



Designation: **E100–15 E100 – 15a**

Standard Specification for ASTM Hydrometers¹

This standard is issued under the fixed designation E100; 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 specification covers glass hydrometers of various scale graduation systems, as required by the ASTM Test Methods in which they are used.

1.2 *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:*²

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

D1250 Guide for Use of the Petroleum Measurement Tables

D3290 Specification for Bond and Ledger Papers for Permanent Records (Withdrawn 2010)³

E1 Specification for ASTM Liquid-in-Glass Thermometers

E77 Test Method for Inspection and Verification of Thermometers

E126 Test Method for Inspection, Calibration, and Verification of ASTM Hydrometers

E344 Terminology Relating to Thermometry and Hydrometry

E2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

2.2

ISO 1768:1975 Glass Hydrometers—Conventional Value for the Thermal Cubic Expansion Coefficient (for Use in the Preparation of Measurement Tables for Liquids)

3. Terminology

3.1 *Definitions*—The definitions given in Terminology E344 apply.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ledger paper, n*—a paper characterized by strength, high tearing resistance, erasability, water resistance, ink receptivity, uniformity of surface, and smoothness.

¹ This specification is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.05 on Liquid-in-Glass Thermometers and Hydrometers.

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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.

³ The last approved version of this historical standard is referenced on www.astm.org.

3.2.1.1 *Discussion*—

Originally, ledger paper was used especially for pen and ink records. Most ledger papers are surface sized, frequently subjected to appreciable wear, and shall have a high degree of permanence and durability.

3.2.2 *length of the scale, n*—length of the nominal range in the stem, not including graduations extending above and below the nominal limits.

3.2.3 *relative density (formerly specific gravity), n*—ratio of the mass of a given volume of material at a stated temperature to the mass of an equal volume of gas-free distilled water at the same or different temperature. Both reference temperatures shall be explicitly stated.

3.2.3.1 *Discussion*—

Common reference temperatures include 60°F/60°F, 20°C/20°C, 20°C/4°C. The historic term specific gravity may still be found.

3.2.4 *specific gravity, n*—an historic term, replaced by *relative density*.

3.2.4.1 *Discussion*—

hydrometers manufactured to this standard may be marked sp. gr., rel. density, or with both designations. The two terms are both equally acceptable in this standard and are used interchangeably.

3.2.5 *thermohydrometer, n*—glass hydrometer having an integral thermometer.

3.2.6 *top of the hydrometer, n*—top of the finished instrument.

3.2.7 *total length, n*—overall length of the finished instrument.

4. Specifications

4.1 Individual hydrometers shall conform to the detailed specifications in Table 1 and to the general requirements specified in Sections 5 – 15.

4.2 Hydrometers shall be subjected to the inspection criteria found in Section 16 and the standardization criteria found in Section 17.

4.3 Hydrometers manufactured to previous revisions of this specification shall retain the same ASTM status as those meeting current specifications.

4.4 At the time of purchase, scale errors shall be within the maximum scale error found in Table 1.

NOTE 1—**Caution**—Users should be aware that both temperature and density indications of thermohydrometers may change with rough handling, shock, exposure to aggressive liquids, and thermal cycling, among other factors. Consequently, test results and performance obtained at the time of manufacture may not necessarily apply throughout an extended period of use. Periodic calibration or verification of these instruments, in accordance with procedures set forth in Test Method E126 (for the hydrometer), or Test Method E77 (for the integral thermometer), is recommended.

5. Type

5.1 Hydrometers shall be of the constant-mass, variable-displacement type. Hydrometers shall be made of glass, except for the scale, ballast, and the thermometric liquid of thermohydrometers.

5.2 The outer surface of the stem and body shall be symmetrical about the vertical axis. There shall be no uneven or unnecessary thickening of the walls, and no abrupt changes or constrictions that would hinder thorough cleaning or tend to trap air bubbles when the instrument is immersed.

5.3 The hydrometer shall always float with its axis vertical in liquids for which it is intended.

5.4 The hydrometer shall be thoroughly dry on the inside when sealed. The top of the stem shall be neatly rounded without unnecessary thickening.

