Standard Test Method for DENSITY, RELATIVE DENSITY (SPECIFIC GRAVITY), OR API GRAVITY OF CRUDE PETROLEUM AND LIQUID PETROLEUM PRODUCTS BY HYDROMETER METHOD[1]

This standard is issued under the fixed designation D 1298; 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.

This method has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This method covers the laboratory determination, using a glass hydrometer, of the density, relative density (specific gravity), or API gravity of crude petroleum, petroleum products, or mixtures of petroleum and nonpetroleum products normally handled as liquids, and having a Reid vapor pressure (Method D 323, or IP 69) of 26 lb or less. Values are measured on a hydrometer at convenient temperatures, readings of density being reduced to 15°C, and readings of relative density (specific gravity) and API gravity to 60°F, by means of international standard tables. By means of these same tables, values determined in any one of the three systems of measurement are convertible to equivalent values in either of the other two so that measurements may be made in the units of local convenience.

2. Applicable Documents

2.1 *ASTM Standards:*

D 1250 Petroleum Measurement Tables[2]

D 323 Test for Vapor Pressure of Petroleum Products[2]

E 1 Specification for ASTM Thermometers[3]

E 100 Specification for ASTM Hydrometers[4]

3. Field of Application

3.1 The hydrometer method is most suitable for determining the density, relative density (specific gravity), or API gravity of mobile transparent liquids. It can also be used for viscous oils by allowing sufficient time for the hydrometer to reach equilibrium, or for opaque oils by employing a suitable meniscus correction.

3.2 When used in connection with bulk oil measurements, volume correction errors are minimized by observing the hydrometer reading at a temperature close to that of the bulk oil temperature.

4. Summary of Method

4.1 The sample is brought to the prescribed temperature and transferred to a cylinder at approximately the same temperature. The appropriate hydrometer is lowered into the sample and allowed to settle. After temperature equilibrium has been reached, the hydrometer scale is read, and the temperature of the sample is noted. If necessary the cylinder and its contents may be placed in a constant temperature bath to avoid excessive temperature variation during the test.

5. Significance

5.1 Accurate determination of the density, relative density (specific gravity), or API gravity of petroleum and its products is necessary for the conversion of measured volumes to

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[1] This method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants, the API Central Committee on Petroleum Measurement, and the IP Standardization Committee.

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[2] *Annual Book of ASTM Standards*, Part 23.

[3] *Annual Book of ASTM Standards*, Parts 25 and 44.

[4] *Annual Book of ASTM Standards*, Parts 25, 41 and 44.

volumes at the standard temperatures of 15°C or 60°F.

5.2 Density, relative density (specific gravity), or API gravity is a factor governing the quality of crude petroleum; crude petroleum prices are frequently posted against values in degrees API. However, this property of petroleum is an uncertain indication of its quality unless correlated with other properties.

6. Definitions

6.1 *density*—for the purpose of this method, the mass (weight in vacuo) of liquid per unit volume at 15°C. When reporting results, explicitly state the density in units of mass (kilograms) and volume (litres), together with the standard reference temperature, for example, kilograms per litre at 15°C.

6.2 *relative density (specific gravity)*—for the purpose of this method, the ratio of the mass of a given volume of liquid at 15°C (60°F) to mass of an equal volume of pure water at the same temperature. When reporting results, explicitly state the standard reference temperature, for example, relative density (specific gravity) 60/60°F.

6.3 *API gravity*—a special function of relative density (specific gravity) 60/60°F, represented by:

$$\text{API gravity, deg} = (141.5/\text{sp gr } 60/60°\text{F}) - 131.5$$

No statement of reference temperature is required, since 60°F is included in the definition.

6.4 *observed values*—values observed at temperatures other than the specified reference temperature. These values are only hydrometer readings and not density, relative density (specific gravity), or API gravity at that other temperature.

7. Apparatus

7.1 *Hydrometers*, glass, graduated in units of density, relative density (specific gravity), or API gravity as required, conforming to ASTM specifications or specifications of the British Standards Institution as listed in Table 1.

7.2 *Thermometers*, having ranges shown in Table 2 and conforming to specifications of the American Society for Testing and Materials or the Institute of Petroleum.

7.3 *Hydrometer Cylinder*, clear glass, plastic (Note 1), or metal. For convenience in pouring, the cylinder may have a lip on the rim. The inside diameter of the cylinder shall be at least 25 mm greater than the outside diameter of the hydrometer used in it. The height of the cylinder shall be such that the appropriate hydrometer floats in the sample with at least 25-mm clearance between the bottom of the hydrometer and the bottom of the cylinder.

