



Standard Test Methods for Flash-Point by Pensky-Martens Closed Cup Tester¹

This standard is issued under the fixed designation D 93; 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 test method has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

INTRODUCTION

This flash point test method is a dynamic test method and depends on definite rates of temperature increases to control the precision of the test method. The rate of heating may not in all cases give the precision quoted in the test method because of the low thermal conductivity of certain materials. To improve the prediction of flammability, Test Method D 3941, an equilibrium method, was developed in which the heating rate is slower. This allows the vapor above the test specimen and the test specimen to be at about the same temperature. If your specification requires Test Method D 93, do not substitute Test Method D 3941 or any other test method without obtaining comparative data and agreement from the specifier.

This test method contains two procedures: Procedure A for fuel oils, lubricating oils, and other homogeneous liquids, and Procedure B for non-homogeneous materials which are mixtures of liquids with solids, liquids that tend to form a surface film under test conditions or are liquids with a kinematic viscosity which is not capable of uniform heating under the stirring and heating conditions of Procedure A. Procedure B provides a reduced heating rate and an increased stirring rate to improve thermal equilibrium.

1. Scope

1.1 This test method covers the determination of the flash point of petroleum products in the temperature range from 40 to 360°C by a manual Pensky-Martens closed-cup apparatus or an automated Pensky-Martens closed-cup apparatus.

NOTE 1—Flash point determination as above 250°C can be performed, however, the precisions have not been determined above this temperature.

1.2 This test method is applicable to fuel oils, lube oils, liquids with suspensions of solids, liquids that tend to form a surface film under test conditions, and other liquids with viscosities of 5.5 mm²/s (5.5 cSt) or more at 40°C (104°F).

NOTE 2—Liquids having kinematic viscosities less than 5.5 mm²/s (cSt) at 40°C (104°F), do not contain suspended solids, or do not have a tendency to form a surface film while under test conditions, can be tested in accordance with Test Method D 56.

1.3 This test method is applicable for the detection of contamination of relatively nonvolatile or nonflammable materials with volatile or flammable materials.

1.4 The values stated in SI units shall be regarded as the standard. The values given in parentheses are provided for information only.

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 and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazards statements, see Notes 3, 4, 9, 11, 13, 14, 18, 20, 21, 22, 24, 25, 26, 28, and 29.

2. Referenced Documents

2.1 ASTM Standards:

- D 56 Test Methods for Flash Point by Tag Closed Tester²
- D 3941 Test Method for Flash Point by the Equilibrium Method with a Closed-Cup Apparatus³
- D 4057 Practice for Manual Sampling for Petroleum and Petroleum Products⁴
- D 4177 Practice for Automatic Sampling of Petroleum and Petroleum Products⁴
- E 1 Specification for ASTM Thermometers⁵
- E 300 Practice for Sampling Industrial Chemicals⁶

¹ These test methods are under the joint jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and are the direct responsibility of Subcommittee D02.08 on Volatility. In the IP, these test methods are under the jurisdiction of the Standardization Committee.

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² Annual Book of ASTM Standards, Vol 05.01.

³ Annual Book of ASTM Standards, Vol 06.01.

⁴ Annual Book of ASTM Standards, Vol 05.02.

⁵ Annual Book of ASTM Standards, Vol 14.03.

⁶ Annual Book of ASTM Standards, Vol 15.05.

2.2 ISO Standards⁷

Guide 34 Quality Systems Guidelines for the Production of Reference Materials

Guide 35 Certification of Reference Material—General and Statistical Principles

3. Terminology

3.1 Definitions:

3.1.1 *flash point, n*—in petroleum products, the lowest temperature corrected to a barometric pressure of 101.3 kPa (760 mm Hg), at which application of an ignition source causes the vapors of a specimen of the sample to ignite under specified conditions of test.

3.1.1.1 *Discussion*—The test specimen is deemed to have flashed when a flame appears and instantaneously propagates itself over the entire surface of the test specimen.

3.1.1.2 *Discussion*—When the ignition source is a test flame, the application of the test flame may cause a blue halo or an enlarged flame prior to the actual flash point. This is not a flash point and shall be ignored.

3.1.2 *dynamic, adj*—in petroleum products—the condition where the vapor above the test specimen and the test specimen are not in temperature equilibrium at the time that the ignition source is applied.

3.1.2.1 *Discussion*—This is primarily caused by the heating of the test specimen at the constant prescribed rate with the vapor temperature lagging behind the test specimen temperature.

3.1.3 *equilibrium, n*—in petroleum products—the condition where the vapor above the test specimen and the test specimen are at the same temperature at the time the ignition source is applied.

3.1.3.1 *Discussion*—This condition may not be fully achieved in practice, since the temperature may not be uniform throughout the test specimen, and the test cover and shutter on the apparatus can be cooler.

4. Summary of Test Method

4.1 A 75-mL test specimen is heated at a slow constant rate with continual stirring in a brass test cup of specified dimensions with a cover of specified dimensions. An ignition source is directed into the test cup at regular intervals with simultaneous interruption of the stirring. The flash point is the lowest liquid temperature at which application of the ignition source causes the vapor of the test specimen of the sample to ignite.

5. Significance and Use

5.1 The flash point temperature is one measure of the tendency of the test specimen to form a flammable mixture with air under controlled laboratory conditions. It is only one of a number of properties which must be considered in assessing the overall flammability hazard of a material.

5.2 Flash point is used in shipping and safety regulations to define *flammable* and *combustible* materials. One should consult the particular regulation involved for precise definitions of these classifications.

NOTE 3—The U.S. Department of Transportation (DOT)⁸ and U.S. Department of Labor (OSHA) have established that liquids with a flash point under 37.8°C (100°F) are flammable, as determined by this test method, for those liquids which have a kinematic viscosity of 5.8 mm²/s (cSt) or more at 37.8°C or 9.5 mm²/s (cSt) or more at 25°C (77°F), or that contain suspended solids, or have a tendency to form a surface film while under test. Other classification flash points have been established by these departments for liquids using this test method.

5.3 This test method should be used to measure and describe the properties of materials, products, or assemblies in response to heat and an ignition source under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test method may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.

5.4 This test method provides the only closed cup flash point test procedures for temperatures up to 370°C (698°F).

6. Apparatus

6.1 *Pensky-Martens Closed Cup Apparatus (manual)*—This apparatus consists of the test cup, test cover and shutter, stirring device, heating source, ignition source device, air bath, and top plate described in detail in Annex A1. The assembled manual apparatus, test cup, test cup cover, and test cup assembly are illustrated in Figs. A1.1, A1.2, A1.3, and A1.4, respectively. Dimensions are listed respectively.

6.2 *Pensky-Martens Closed Cup Apparatus (automated)*—This apparatus is an automated flash point instrument that is capable of performing the test in accordance with Section 11, Procedure A, and Section 12, Procedure B, of this test method. The apparatus shall use the test cup, test cover and shutter, stirring device, heating source, and ignition source device described in detail in Annex A1.

6.3 *Temperature Measuring Device*—Is a thermometer having a range as shown as follows and conforming to the requirements prescribed in Specification E 1 or in Annex A3, or an electronic temperature measuring device, such as resistance thermometers or thermocouples. The device shall exhibit the same temperature response as the mercury thermometers.