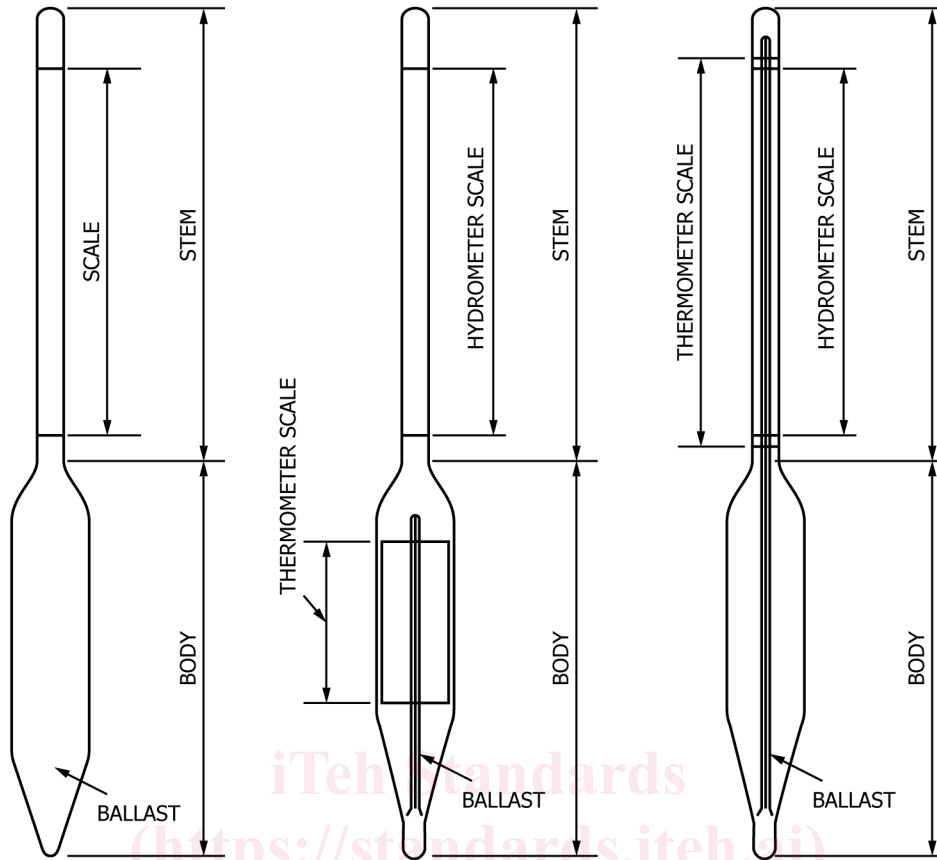
5.5 The glass shall be smooth, transparent, and free of bubbles, cracks, strain patterns, or other imperfections that might interfere with the use of the hydrometer. The glass shall adequately resist the reaction of chemical agents to which hydrometers may be exposed and shall have suitable thermal properties to permit its use over the range of temperatures to which it may be subjected. In general, glasses suitable for constructing the bulbs of thermometers are satisfactory for hydrometers.

5.6 ~~The API hydrometers are intended to be used in conjunction with Test Method D287, hydrometer readings being corrected using Guide D1250, IP 200. Therefore, these hydrometers shall be made of glass having a coefficient of volumetric or cubical expansion of~~ shall be fabricated from soda-lime glass tubing having a thermal cubical expansion coefficient of $(25 \pm 2) \times 10^{-6}$ approximately $0.000023/1^{\circ}\text{C}$ per $^{\circ}\text{C}$.

NOTE 2—The value of the thermal cubical expansion coefficient given above is consistent with the conventional value given in ISO 1768:1975 or 0.0000128/1°F at 15.56°C (60°F).

6. Body

6.1 The preferred shapes for the bodies of hydrometers are shown in Figs. 1 and 2.



(a) Plain Hydrometer

(b) Thermohydrometer with Thermometer in Body

(c) Thermohydrometer with Thermometer in Stem

FIG. 1 Typical Hydrometers Designs

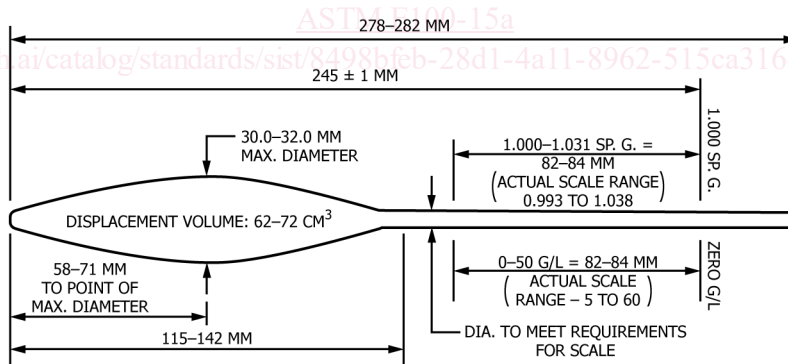


FIG. 2 Soil Hydrometers

7. Ballast

7.1 Material used for ballast shall be secured to the lower part of the body, and no loose material of any sort may be inside a hydrometer. When cement is used to hold the ballast securely in place, this cement shall not soften below 105°C (221°F).