NOTE 1—hydrometer cylinders constructed of plastic materials shall be resistant to discoloration or attack by oil samples and must not become opaque under prolonged exposure to sunlight and oil samples.

7.4 *Constant-Temperature Bath*, for use when the nature of the sample requires a test temperature much above or below room temperature or the requirements of 9.8 cannot otherwise be met.

NOTE 2—The user should ascertain that the instruments used for this test conform to the requirements set out above with respect to materials, dimensions, and scale errors. In cases where the instrument is provided with a calibration certificate issued by a recognized standardizing body, the instrument is classed as "certified" and the appropriate corrections listed shall be applied to the observed readings. Instruments which satisfy the requirements of this test method, but are not provided with a recognized calibration certificate, are classed as "uncertified."

8. Temperature of Test

8.1 The density, relative density (specific gravity), or API gravity by the hydrometer method is most accurate at or near the reference temperature of 15°C or 60°F. Use these or any other temperatures between −18 and +90°C (0 and 195°F), so far as it is consistent with the type of sample and necessary limiting conditions shown in Table 3.

8.2 When the hydrometer value is to be used to select multipliers for correcting volumes to standard temperatures, the hydrometer reading should be made preferably at a temperature within ± 3°C (± 5°F) of the temperature at which the bulk volume of the oil was measured (Note 3). However, in cases when appreciable amounts of light fractions may be lost during determination at the bulk oil temperature, the limits given in Table 3 should be applied.

NOTE 3—Volume and density (relative density (specific gravity), API gravity) correction tables are based on an average expansion for a number of typical materials. Since the same coefficients were used in computing both sets of tables, corrections made over the same temperature interval minimize errors arising from possible differences between the coefficients of the material under test and the standard coefficients. This effect becomes more impor-

tant as temperatures diverge significantly from 15°C (60°F).

9. Procedure

9.1 Adjust the temperature of the sample according to the information given in Section 8. Bring the hydrometer cylinder (Note 4) and thermometer to approximately the same temperature as the sample to be tested.

NOTE 4—When testing completely opaque samples, metal hydrometer cylinders may be used. When such cylinders are used, accurate reading of the hydrometer can only be assured if the level of the sample is within 5 mm of the top of the cylinder.

9.2 Transfer the sample to a clean hydrometer cylinder without splashing, to avoid the formation of air bubbles, and to reduce to a minimum evaporation of the lower boiling constituents of more volatile samples. Transfer highly volatile samples to the cylinder by water displacement or by siphoning (Note 5). Remove any air bubbles formed, after they have collected on the surface of the sample, by touching them with a piece of clean filter paper before inserting the hydrometer.

NOTE 5—Highly volatile samples containing alcohols or other water-soluble material should always be transferred by siphoning.

9.3 Place the cylinder containing the sample in a vertical position in a location free from air currents. Ensure that the temperature of the sample does not change appreciably during the time necessary to complete the test; during this period, the temperature of the surrounding medium should not change more than 2°C (5°F). When testing at temperatures much above or below room temperature, a constant-temperature bath may be necessary to avoid excessive temperature changes.

9.4 Lower the hydrometer gently into the sample. Take care to avoid wetting the stem above the level to which it will be immersed in the liquid. Continuously stir the sample with the thermometer, taking care that the mercury thread is kept fully immersed and that the stem of the hydrometer is not wetted above the immersion level. As soon as a steady reading is obtained, record the temperature of the sample to the nearest 0.25°C (0.5°F) and then remove the thermometer.

9.5 Depress the hydrometer about two scale divisions into the liquid, and then release it. The remainder of the stem of the hydrometer, which is above the level of the liquid, must be kept dry since unnecessary liquid on the stem affects the reading obtained. With samples of low viscosity, impart a slight spin to the hydrometer on releasing to assist in bringing it to rest, floating freely away from the walls of the cylinder. Allow sufficient time for the hydrometer to come to rest, and for all air bubbles to come to the surface. This is particularly necessary in the case of more viscous samples.