Temperature Range	Thermometer Number	
	ASTM	IP
−5 to +110°C (20 to 230°F)	9C (9F)	15C
+10 to 200°C (50 to 392°F)	88C (88F)	101C
+90 to 370°C (200 to 700°F)	10C (10F)	16C

6.4 *Ignition Source*—Natural gas flame, bottled gas flame, and electric ignitors (hot wire) have been found acceptable for use as the ignition source. The gas flame device described in detailed in Fig. A1.4 requires the use of the pilot flame described in A1.1.2.3. The electric ignitors shall be of the hot-wire type and shall position the heated section of the

⁸ For information on U.S. Department of Transportation regulations, see Codes of U.S. Regulations 49 CFR Chapter 1 and the U.S. Department of Labor, see 29 CFR Chapter XVII. Each of these items is revised annually and may be procured from the Superintendent of Documents, Government Printing Office, Washington, DC 20402.

⁷ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

ignitor in the aperture of the test cover in the same manner as the gas flame device.

NOTE 4: **Warning**—Gas pressure supplied to the apparatus should not be allowed to exceed 300 mm (11.8 in.) of water pressure.

7. Reagents and Materials

7.1 *Cleaning Solvents*—Use suitable solvent capable of cleaning out the specimen from the test cup and drying the test cup and cover. Some commonly used solvents are toluene and acetone.

NOTE 5: **Warning**—Toluene, acetone, and many solvents are flammable and a health hazard. Dispose of solvents and waste material in accordance with local regulations.

8. Sampling

8.1 Obtain a sample in accordance with instructions given in Practices D 4057, D 4177, or E 300.

8.2 At least 75 mL of sample is required for each test. Refer to Practice D 4057.

8.3 Erroneously high flash points may be obtained if precautions are not taken to avoid the loss of volatile material. Do not open containers unnecessarily, to prevent loss of volatile material or possible introduction of moisture, or both. Do not make a transfer unless the sample temperature is at least the equivalent of 18°C or 32°F below the expected flash point. When possible, flash point shall be the first test performed on a sample and the sample shall be stored at or below room temperature.

NOTE 6—Typically when the same sample is to be used for vapor pressure analysis, the vapor pressure specimen is obtained first.

8.4 Do not store samples in plastic (polyethylene, polypropylene, etc.) containers, since volatile material may diffuse through the walls of the enclosure. Samples in leaky containers are suspect and not a source of valid results.

8.5 Samples of very viscous materials can be warmed until they are reasonably fluid before they are transferred; however, no sample shall be heated more than is absolutely necessary. The sample shall not be heated and transferred unless its temperature is more than 18°C or 32°F below its expected flash point. When the sample has been heated above this temperature, allow the sample to cool until its temperature is at least 18°C or 32°F below the expected flash point before transferring.

NOTE 7—Volatile vapors can escape during heating when the sample container is not properly sealed.

8.6 Samples containing dissolved or free water may be dehydrated with calcium chloride or by filtering through a qualitative filter paper or a loose plug of dry absorbent cotton. Warming the sample is permitted, but it shall not be heated for prolonged periods or greater than a temperature of 18°C 32°F below its expected flash point.

NOTE 8—If the sample is suspected of containing volatile contaminants, the treatment described in 8.5 and 8.6 should be omitted.

9. Preparation of Apparatus

9.1 Support the manual or automated apparatus on a level steady table.

9.2 Tests are to be performed in a draft-free room or compartment. Tests made in a laboratory hood or in any location where drafts occur are not reliable.

NOTE 9—A shield, of the approximate dimensions 460 mm (18 in.) square and 610 mm (24 in.) high, or other suitable dimensions, and having an open front is recommended to prevent drafts from disturbing the vapors above the test cup.

NOTE 10—With some samples whose vapors or products of pyrolysis are objectionable, it is permissible to place the apparatus along with a draft shield in a ventilation hood, the draft of which is adjustable so that vapors can be withdrawn without causing air currents over the test cup during the ignition source application period.

9.3 Prepare the manual apparatus or the automated apparatus for operation in accordance with the manufacturer's instructions for calibrating, checking, and operating the equipment.

NOTE 11: **Warning**—Gas pressure should not be allowed to exceed 300 mm (11.8 in.) of water pressure.

9.4 Thoroughly clean and dry all parts of the test cup and its accessories before starting the test, to ensure the removal of any solvent which had been used to clean the apparatus.

NOTE 12—Use suitable solvent capable of removing all of the specimen from the test cup and drying the test cup and cover. Some commonly used solvents are toluene and acetone.

NOTE 13: **Warning**—Toluene, acetone, and many solvents are flammable. Health hazard. Dispose of solvents and waste material in accordance with local regulations.

10. Calibration and Standardization

10.1 Adjust the automated flash point detection system (when used) in accordance with the manufacturer's instructions.

10.2 Calibrate the temperature measuring device in accordance with the manufacturer's instructions.

10.3 Verify the performance of the manual apparatus or the automated apparatus at least once per year by determining the flash point of a certified reference material (CRM) such as those listed in Annex A4, which is reasonably close to the expected temperature range of the samples to be tested. The material shall be tested according to Procedure A of this test method and the observed flash point obtained in 11.1.8 or 11.2.4 shall be corrected for barometric pressure (see Section 13). The flash point obtained shall be within the limits stated in Table A4.1 for the identified CRM or within the limits calculated for an unlisted CRM (see Annex A4).

10.4 Once the performance of the apparatus has been verified, the flash point of secondary working standards (SWSs) can be determined along with their control limits. These secondary materials can then be utilized for more frequent performance checks (see Annex A4).

NOTE 14—The flash point temperature of 1,4-dimethylbenzene is a relatively low temperature and may not allow the specified rate of heating to be achieved. Cooling the material to the specified specimen insertion temperature may cause the material to crystallize. The ASTM Coordinating Committee on Flash Point is in the process of determining more suitable calibration fluids.

10.5 When the flash point obtained is not within the limits stated in 10.3 or 10.4, check the condition and operation of the apparatus to ensure conformity with the details listed in Annex A1, especially with regard to tightness of the lid (A1.1.2.2), the action of the shutter, the position of the ignition source (A1.1.2.3), and the angle and position of the temperature measuring device (A1.1.2.4). After any adjustment, repeat the test in 10.3 using a fresh test specimen, with special attention to the procedural details prescribed in this test method.

PROCEDURE A—DETERMINATION OF FLASH POINT OF FUEL OILS, LUBRICATING OILS AND OTHER HOMOGENEOUS LIQUIDS (see Introduction)

11. Procedure

11.1 *Manual Apparatus:*

11.1.1 Fill the test cup with the test specimen to the filling mark inside of the test cup. The temperature of the test cup and test specimen shall be at least 18°C or 32°F below the expected flash point. If too much test specimen has been added to the test cup, remove the excess using a syringe or similar device for withdrawal of fluid. Place the test cover on the test cup and place the assembly into the apparatus. Be sure the locating or locking device is properly engaged. Insert the temperature measuring device into its holder.

11.1.2 Light the test flame, and adjust it to a diameter of 3.2 to 4.8 mm (0.126 to 0.189 in.), or switch on the electric igniter and adjust the intensity in accordance with the manufacturer's instructions.

NOTE 15: **Warning**—Gas pressure should not be allowed to exceed 40 kPa (300 mm) of water pressure.