7.2 A solid material, such as a shot, may be placed in a small bulb below the main bulb of the hydrometer and then melted or secured by cement.

7.3 If steel shot is used and sealed with wax, the wax shall not soften below 105°C (221°F).

7.4 Mercury shall not be used as ballast material in plain form hydrometers.

8. Stem

8.1 The stem shall be uniform in cross section, with no perceptible irregularities. It shall extend at least 15 mm above the top graduation and remain cylindrical for at least 3 mm below the lowest graduation.

9. Scale

9.1 The material for the scale is not specified. However, if paper is used, it shall only be ledger paper, meeting the specifications in Specification **D3290**. The scale may be anchored by a design which prevents it from moving; otherwise, it shall be fixed in place with cement that will not soften below 105°C (221°F) and will not deteriorate with time. The paper shall show no evidence of scorching or charring when received or after use at 105°C (221°F). The scale shall be straight and without twist.

10. Markings

10.1 Graduation lines and inscriptions shall be in a permanent black marking material, such as India ink.

10.2 All graduation lines shall be straight, fine lines not exceeding one fifth of the graduation interval in thickness, and in no case more than 0.2 mm. The lines shall be perpendicular to the vertical axis of the hydrometer. The lengths of main division lines, subdivision lines, and intermediate lines, if used, shall be so chosen as to facilitate readings. The shortest lines shall be at least 2 mm long.

10.3 All numbers on API hydrometers shall be complete. The numbers for the 0.050 graduation lines on relative density (specific gravity) and density hydrometers shall include the values for the first three decimal places, for example: 0.750, 0.900, 1.100; the other numbered lines may be abbreviated.

10.4 Relative density (specific gravity) hydrometers may be marked sp. gr., rel. density, or with both designations. The two terms are both acceptable in this standard and are used interchangeably.

10.5 For cemented scales, there shall be a permanent reference mark on the stem or on the scale of the hydrometer corresponding to a designated reference mark on the scale.

NOTE 3—An etched mark, visible to the naked eye, on the stem corresponding to the first nominal line on the scale or a red length of glass inside the stem ending at the top nominal line are examples of acceptable means of scale slip indicators.

11. Graduation

11.1 All hydrometers shall be graduated to read correctly where the plane of the level liquid surface intersects the stem.

11.2 Hydrometers indicating density shall be graduated to indicate, at the temperature marked on the scale, the density of liquids in kilograms per cubic metre.

11.3 Relative Density (specific gravity) hydrometers shall be graduated to indicate the ratio of the mass of a unit volume of the liquid at the stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.

11.4 API hydrometers shall be graduated to give degrees of API gravity obtained as follows:

$$\text{API Gravity, deg} = [141.5/(\text{relative density @ } 60/60^\circ\text{F})] - 131.5 \quad (1)$$

11.5 A list of liquids suitable for comparisons of hydrometers is found in Table 2 of Practice **E126**.

12. Thermohydrometers

12.1 The thermometer shall be of the mercury-in-glass type. **Warning**—Mercury has been designated by EPA and many state agencies as a hazardous material that can cause central nervous system, kidney, and liver damage. Mercury, or its vapor, may be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury containing products. See the applicable product Material Safety Data Sheet (MSDS) for details and EPA's website, <http://www.epa.gov/mercury/faq.htm>, for additional information. Users should be aware that selling mercury or mercury containing products, or both, into your state may be prohibited by state law.

12.2 The capillary stem shall be essentially parallel to the hydrometer axis.

12.3 When the thermometer scale is located in the stem of the hydrometer, the scale shall be in red to distinguish it from the hydrometer scale.

12.4 When the thermometer scale is in the stem, calibration and testing of the thermometer shall be based on immersion of the thermometer scale to the level of the mercury in the thermometer stem (total immersion).