9.6 When the hydrometer has come to rest, floating freely away from the walls of the cylinder (Note 6), estimate the hydrometer scale reading to the nearest 0.0001 relative density (specific gravity) or density or 0.05° API. The correct hydrometer reading is that point on the hydrometer scale at which the principal surface of the liquid cuts the scale. Determine this point by placing the eye slightly below the level of the liquid and slowly raising it until the surface, first seen as a distorted ellipse, appears to become a straight line cutting the hydrometer scale. (see Fig. 1.)

NOTE 6—When using a plastic cylinder, dissipate any static charge. Static charges often build up when using such cylinders and may prevent the hydrometer from floating freely.

9.7 With an opaque liquid take a reading by observing, with the eye slightly above the plane of the surface of the liquid, the point on the hydrometer scale to which the sample rises. This reading, at the top of the meniscus, requires correction since hydrometers are calibrated to be read at the principal surface of the liquid. The correction for the particular hydrometer in use may be determined by observing the maximum height above the principal surface of the liquid to which oil rises on the hydrometer scale when the hydrometer in question is immersed in a transparent oil having a surface tension similar to that of the sample under test (see Fig. 2).

NOTE 7—Alternatively, corrections as given in Table I may be applied.

9.8 Immediately after observing the hydrometer scale value, again cautiously stir the sample with the thermometer keeping the mercury thread fully immersed. Record the temperature of the sample to the nearest 0.2°C (0.5°F) (Note 8). Should this temperature differ from the previous reading by more than 0.5°C (1°F), repeat the hydrometer test and then

thermometer observations until the temperature becomes stable within 0.5°C (1°F).

NOTE 8—After use at a temperature higher than 38°C (100°F), allow all hydrometers of the lead shot in wax type to drain and cool in a vertical position.

10. Calculations and Report

10.1 Apply any relevant corrections to the observed thermometer reading (for scale or bulb) and to the hydrometer reading (scale). For opaque samples, make the appropriate correction to the observed hydrometer reading as given in 9.7. Record to the nearest 0.0001 density or relative density (specific gravity) or 0.1° API the final corrected hydrometer scale reading (Note 9). After application of any relevant corrections record to the nearest 0.5°C or 1°F, the mean of the temperature values observed immediately before and after the final hydrometer reading.

NOTE 9—Hydrometer scale readings at temperatures other than calibration temperatures (15°C or 60°F) should not be considered as more than scale readings since the hydrometer bulb changes with temperature.

10.2 To convert corrected values from 10.1 to standard temperature, use the following from the Petroleum Measurement Tables (D 1250):

10.2.1 When a density scaled hydrometer has been employed, use Tables 53 A or 53 B to obtain density at 15°C.

10.2.2 When a relative density (specific gravity) hydrometer has been employed, use Tables 23 A or 23 B to obtain Relative Density (Specific Gravity) 60/60 F, and

10.2.3 When an API gravity scaled hydrometer has been employed, use Tables 5 A or 5 B to obtain the gravity in API degrees.

10.3 When a value is obtained with a hydrometer scaled in one of the units described herein and a result is required in one of the other units, make the conversion by one of the appropriate tables given in Standard D 1250, Physical Data Tables. For conversion from density at 15°C, use Table 51; from relative density (specific gravity) 60/60 F, use Table 21; from API gravity, use Table 3.

10.4 Report the final value as density in kilograms per litre at 15°C, or as relative density (specific gravity) at 60/60°F, or as gravity in degrees API, as applicable.

11. Precision

11.1 The following criteria should be used for judging the acceptability of results:

11.1.1 *Repeatability*—Duplicate results by the same operator should be considered suspect if the results differ by more than the following amounts:

Product	Temperature Range	Units	Repeatability
Transparent	−2 to 24.5°C	density	0.0005
Nonviscous	29 to 76°F	relative density (specific gravity)	0.0005
	42 to 78°F	API gravity	0.1
Opaque	−2 to 24.5°C	density	0.0006
	29 to 76°F	relative density (specific gravity)	0.0006
	42 to 78°F	API gravity	0.2

11.1.2 *Reproducibility*—The results submitted by each of two laboratories should not be considered suspect unless the results differ by more than the following amounts:

Product	Temperature Range	Units	Reproducibility
Transparent	−2 to 24.5°C	density	0.0012
Nonviscous	29 to 76°F	relative density (specific gravity)	0.0012
	42 to 78°F	API gravity	0.3
Opaque	−2 to 24.5°C	density	0.0015
	29 to 76°F	relative density (specific gravity)	0.0015
	42 to 78°F	API gravity	0.5

11.1.3 For very viscous products, or when the conditions given in 11.1.1 and 11.1.2 are not compiled with, no specific variations can be given.