NOTE 16: **Caution**—Exercise care when using a gas test flame. If it should be extinguished it will not ignite the vapors in the test cup, and the gas for the test flame that then enters the vapor space can influence the result.

NOTE 17: **Warning**—The operator should exercise and take appropriate safety precautions during the initial application of the ignition source, since test specimens containing low-flash material can give an abnormally strong flash when the ignition source is first applied.

NOTE 18: **Warning**—The operator should exercise and take appropriate safety precautions during the performance of this test method. The temperatures attained during this test method, up to 370°C (698°F), are considered hazardous.

11.1.3 Apply the heat at such a rate that the temperature, as indicated by the temperature measuring device, increases 5 to 6°C (9 to 11°F)/min.

11.1.4 Turn the stirring device at 90 to 120 rpm, stirring in a downward direction.

NOTE 19: **Caution**—Meticulous attention to all details relating to the ignition source, size of test flame or intensity of the electric ignitor, rate of temperature increase, and rate of dipping the ignition source into the vapor of the test specimen is desirable for good results.

11.1.5 *Application of Ignition Source:*

11.1.5.1 If the test specimen is expected to have a flash point of 110°C or 230°F or below, apply the ignition source when the temperature of the test specimen is $23 \pm 5^\circ\text{C}$ or $41 \pm 9^\circ\text{F}$ below the expected flash point and each time thereafter at a temperature reading that is a multiple of 1°C or 2°F. Discontinue the stirring of the test specimen and apply the ignition source by operating the mechanism on the test cover which controls the shutter so that the ignition source is lowered into the vapor space of the test cup in 0.5 s, left in its lowered position for 1 s, and quickly raised to its upward position.

11.1.5.2 If the test specimen is expected to have a flash point above 110°C or 230°F, apply the ignition source in the manner described in 11.1.5.1 at each temperature increase of 2°C or 5°F, beginning at a temperature of $23 \pm 5^\circ\text{C}$ or $41 \pm 9^\circ\text{F}$ below the expected flash point.

11.1.6 When testing materials to determine if volatile material contamination is present, it is not necessary to

adhere to the temperature limits for initial ignition source application as stated in 11.1.5.

11.1.7 When testing materials where the expected flash point temperature is not known, bring the material to be tested and the tester to a temperature of $15 \pm 5^\circ\text{C}$ or $60 \pm 10^\circ\text{F}$. When the material is known to be very viscous at this temperature, heat the specimen to a starting temperature as described in 8.5. Apply the ignition source, in the manner described in 11.1.5.1, beginning at least 5°C or 10°F higher than the starting temperature.

NOTE 20—Flash Point results determined in an “unknown expected flash point mode” should be considered approximate. This value can be used as the expected flash point when a fresh specimen is tested in the standard mode of operation.

11.1.8 Record as the observed flash point the reading on the temperature measuring device at the time ignition source application causes a distinct flash in the interior of the test cup.

NOTE 21—The sample is deemed to have flashed when a large flame appears and instantaneously propagates itself over the entire surface of the test specimen.

11.1.9 When the ignition source is a test flame, the application of the test flame may cause a blue halo or an enlarged flame prior to the actual flash point. This is not a flash and shall be ignored.

11.1.10 When a flash point is detected on the first application, the test shall be discontinued, the result discarded, and the test repeated with a fresh test specimen. The first application of the ignition source with the fresh test specimen shall be $23 \pm 5^\circ\text{C}$ or $41 \pm 9^\circ\text{F}$ below the temperature at which a flash point was detected on the first application.

11.1.11 When a flash point is detected at a temperature which is greater than 28°C or 50°F above the temperature of the first application of the ignition source, or when a flash point is detected at a temperature which is less than 18°C or 32°F above the temperature of the first application of the ignition source, the result shall be considered approximate, and the test repeated with a fresh test specimen. Adjust the expected flash point for this next test to the temperature of the approximate result. The first application of the ignition source with the fresh test specimen shall be $23 \pm 5^\circ\text{C}$ or $41 \pm 9^\circ\text{F}$ below the temperature at which the approximate result was found.

11.1.12 When the apparatus has cooled down to a safe handling temperature, less than 55°C (130°F), remove the test cover and the test cup and clean the apparatus as recommended by the manufacturer.

NOTE 22—Exercise care when cleaning and positioning the lid assembly so not to damage or dislocate the flash detection system or temperature measuring device. See the manufacturer's instructions for proper care and maintenance.

11.2 *Automated Apparatus:*

11.2.1 The automated apparatus shall be capable of performing the procedure as described in 11.1, including

control of the heating rate, stirring of the test specimen, application of the ignition source, detection of the flash point, and recording the flash point.

11.2.2 Fill the test cup with the test specimen to the filling mark inside of the test cup. The temperature of the test cup and test specimen shall be at least 18°C or 32°F below the expected flash point. If too much test specimen has been added to the test cup, remove the excess using a syringe or similar device for withdrawal of fluid. Place the test cover on the test cup and place the assembly into the apparatus. Be sure the locating or locking device is properly engaged. Insert the temperature measuring device into its holder.

11.2.3 Light the test flame, when necessary, and adjust it to a diameter of 3.2 to 4.8 mm (0.126 to 0.189 in.).

PROCEDURE B—DETERMINATION OF FLASH POINT OF LIQUIDS THAT TEND TO FORM A SURFACE FILM, LIQUIDS WITH SUSPENSIONS OF SOLIDS AND NON-HOMOGENEOUS LIQUIDS (see Introduction)

12. Procedure

12.1 Manual Apparatus:

12.1.1 Fill the test cup with the test specimen to the filling mark inside of the test cup. The temperature of the test cup and test specimen shall be at least 18°C or 32°F below the expected flash point. If too much test specimen has been added to the test cup, remove the excess using a syringe or similar device for withdrawal of fluid. Place the test cover on the test cup and place the assembly into the apparatus. Be sure the locating or locking device is properly engaged. Insert the temperature measuring device into its holder.

12.1.2 Light the test flame and adjust it to a diameter of 3.2 to 4.8 mm (0.126 to 0.189 in.), or switch on the electric igniter and adjust the intensity in accordance with the manufacturer's instructions.

NOTE 27: **Warning**—Gas pressure should not be allowed to exceed 40 kPa (300 mm) of water pressure.

NOTE 28: **Caution**—Exercise care when using a gas test flame. If it should be extinguished it will not ignite the vapors in the test cup and the gas for the test flame that then enters the vapor space can influence the result.

NOTE 29: **Warning**—The operator should exercise and take appropriate safety precautions during the initial application of the ignition source, since test specimens containing low-flash material may give an abnormally strong flash when the ignition source is first applied.

NOTE 30: **Warning**—The operator should exercise and take appropriate safety precautions during the performance of this test method. The temperatures attained during this test method, up to 370°C (698°F), are considered hazardous.

12.1.3 Turn the stirring device at 250 ± 10 rpm, stirring in a downward direction.

12.1.4 Apply the heat at such a rate that the temperature as indicated by the temperature measuring device increases 1 to 1.5°C (2 to 3°F)/min.

12.1.5 Proceed as prescribed in Section 11, with the exception of the preceding requirements for rates of stirring and heating.