12.5 The requirements in Section 9 for the scale of the hydrometer shall apply also to the scale of the thermometer.

12.6 The thermometer shall be calibrated in accordance with Test Method **E77**.

13. Special Inscription

13.1 There shall appear on the scale or an extension thereof, or on a suitable label cemented permanently to the inside of the instrument, an inscription that indicates the purpose of the hydrometer. If necessary, this inscription should denote the liquid for which the hydrometer is intended, the temperature at which it is to be used, and the character of the indication—measure of the hydrometer. The thermometer of a thermohydrometer shall also comply with this requirement.

13.2 The designation of standard temperature and reference temperature may be abbreviated, for example, sp gr 60/60°F, means that the hydrometer indicates at 60°F the relative density (specific gravity) of the liquid, referred to water at 60°F as unity; inscription shall also indicate the ASTM hydrometer or thermohydrometer number, which shall include the (two-digit) year of its designation or most recent revision, for example: ASTM 1H-62.

13.3 The inscription shall include also the hydrometer number (1H, 6H, and so forth) but not the year designation (62, and so forth); also include a unique serial number; number and the name or trademark of the manufacturer or vendor.

14. Standardization

14.1 Hydrometers shall be calibrated and verified per Practice E126.

14.2 When calibrations are made at three scale points, the calibration points shall include at least 80 % of the graduated interval of the scale. Neither of the extreme points shall be farther from the nearest end of the graduated scale than a distance represented by 25 % of the length of the graduated scale. No two adjacent points shall be farther apart than 50 % of the length of the graduated scale.

14.3 When calibrating thermohydrometers, the thermometer in the instrument shall not be used to determine the temperature of the bath. An ASTM Gravity Thermometer as prescribed in Specifications E1 (ASTM 12C/ASTM 12F or ASTM 136C/ASTM 136F) or E2251 (ASTM S12C/ASTM S12F), or an instrument of equal sensitivity and accuracy, shall be used.

15. Case

15.1 The hydrometer shall be supplied in suitable packaging on which shall appear the ASTM number, name, and range, as given in Table 1.

15.2 The thermohydrometer packaging shall meet the requirements of 15.1 and shall also ensure that no mercury leakage will occur should the thermohydrometer break in shipment or storage. Thermohydrometers shall be properly labeled to warn users/handlers that the instrument inside the packaging contains mercury.

16. Procedure for Inspections

16.1 Manufacturers shall perform the following inspections before releasing finished instruments. For quality assurance purposes a robust percentage of each lot of instruments shall be inspected. If a Certificate of Conformance, however named, is issued for each instrument, the certificate shall state the quality assurance procedure the manufacturer uses to issue the certificate.

16.2 Visual Inspection:

16.2.1 Inspect the hydrometer carefully to be certain there are no cracks, fissures, deep scratches, rough areas, or other obvious damage to the glass. Reject the hydrometer if any of these defects are present. The glass of the hydrometer shall meet all the requirements of 5.5.

16.2.2 Inspect the hydrometer carefully for loose pieces of ballast or other foreign material within the instrument. If present, reject the instrument.

16.2.3 Inspect the paper scale within the hydrometer stem. The paper scale shall be straight and without twist.

16.2.4 Inspect for the presence of a scale slippage indicator. If a permitted scale slippage indicator is damaged, incorrectly positioned, or not present, reject the instrument.

16.3 Dimensional Inspection:

16.3.1 Check the linear dimensions and diameters for compliance with the requirements in Table 1 by comparing the hydrometer using graduated metal scales of the conventional type or metal templates with lines ruled at suitable distances from reference points corresponding to the maximum and minimum values defined in Table 1. A micrometer may also be used for checking diameters.

16.3.2 Inspect the hydrometers for correctness of the graduation spacing. API hydrometers are graduated with equal spacing. The interval between graduations of density and relative density (specific gravity) hydrometers is smaller near the bottom of the scale. The proper spacing shall be obtained from the following formula:

$$l = L \times d_2/d \times (d - d_1)/(d_2 - d_1) \quad (2)$$

where:

- l = distance from the top line to any line, d , between the top and the bottom,
- L = distance between the top and the bottom graduations of the scale,
- d_2 = density value, or relative density (specific gravity), of the bottom line, and
- d_1 = density value, or relative density (specific gravity), of the top line.

16.3.3 The scale lengths for the integral thermometer in the thermohydrometer shall also be checked with graduated metal scales or templates for compliance with Table 1.