TABLE 1 Recommended Hydrometers

Specification	Type	Units	Range		Scale		Meniscus Correction
			Total	Each Unit	Interval	Error	
BS 718:1960 L50 SP	special petroleum	density, kg/litre at 15°C	0.600 to 1.100	0.050	0.0005	± 0.0003	+ 0.0007
BS 718:1960 M50 SP	special petroleum	density, kg/litre at 15°C	0.600 to 1.100	0.050	0.001	± 0.0006	+ 0.0014
BS 718:1960 L50 SP	special petroleum	relative density (specific gravity) 60/60°F	0.600 to 1.100	0.050	0.0005	± 0.0003	+ 0.0007
BS 718:1960 M50 SP	special petroleum	relative density (specific gravity) 60/60°F	0.600 to 1.100	0.050	0.001	± 0.0006	+ 0.0014
Specification E 100, Nos. 82H to 90H	long, plain	relative density (specific gravity), 60/60°F	0.650 to 1.100	0.050	0.0005	± 0.0005	
Specification E 100, Nos. 1H to 10H	long, plain	API	−1 to + 101	12	0.1	± 0.1	

TABLE 2 Recommended Thermometers

Specification	Type	Scale	Range	Graduation Interval	Scale Error
IP 64 C	density, wide range gravity	C	−20 to + 102	0.2	± 0.1
Specification E 1 No. 12 C	density, wide range gravity	C	−20 to + 102	0.2	± 0.1
IP 64 F	relative density (specific gravity), wide range gravity	F	−5 to + 215	0.5	± 0.25
Specification E 1 No. 12 F	relative density (specific gravity), wide range gravity	F	−5 to + 215	0.5	± 0.25

TABLE 3 Limiting Conditions and Test Temperatures

Sample Type	Initial Boiling Point	Other Limits	Test Temperature
Highly volatile		reid vapor pressure below 26 lb	Cool in original closed container to 2°C (35°F) or lower
Moderately volatile	120°C (250°F) and below		Cool in original closed container to 18°C (65°F) or lower
Moderately volatile and viscous	120°C (250°F) and below	viscosity too high at 18°C (65°F)	Heat to minimum temperature to obtain sufficient fluidity
Nonvolatile	Above 120°C (250°F)		Use any temperature between − 18 and 90°C (0 and 195°F) as convenient
Mixtures with non-petroleum products			Test at 15 ± 0.2°C (60 ± 0.5°F)