12.2 Automated Apparatus:

12.2.1 The automated apparatus shall be capable of performing the procedure as described in 12.1, including control of the heating rate, stirring of the test specimen, application of the ignition source, detection of the flash

NOTE 23: **Warning**—Gas pressure should not be allowed to exceed 40 kPa (300 mm) of water pressure.

NOTE 24: **Caution**—Exercise care when using a gas test flame. If it should be extinguished it will not ignite the vapors in the test cup and the gas for the test flame that then enters the vapor space can influence the result.

NOTE 25: **Warning**—The operator should exercise and take appropriate safety precautions during the initial application of the ignition source, since test specimens containing low-flash material may give an abnormally strong flash when the ignition source is first applied.

NOTE 26: **Warning**—The operator should exercise and take appropriate safety precautions during the performance of this test method. The temperatures attained during this test method, up to 370°C (698°F), are considered hazardous.

11.2.4 Start the automated apparatus in accordance with the manufacturer's instructions. The apparatus shall follow the procedural details described in 11.1.3 through 11.1.8.

point, and recording the flash point.

12.2.2 Fill the test cup with the test specimen to the filling mark inside of the test cup. The temperature of the test cup and test specimen shall be at least 18°C or 32°F below the expected flash point. If too much test specimen has been added to the test cup, remove the excess using a syringe or similar device for withdrawal of fluid. Place the test cover on the test cup and place the assembly into the apparatus. Be sure the locating or locking device is properly engaged. Insert the temperature measuring device into its holder.

12.2.3 Light the test flame, when necessary, and adjust it to a diameter of 3.2 to 4.8 mm (0.126 to 0.189 in.).

NOTE 31: **Warning**—Gas pressure should not be allowed to exceed 40 kPa (300 mm) of water pressure.

NOTE 32: **Caution**—Exercise care when using a gas test flame. If it should be extinguished it will not ignite the vapors in the test cup and the gas for the test flame that then enters the vapor space can influence the result.

NOTE 33: **Warning**—The operator should exercise and take appropriate safety precautions during the initial application of the ignition source, since test specimens containing low-flash material can give an abnormally strong flash when the ignition source is first applied.

NOTE 34: **Warning**—The operator should exercise and take appropriate safety precautions during the performance of this test method. The temperatures attained during this test method, up to 370°C (698°F), are considered hazardous.

12.2.4 Start the automated apparatus in accordance with the manufacturer's instructions. The apparatus shall follow the procedural details in accordance with 12.1.3 through 12.1.5.

13. Calculation

13.1 Observe and record the ambient barometric pressure (See Note 30) at the time of the test. When the pressure differs from 101.3 kPa (760 mm Hg), correct the flash point as follows:

$$\text{Corrected flash point} = C + 0.25 (101.3 - P) \quad (1)$$

$$\text{Corrected flash point} = F + 0.06 (760 - P) \quad (2)$$

$$\text{Corrected flash point} = C + 0.033 (760 - P) \quad (3)$$

where:

C = observed flash point, °C,

F = observed flash point, °F,

P = ambient barometric pressure, mm Hg, and
 K = ambient barometric pressure, kPa.

NOTE 35—The barometric pressure used in this calculation is the ambient pressure for the laboratory at the time of the test. Many aneroid barometers, such as those used at weather stations and airports, are precorrected to give sea level readings and would not give the correct reading for this test.

13.2 When the ambient barometric pressure is below 101.3 kPa (760 mm), round up the corrected flash point to the nearest 0.5°C (1°F) and record. When the ambient barometric pressure is above 101.3 kPa (760 mm), round down the corrected flash point to the nearest 0.5°C and record.

14. Report

14.1 Report the corrected flash point as the ASTM D 93 – IP 34, Procedure A or Procedure B Pensky-Martens Closed Cup Flash Point of the test specimen.

15. Precision and Bias

15.1 *Precision—Procedure A*—The precision of this procedure as determined by the statistical examination of the interlaboratory test results, is as follows:

15.1.1 *Repeatability*—The difference between successive results, obtained by the same operator with the same apparatus under constant operating conditions on identical test material, would in the long run, in the normal and correct operation of the test method, exceed the following values in 1 case in 20.

$$\begin{aligned} r &= AX, \\ A &= 0.035, \\ X &= \text{reported result in } ^\circ\text{C, and} \\ r &= \text{repeatability.} \end{aligned} \quad (4)$$

15.1.2 *Reproducibility*—The difference between two single and independent results, obtained by different operators working in different laboratories on identical material, would in the long run, in the normal and correct operation of the test method, exceed the following values only in 1 case in 20.

$$\begin{aligned} R &= BX, \\ B &= 0.078, \\ X &= \text{reported result in } ^\circ\text{C, and} \\ R &= \text{reproducibility.} \end{aligned} \quad (5)$$

15.1.3 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, bias has not been determined.

15.1.4 *Relative Bias*—Statistical evaluation of the data did not detect any significant difference between the reproducibility variances of manual and automated Pensky-Martens flash point results for the samples studied. Evaluation of the data did not detect any significant difference

between averages of manual and automated Pensky-Martens flash point for the samples studied with the exception of cycle oil and fuel oil which showed some bias. In any case of dispute, the manual procedure shall be considered the referee test.

NOTE 36—The precision statements were derived on clear liquids only. Refer to the research report⁹ for information regarding relative bias and types of samples. Additional studies are in progress concerning relative bias.

15.1.5 The precision data were developed in a 1991 cooperative test program⁹ using 5 samples of fuel and lubricating oils. Twelve laboratories participated with the manual apparatus and 21 laboratories participated with the automated equipment. The apparatus used either a gas test flame or an electric resistance (hot wire) device for the ignition source. Information on the type of samples and their average flash point are in the research report available at ASTM Headquarters. Request RR:D02-1008.

15.2 *Precision—Procedure B*—The precision of this procedure as determined by the statistical examination of the interlaboratory test results, is as follows:

15.2.1 *Repeatability*—The difference between successive results obtained by the same operator with the same apparatus under constant operating conditions on identical test materials would, in the long run, in the normal and correct operation of the test method, exceed the following value in 1 case in 20:

Repeatability 5°C (9°F)

15.2.2 *Reproducibility*—The difference between two single and independent results obtained by different operators working in different laboratories on identical material would, in the long run, exceed the following value only in 1 case in 20.

Reproducibility 10°C (18°F)

15.2.3 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, bias has not been determined.

15.2.4 The precision data for Procedure B is not known to have been developed in accordance with RR:D02-1007.

NOTE 37—Procedure B was not tested in the 1991 interlaboratory program. Committee D-2 intends to conduct an interlaboratory test utilizing Procedure B.

16. Keywords

16.1 automated flash point; automated Pensky-Martens closed cup; flammability; flash point; Pensky-Martens closed cup

⁹ The results of the 1991 interlaboratory cooperative test program are available from ASTM Headquarters. Request ASTM RR:D02 – 1008.

