highly volatile samples, cool the sample prior to measurement. Follow the manufacturer’s instructions.

NOTE 3—Overfilled sample vials can result in cross-contamination between sample vials.

9. Preparation of Apparatus

9.1 Set up the density analyzer following the manufacturer’s instructions. Set the internal temperature control so that the desired test temperature is established and maintained in the U-tube of the analyzer. Verify the instrument’s calibration at the same temperature at which the density or relative density of the sample is to be measured or perform an adjustment (see 3.2.1—Discussion) in preparation of analyzing samples. (**Warning**—Precise setting and control of the test temperature in the U-tube is extremely important. An error of 0.1 °C can result in a change in density of one in the fourth decimal when measuring in units of grams per millilitre.)

10. Verification and Adjustment

10.1 As a minimum requirement, calibration verification of the instrument is required when first set up and whenever the test temperature is changed. Whenever the apparatus fails a calibration verification without discernible cause, the apparatus must be adjusted. See 3.2.1.

10.2 The adjustment routine for digital density meters involves using a minimum of two reference media. Typically, this will be air and freshly boiled reagent water under atmospheric conditions. (**Warning**—Handling water at boiling or near boiling temperature can present a safety hazard. Wear appropriate personal protective equipment.) Other materials such as *n*-nonane, *n*-tridecane, cyclohexane, and *n*-hexadecane (for high temperature applications) can also be used as appropriate adjustment materials, provided the reference materials have density values that are certified and traceable to national standards.

10.3 Follow the manufacturer’s instructions for the proper adjustment of the apparatus. If the apparatus is adjusted using air and reagent water, observe the proper entries of air and water density values.

10.3.1 The density of air varies with pressure and relative humidity (see Table 1). Therefore, it is important that the dewpoint of ambient air is below the adjustment temperature of the instrument as to avoid condensation of water in the U-tube.

TABLE 1 Density of Water^A

NOTE 1—Several metrological entities have issued water density tables and alternative water density data is referenced in publications external to ASTM and this test method. Using water density data from an alternative recognized source does not pose a compliance issue with this test method as the variation in the data typically is limited to the sixth decimal place.

Temperature, °C	Density, g/mL	Temperature, °C	Density, g/mL	Temperature, °C	Density, g/mL
0.01	0.999844	21.0	0.997996	40.0	0.992216
3.0	0.999967	22.0	0.997773	45.0	0.990213
4.0	0.999975	23.0	0.997541	50.0	0.988035
5.0	0.999967	24.0	0.997299	55.0	0.985693
10.0	0.999703	25.0	0.997048	60.0	0.983196
15.0	0.999103	26.0	0.996786	65.0	0.980551
15.56	0.999016	27.0	0.996516	70.0	0.977765
16.0	0.998946	28.0	0.996236	75.0	0.974843
17.0	0.998778	29.0	0.995947	80.0	0.971790
18.0	0.998599	30.0	0.995650	85.0	0.968611
19.0	0.998408	35.0	0.994033	90.0	0.965310
20.0	0.998207	37.78	0.993046	99.9	0.958421

^A Densities conforming to the International Temperature Scale 1990 (ITS 90) were extracted from Lemmon, E. W., McLinden, M. O., and Friend, D. G., "Thermophysical Properties of Fluid Systems," *NIST Chemistry WebBook*, NIST Standard Reference Database No. 68, Eds. P.J. Linstrom and W.G. Mallard, National Institute of Standards and Technology, Gaithersburg, MD, <http://webbook.nist.gov> (retrieved July 24, 2013).

This can be achieved by flushing ambient air through a desiccant container and into the U-tube.

10.3.2 The density of air varies with ambient pressure as a consequence of site elevation and atmospheric changes in pressure. The air density can be calculated using this formula:

$$\rho_{\text{air}} = 0.001293[273.15 / T][P/101.325] \text{g/mL} \quad (2)$$

where:

ρ_{air} = density of air,

T = temperature, K, and

P = site atmospheric pressure at the time of adjustment, kPa.

NOTE 4—P should preferably be determined by direct measurement of the barometric pressure at the site of calibration. If direct measurement is not available, and common sources providing weather data are consulted, the pressure reported is typically corrected to Sea Level, P_{SL} . Therefore, such pressure data must be corrected back to site pressure, P. For correction of P_{SL} to P:

$$P = P_{\text{SL}} - [\text{Site Elevation (meters)} / 82.3] \quad (3)$$

NOTE 5—In the International Standard Atmosphere, ISA, the pressure drops 1 kPa per 82.3 m of elevation.

10.3.3 The water density values are given in [Table 1](#). Water density values are considered constant with respect to pressure in the range of normally occurring atmospheric pressure.

11. Quality Control Checks

11.1 Confirm the instrument is in statistical control at least once a week when it is in use, by analyzing a quality control (QC) sample that is representative of samples typically analyzed. Analysis of a single QC sample can be sufficient. Analysis of QC sample results can be carried out using control chart techniques.⁵ If the QC sample result determined causes

the laboratory to be in an out-of-control situation, such as exceeding the laboratory's control limits, instrument adjustment is required. An ample supply of QC sample material should be available for the intended period of use, and must be homogeneous and stable under the anticipated storage conditions. Prior to monitoring the measurement process, the user of the method needs to determine the average and control limits of the QC sample. The QC sample precision should be checked against the method precision to ensure data quality.

11.2 Although not mandatory, it is recommended that periodic analyses of certified density standards (that is, traceable to national standards) that are separate from those that may be used in adjusting the instrument, be used to confirm testing accuracy.

12. Procedure

12.1 Manual Injection:

12.1.1 Introduce a volume of about 1 mL to 2 mL, of sample into the clean, dry U-tube of the instrument using a suitable syringe or alternative, as described in [6.3](#).

12.1.2 The sample can also be introduced by siphoning. Plug the external TFE-fluorocarbon capillary tube into the entry port of the U-tube. Immerse the other end of the capillary in the sample and apply suction to the other port using a syringe or vacuum line until the U-tube is properly filled (see [Note 1](#)).

12.1.3 Ensure that the U-tube is properly filled and that no gas bubbles are present. The sample must be homogeneous and free of even the smallest gas bubbles. Check the integrity of the filled sample by using optical or physical methods to verify absence of gas bubbles. If gas bubbles are detected, empty and refill the U-tube, and recheck for gas bubbles.

NOTE 6—If the sample is too dark in color to determine the absence of bubbles with certainty, the density cannot be measured within the stated precision limits of [Section 15](#).

12.1.4 For most instrument models, it is recommended to turn the illumination light off with minimal delay after sample introduction and checking for bubbles because the heat generated can affect the measurement temperature. For some models however, the cell light may be left on without affecting results. Refer to the manufacturer's recommendations concerning whether to leave the illumination light off or on.

12.1.5 After the instrument displays a steady reading to four significant figures for density, relative density, or API Gravity, and five for T-values, indicating that temperature equilibrium has been reached, record the density, relative density, API Gravity or T-values, or both, as appropriate. For instruments that can print out results from the display, the print out can be used to meet the recording requirements.

12.1.6 Based on the 1999 ILS⁶ testing protocols (see [Note 9](#)), precision determinations involving a single manual injection, as well as taking the average of two manual injections, was evaluated. See the Precision and Bias section for more details. If the laboratory performs a single manual

⁵ ASTM MNL 7, *Manual on Presentation of Data Control Chart Analysis*, Section 3: Control Charts for Individuals, 6th ed., ASTM International, W. Conshohocken, PA.

⁶ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1734. Contact ASTM Customer Service at service@astm.org.