17. Calibration and Verification

17.1 Hydrometers shall be calibrated or verified, or both, in accordance with Practice E126.

TABLE 1 Specifications for ASTM Hydrometers

API Gravity Hydrometers		Relative Density (Specific Gravity) Hydrometers		Relative Density (Specific Gravity) Hydrometers	
For Petroleum Products and Other Liquids of Similar Surface Tensions (33 dynes/cm or less)				For General Use	
ASTM Hydrometer No.	Nominal API Gravity Range, deg	ASTM Hydrometer No.	Nominal Rel. Density (Sp. Gr.) Range	ASTM Hydrometer No.	Nominal Rel. Density (Sp. Gr.) Range
1H-62	-1 to + 11	82H-62	0.650 to 0.700	For Alcohols ^A	
2H-62	9 to 21	83H-62	0.700 to 0.750	98H-62	0.950 to 1.000
3H-62	19 to 31	84H-61	0.750 to 0.800	For Heavy Liquids ^A	
4H-62	29 to 41	85H-62	0.800 to 0.850	111H-62	1.000 to 1.050
5H-62	39 to 51	86H-62	0.850 to 0.900	112H-62	1.050 to 1.100
6H-62	49 to 61	87H-62	0.900 to 0.950	113H-62	1.100 to 1.150
7H-62	59 to 71	88H-62	0.950 to 1.000	114H-62	1.150 to 1.200
8H-62	69 to 81	89H-62	1.000 to 1.050	115H-62	1.200 to 1.250
9H-62	79 to 91	90H-62	1.050 to 1.100	116H-62	1.250 to 1.300
10H-62	89 to 101			117H-62	1.300 to 1.350
11H-03	37 to 49			118H-62	1.350 to 1.400
12H-03	64 to 76			119H-62	1.400 to 1.450
				120H-62	1.450 to 1.500
Standard temperature, °F	60	60/60		60/60	
Subdivisions	0.1° API	0.0005		0.0005	
Intermediate lines at	0.5° API	0.001		0.001	
Main (numbered) lines at	1.0° API	0.005		0.005	
Scale error at any point not to exceed	0.1° API	0.0005		0.0005	
Total length, mm	325 to 335	325 to 335		325 to 335	
Length of nominal scale, mm	125 to 145	125 to 145		125 to 145	
Scale extension beyond nominal range limits, max	0.2°	0.0025		0.0025	
Body diameter, mm	23 to 27	23 to 27		23 to 27	
Stem diameter min, mm	4.0	5.0		4.0	

API Gravity Hydrometers			
For Petroleum Products and Other Liquids of Similar Surface Tensions (33 dynes/cm or less)			
ASTM Hydrometer No.	Nominal API Gravity Range, deg	ASTM Hydrometer No.	Nominal API Gravity Range, deg
21H-62	0 to 6	31H-62	50 to 56
22H-62	5 to 11	32H-62	55 to 61
23H-62	10 to 16	33H-62	60 to 66
24H-62	15 to 21	34H-62	65 to 71
25H-62	20 to 26	35H-62	70 to 76
26H-62	25 to 31	36H-62	75 to 81
27H-62	30 to 36	37H-62	80 to 86
28H-62	35 to 41	38H-62	85 to 91
29H-62	40 to 46	39H-62	90 to 96
30H-62	45 to 51	40H-62	95 to 101
Standard temperature, °F		60	
Subdivision, °API		0.1	
Intermediate lines at, °API		0.5	
Main (numbered) lines at, °API		1.0	
Scale error at any point not to exceed, °API		0.2	
Total length, mm		158 to 168	
Length of nominal scale, mm		48 to 61	
Scale extension beyond nominal range limits, max		0.2 °API	
Body diameter, mm		12 to 15	
Stem diameter min, mm		2.5	

API Gravity Thermohydrometers	
For Petroleum Products and Other Liquids of Similar Surface Tensions (33 dynes/cm or less)	
Thermometer Scale in Body	
ASTM Hydrometer No.	Nominal API Gravity Range, deg
41H-66	15 to 23
42H-66	22 to 30
43H-66	29 to 37
44H-66	36 to 44
45H-66	43 to 51
Hydrometer	
Total length, mm	374 to 387
Body diameter, mm	18 to 25
Stem diameter, min, mm	4.0
Hydrometer Scale	