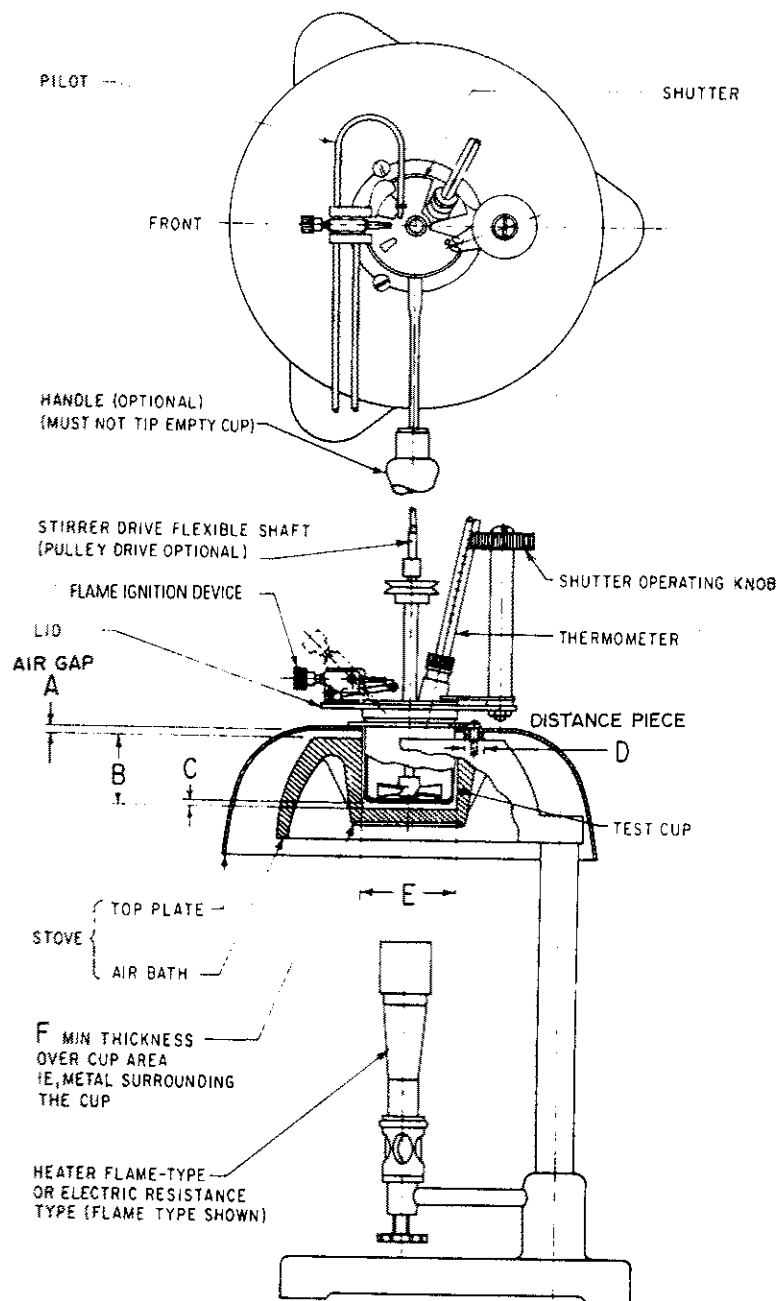
ANNEXES

(Mandatory Information)

A1. APPARATUS SPECIFICATIONS

A1.1 A typical assembly of the apparatus, gas heated, is shown in Fig. A1.1. The apparatus shall consist of a test cup, cover, and stove conforming to the following requirements:

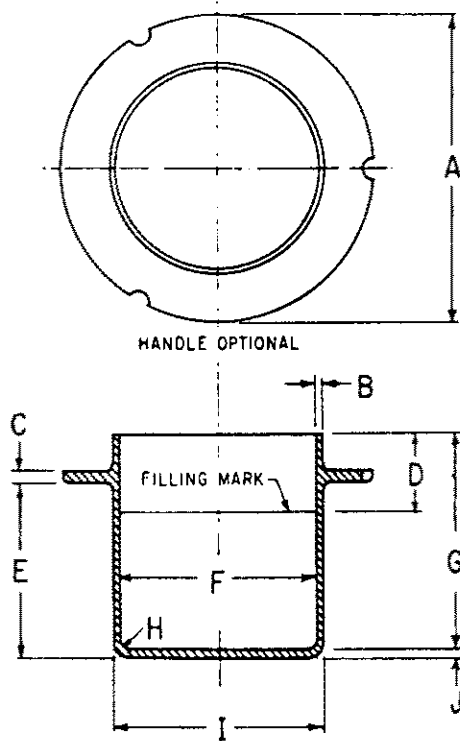
A1.1.1 *Cup*—The cup shall be of brass, or other nonrusting metal of equivalent heat conductivity, and shall conform to the dimensional requirements in Fig. A1.2. The



	mm		(in.)	
	min	max	(min)	(max)
A	4.37	5.16	(0.172)	(0.203)
B	41.94	42.06	(1.651)	(1.656)
C	1.58	3.18	(0.062)	(0.125)
D	...	9.52	(...)	(0.375)
E	57.23	57.86	(2.253)	(2.278)
F	6.35	...	(0.25)	(...)

NOTE—Lid assembly can be positioned either right or left-handed.

FIG. A1.1 Pensky-Martens Closed Flash Tester



	mm		(in.)	
	min	max	(min)	(max)
A	79.0	79.8	(3.11)	(3.14)
B	1.0	...	(0.04)	(...)
C	2.8	3.6	(0.11)	(0.14)
D	21.72	21.84	(0.855)	(0.860)
E	45.47	45.72	(1.790)	(1.800)
F	50.72	50.85	(1.997)	(2.002)
G	55.75	56.00	(2.195)	(2.205)
H	3.8	4.0	(0.15)	(0.16)
I	53.90	54.02	(2.122)	(2.127)
J	2.29	2.54	(0.090)	(0.100)

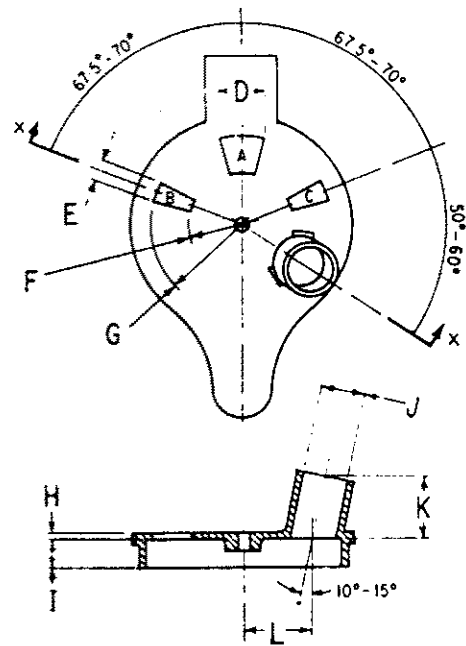
FIG. A1.2 Test Cup

flange shall be equipped with devices for locating the position of the cup in the stove. A handle attached to the flange of the cup is a desirable accessory. The handle shall not be so heavy as to tip over the empty cup.

A1.1.2 Cover:

A1.1.2.1 Cover Proper—The cover shown in Fig. A1.3 shall be of brass (A1.1.1) and shall have a rim projecting downward almost to the flange of the cup. The rim shall fit the outside of the cup with a clearance not exceeding 0.36 mm (0.014 in.) on the diameter. There shall be a locating or locking device, or both, engaging with a corresponding device on the cup. The four openings in the cover, A, B, C, and D, are shown in Fig. A1.3. The upper edge of the cup shall be in close contact with the inner face of the cover throughout its circumference.