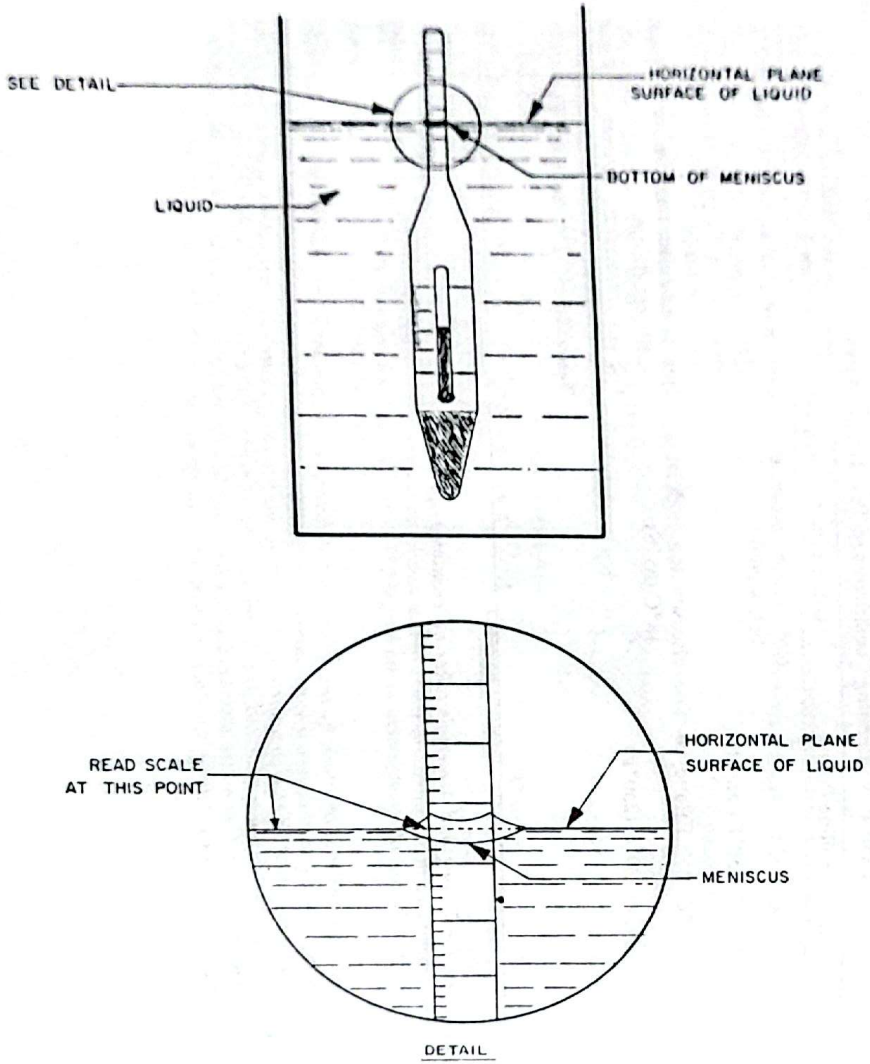

FIG. 1 Hydrometer Scale Reading for Transparent Liquids[a]

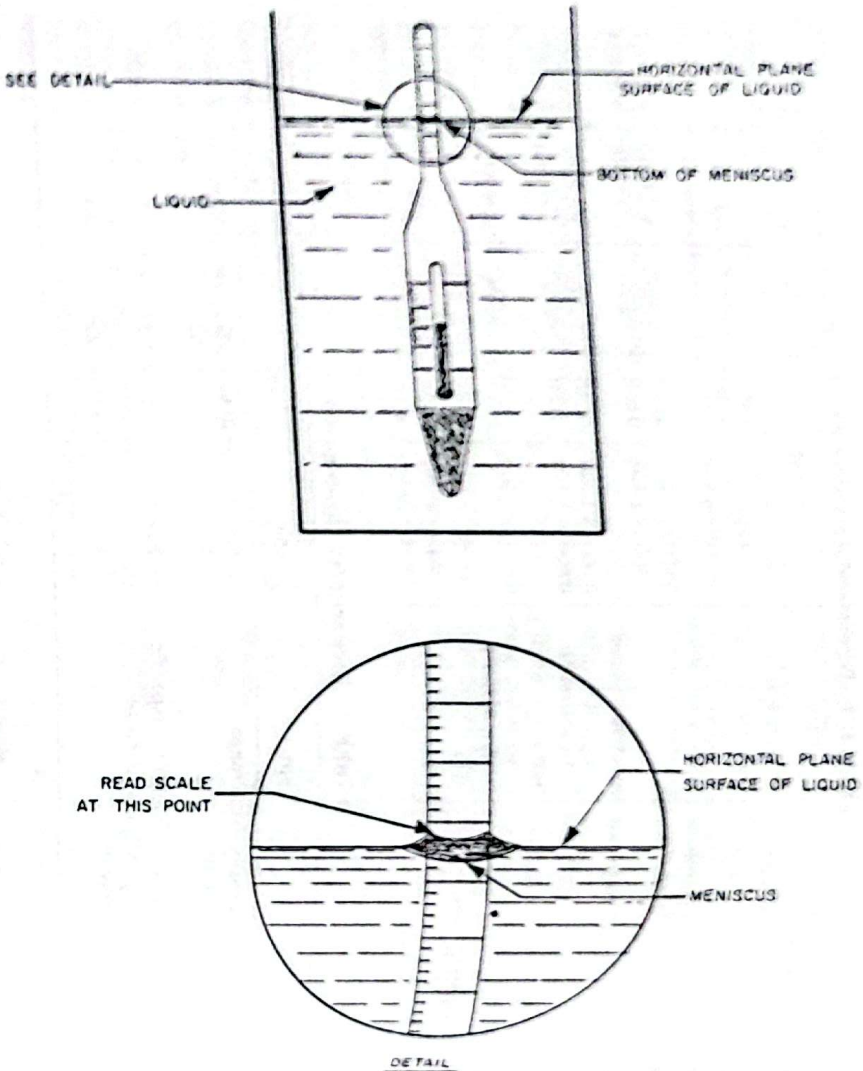

FIG. 2 Hydrometer Scale Reading for Opaque Fluids[a]

[a] Editorial changes to Figs. 1 and 2 are presently underway.