A1.1.2.2 Shutter—The cover shall be equipped with a brass (Section 3) shutter (Fig. A1.4), approximately 2.4 mm ($\frac{3}{32}$ in.) thick, operating on the plane of the upper surface of the cover. The shutter shall be so shaped and mounted that it rotates on the axis of the horizontal center of the cover between two stops, so placed, that when in one extreme position, the openings A, B, and C in the cover are



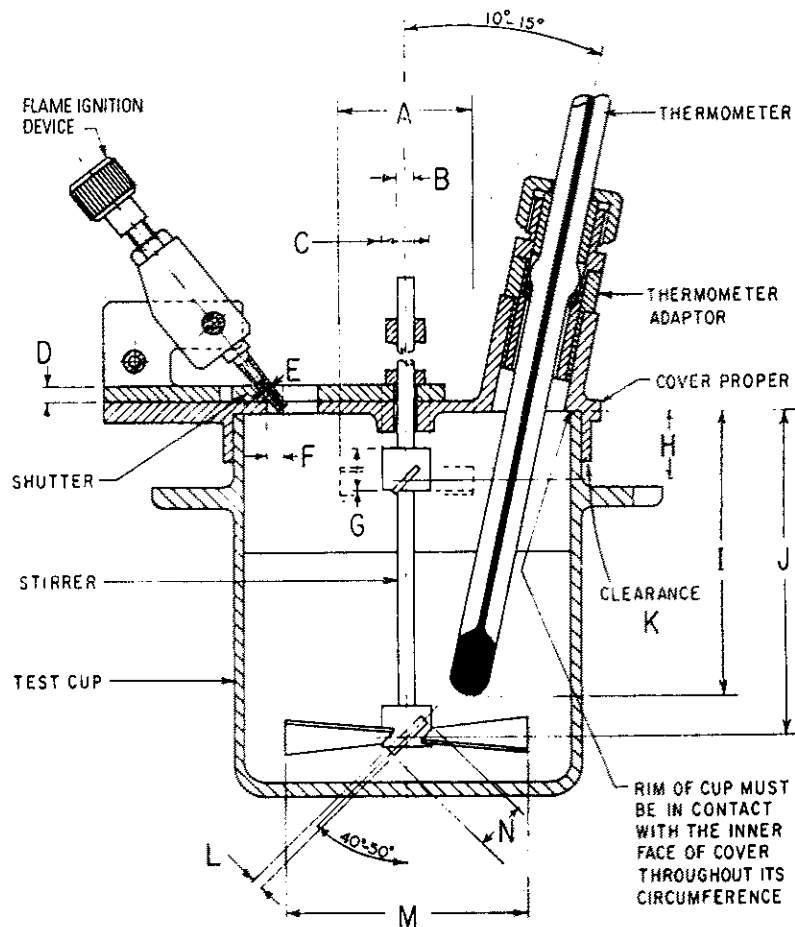
	mm		(in.)	
	min	max	(min)	(max)
D	12.7	13.5	(0.50)	(0.53)
E	4.8	5.6	(0.19)	(0.22)
F	13.5	14.3	(0.53)	(0.56)
G	23.8	24.6	(0.94)	(0.97)
H	1.2	2.0	(0.05)	(0.08)
I	7.9	...	(0.31)	(...)
J	12.27	12.32	(0.483)	(0.485)
K	16.38	16.64	(0.645)	(0.655)
L	18.65	19.45	(0.734)	(0.766)

FIG. A1.3 Cover Proper

completely closed, and when in the other extreme position, these openings are completely opened. The mechanism operating the shutter should be of the spring type and constructed so that when at rest the shutter shall exactly close the three openings. When operated to the other extreme, the three cover openings shall be exactly open and the tip of the exposure tube shall be fully depressed.

A1.1.2.3 Flame-Ignition Device—The flame-ignition device (Fig. A1.4) shall have a tip with an opening 0.69 to 0.79 mm (0.027 to 0.031 in.) in diameter. This tip shall be made preferably of stainless steel, although it may be fabricated of other suitable metals. The flame-exposure device shall be equipped with an operating mechanism which, when the shutter is in the open position, depresses the tip so that the center of the orifice is between the planes of the under and upper surfaces of the cover proper at a point on a radius passing through the center of the larger opening A (Fig. A1.3). An electric ignitor is also suitable. The electric ignitors shall be of the electric resistance (hot-wire) type and shall position the heated section of the ignitor in the aperture of the test cover in the same manner as the gas flame device.

A1.1.2.4 Pilot Flame—A pilot flame shall be provided for automatic relighting of the exposure flame. A bead 4 mm ($\frac{3}{16}$ in.) in diameter can be mounted on the cover so that the size of the test flame can be regulated by comparison. The tip



	mm		(in.)	
	min	max	(min)	(max)
A	18.3	19.8	(0.72)	(0.78)
B	2.38	3.18	(0.094)	(0.125)
C	7.6	8.4	(0.30)	(0.33)
D	2.0	2.8	(0.08)	(0.11)
E	0.69	0.79	(0.027)	(0.031)
F	2.0	2.8	(0.08)	(0.11)
G	6.4	10.4	(0.25)	(0.41)
H	9.6	11.2	(0.38)	(0.44)
J ^A	43.0	46.0	(1.69)	(1.81)
J	50.0	51.6	(1.97)	(2.03)
K	...	0.36	(...)	(0.014)
L	1.22	2.06	(0.048)	(0.08)
M	31.8	44.4	(1.25)	(1.75)
N	7.6	8.4	(0.30)	(0.33)

^A Includes tolerance for length of thermometer given in Specification E 1.

FIG. A1.4 Test Cup and Cover Assembly

of the pilot flame shall have an opening the same size as the tip of the flame exposure device (0.69 to 0.79 mm (0.027 to 0.031 in.) in diameter).

A1.1.2.5 Stirring Device—The cover shall be equipped with a stirring device (Fig. A1.4) mounted in the center of the cover and carrying two 2-bladed metal propellers. In Fig. A1.4 lower propeller is designated by the letters L, M, and N. This propeller shall measure approximately 38 mm from tip to tip, with each of its two blades 8 mm in width with a pitch of 45°. The upper propeller is designated by the letters A, C,

and G. This propeller measures approximately 19 mm, tip to tip, each of its two blades is also 8 mm in width with a pitch of 45°. Both propellers are located on the stirrer shaft in such a manner that, when viewed from the bottom of the stirrer, the blades of one propeller are at 0 and 180° while the blades of the other propeller are at 90 and 270°. A stirrer shaft may be coupled to the motor by a flexible shaft or a suitable arrangement of pulleys.

A1.1.2.6 Stove—Heat shall be supplied to the cup by means of a properly designed stove which is equivalent to an

air bath. The stove shall consist of an air bath and a top plate on which the flange of the cup rests.

A1.1.2.7 *Air Bath*—The air bath shall have a cylindrical interior and shall conform to the dimensional requirements in Fig. A1.1. The air bath may be either a flame or electrically heated metal casting (A1.1.2.8), or an electric-resistance element (A1.1.2.9). In either case, the air bath must be suitable for use at the temperatures to which it will be subjected without deformation.

A1.1.2.8 *Heater, Flame or Electric*—If the heating element is a flame or an electric heater, it shall be so designed and used that the temperatures of the bottom and the walls are approximately the same. In order that the air bath internal surfaces should be at a uniform temperature, it should not be less than 6.4 mm ($\frac{1}{4}$ in.) in thickness unless the heating element is designed to give equal heat flux densities over all the wall and bottom surfaces.

A1.1.2.9 *Heater, Electric Resistance*—If the heater is of the electric resistance type, it shall be constructed so that all parts of the interior surface are heated uniformly. The wall and bottom of the air bath shall not be less than 6.4 mm ($\frac{1}{4}$ in.) in thickness unless the resistance heating elements are distributed over at least 80 % of the wall and all the bottom of the air bath. A heater having such a distribution of the heating elements positioned at least 4.0 mm ($\frac{3}{32}$ in.) away from the internal surface of the heating unit can be used in conjunction with a minimum thickness of 1.58 mm ($\frac{1}{16}$ in.) for the wall and bottom of the air bath.

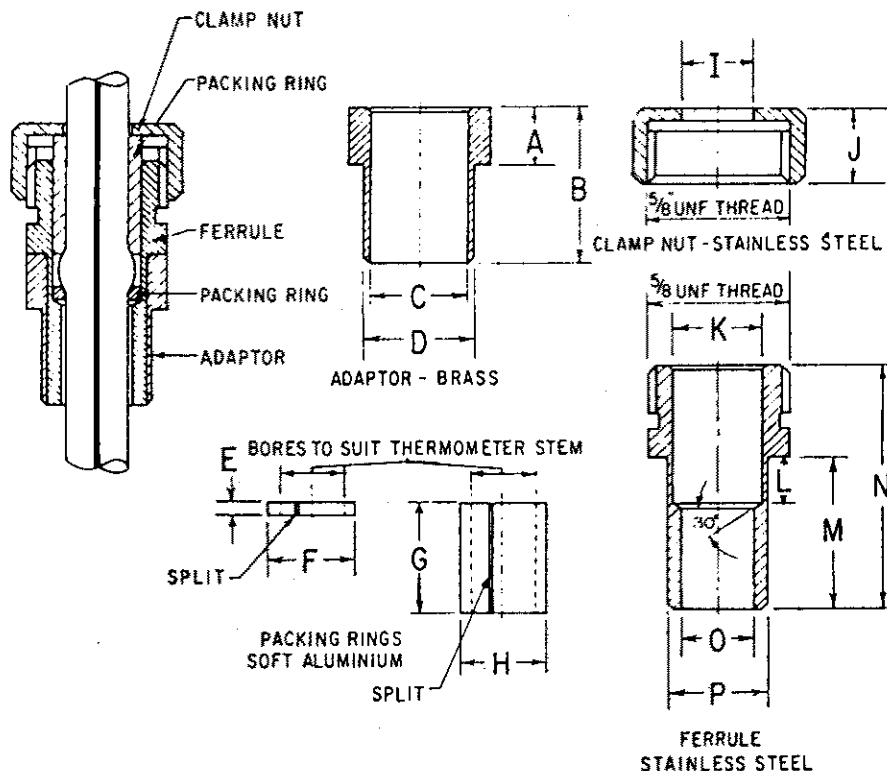
A1.1.2.10 *Top Plate*—The top plate shall be of metal, and shall be mounted with an air gap between it and the air bath. It may be attached to the air bath by means of three screws and spacing bushings. The bushings should be of proper thickness to define an air gap of 4.8 mm ($\frac{3}{16}$ in.), and they shall be not more than 9.5 mm ($\frac{3}{8}$ in.) in diameter.

A2. MANUFACTURING STANDARDIZATION OF THERMOMETER AND FERRULE

A2.1 The low-range thermometer, which conforms also to the specification for the cup thermometer in the tag closed tester (Test Method D 56) and which frequently is fitted with a metal ferrule intended to fit the collar on the cover of the tag flash tester, can be supplemented by an adapter (Fig. A2.1) to be used in the larger diameter collar of the Pensky-Martens apparatus. Differences in dimensions of these col-

lars, which do not affect test results, are a source of unnecessary trouble to manufacturers and suppliers of instruments, as well as to users.

A2.2 Dimensional requirements are shown in Fig. A2.1. Conformity to these requirements is not mandatory, but is desirable to users as well as suppliers of Pensky-Martens testers.



	mm		(in.)	
	min	max	(min)	(max)
A	6.20	6.50	(0.244)	(0.256)
B	17.0	18.0	(0.67)	(0.71)
C	9.80	9.85	(0.386)	(0.388)
D	12.19	12.24	(0.480)	(0.482)
E	1.40	1.65	(0.055)	(0.065)
F	8.56	8.61	(0.337)	(0.339)
G	12.4	13.0	(0.49)	(0.57)
H	8.56	8.61	(0.337)	(0.339)
I	8.1	8.6	(0.32)	(0.34)
J	9.9	10.7	(0.39)	(0.42)
K	8.64	8.69	(0.340)	(0.342)
L	5.1	5.6	(0.20)	(0.22)
M	17.0	17.5	(0.67)	(0.69)
N	27.4	28.2	(1.08)	(1.11)
O	7.11	7.16	(0.280)	(0.282)
P	9.73	9.78	(0.383)	(0.385)

FIG. A2.1 Dimensions for Thermometer Adapter, Ferrule, and Packing Ring

A3. THERMOMETER SPECIFICATIONS

TABLE A3.1 IP Thermometer Specifications

NOTE—The stem shall be made with an enlargement having a diameter of 1.5 to 2.0 mm greater than the stem and a length of 3 to 5 mm, the bottom of the enlargement being 64 to 66 mm from the bottom of the bulb. These dimensions shall be measured with the test gage shown in Fig. A3.1.

Name	IP 15C	IP 16C	IP 101C
	Pensky-Martens Low	Pensky-Martens High	Pensky-Martens Medium
Range	−5 to +110°C	90 to 370°C	20 to 150°C
Graduation	0.5°C	2°C	1°C
Immersion, mm	57	57	57
Overall length ±5 mm	290	280 ± 10	290
Stem diameter, mm	6.0 to 7.0	6.0 to 7.0	6.0 to 7.0
Bulb shape	cylindrical	cylindrical	cylindrical
Bulb length, mm	9 to 13	7 to 10	9 to 13
Bulb diameter, mm	not less than 5.5 and not greater than stem	not less than 4.5 and not greater than stem	not less than 5.5 and not greater than stem
Length of graduated portion, mm	140 to 175	143 to 180	140 to 175
Distance bottom of bulb to, mm	0°C 85 to 95	90°C 80 to 90	20°C 85 to 95
Longer lines at each Figured at each	1 and 5°C 5°C	10 and 20°C 20°C	5°C 5°C
Expansion chamber	required	required	required
Top finish	ring	ring	ring
Scale error not to exceed ±	0.5°C	1 to 260°C 2°C above 260°C	1°C
See notes	1 and Table A3.3 for emergent stem temperatures	1 and Table A3.3 for emergent stem temperatures	1 and Table A3.3 for emergent stem temperatures

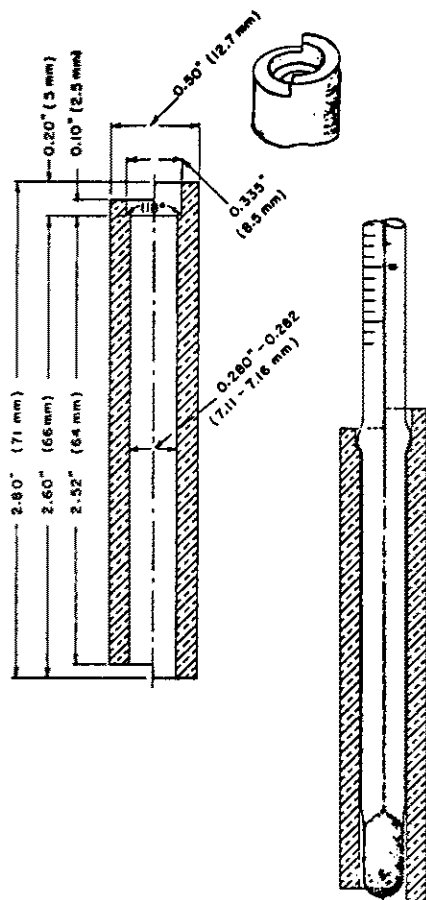
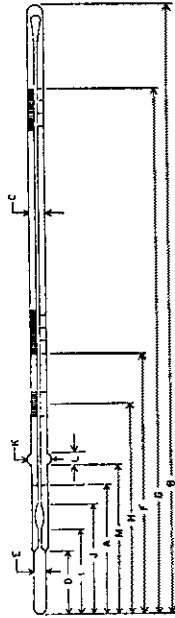


FIG. A3.1 Test Gage for Checking Enlargements on Thermometers

TABLE A3.2 Specifications for ASTM Thermometers
All dimensions are in millimetres.
See Table A3.3 for Standardization Temperature.



ASTM Number and Name	Range	For Test at	Graduations			Special Inscription	Expansion Chamber	Total Length, ± 5	Bulb		Scale Location			Ice Point Scale		Contraction Chamber		Stem Enlargement		
			Sub-divisions	Long Lines at Each	Number at Each				Length	OD	Bottom of Bulb to Line at	Distance	Bottom of Bulb to Line at	Range	Bottom of Bulb to Ice Point	Distance to Bottom, min	Distance to Top, max	OD	Length	Distance to Bottom
9C-62 Pensky-Marten's Low-Range Tag Closed Tester 9F-62	-5 to +110°C		0.5°C 1°F	1°C 5°F	5°C 10°F	ASTM 9C or 9F 57 mm IMM	160°C 320°F	287	9.0 to 13	4.5 to 6.0	0°C 32°F	85 to 98	100°C 212°F					7.5 to 8.5	2.5 to 5.0 ^d	64 to 66
10C-62 Pensky-Marten's High-Range 10F-62	90 to 370°C (200 to 700°F)		2°C 5°F	10°C 25°F	20°C 50°F	ASTM 10C or 10F 57 mm IMM	c	287	8.0 to 10.0	4.5 to 6.0	110°C 230°F	86 to 99	360°C 680°F					7.5 to 8.5	2.5 to 5.0 ^d	64 to 66

^a Scale error: 1°C up to 260°C; 2°C over 260°C.

^b Scale error: 2.5°F up to 500°F; 3.5°F over 500°F.

^c An expansion chamber is provided for relief of gas pressure to avoid distortion of the bulb at higher temperatures. It is not for the purpose of joining mercury separations; and under no circumstances should the thermometer be heated above the highest temperature reading.

^d The length of the enlargement, and the distance from the bottom of the enlargement to the bottom of the bulb shall be measured with the test gage shown in Fig. A3.1.

TABLE A3.3 Standardization Temperatures

NOTE—The emergent column temperatures are those attained when using the thermometers in the test equipment for which the thermometers were originally designed. In some cases these temperatures are markedly different from those realized during standardization.

Tempera- ture	Average Tempera- ture of Emergent Column	Tempera- ture	Average Tempera- ture of Emergent Column	Tempera- ture	Average Tempera- ture of Emergent Column	Tempera- ture	Average Tempera- ture of Emergent Column
Thermometer 9C (-5 to +100°C)		Thermometer 9F (20 to 230°F)		Thermometer 10C (90 to 370°C)		Thermometer 10F (200 to 700°F)	
0°C	19°C	32°F	66°F	100°C	61°C	212°F	141°F
35°C	28°C	100°F	86°F	200°C	71°C	390°F	159°F
70°C	40°C	160°F	106°F	300°C	87°C	570°F	180°F
105°C	50°C	220°F	123°F	370°C	104°C	700°F	220°F
IP 15C (-7 to 110°C)		IP 15F (20 to 230°F)		IP 16C (90 to 370°C)		IP 16F (20 to 700°F)	
0°C	19°C	32°F	66°F	100°C	61°C	200°F	140°F
20°C	20°C	70°F	70°F	150°C	65°C	300°F	149°F
40°C	31°C	100°F	86°F	200°C	71°C	400°F	160°F
70°C	40°C	150°F	104°F	250°C	78°C	500°F	175°F
100°C	48°C	212°F	118°F	300°C	87°C	600°F	195°F
				350°C	99°C	700°F	220°F

TABLE A3.4 Specifications for Medium-Range Pensky-Martens

ASTM No. 88F (88C) Vegetable Oil Flash Thermometer

Name	Medium-Range Pensky-Martens	
Reference Fig. No.	5	
Range	10-200°C	50-392°F
For test at		
A Immersion, mm	57	
Graduations:		
Subdivisions	0.5°C	1°F
Long lines at each	1°C and 5°C	5°F
Numbers at each	5°C	10°F
Scale error, max	0.5°C	1°F
Special inscription	ASTM 88F(88C) 57 mm IMM	
Expansion chamber:		
Permit heating to	205°C	400°F
B Total length, mm	285 to 295	
C Stem OD, mm	6.0 to 7.0	
D Bulb length, mm	8.0 to 12.0	
E Bulb OD, mm	>4.5 and <stem ^A	
Scale location:		
Bottom of bulb to line at	20°C	68°F
F Distance, mm	80 to 90	
G Length of graduated portion, mm	145 to 180	
Ice-point scale:		
Range		
H Bottom of bulb to ice-point, mm		
Contraction chamber:		
I Distance to bottom, min, mm		
J Distance to top, max, mm		
Stem enlargement:		
K OD, mm	7.5 to 8.5	
L Length, mm	2.5 to 5.0 ^A	
M Distance to bottom, mm	64 to 66	

^A Bulb OD shall be greater than 4.5 mm and less than the outside diameter of the stem (C).

A4. VERIFICATION OF APPARATUS PERFORMANCE

A4.1 Certified Reference Material (CRM)—CRM is a stable, pure (99+ mole % purity) hydrocarbon or other stable petroleum product with a method-specific flash point established by a method-specific interlaboratory study following ASTM RR:D02-1007 guidelines or ISO Guide 34 and 35.

A4.1.1 Values of the flash point corrected for barometric pressure for some reference materials and their typical limits are given in Table A4.1 (see Note A4.1). Suppliers of CRMs

will provide certificates stating the method-specific flash point for each material of the current production batch. Calculation of the limits for these other CRMs can be determined from the reproducibility value of this test method, reduced by interlaboratory effect and then multiplied by 0.7. See Research Report RR:S15-1008.

NOTE A4.1—Materials, purities, flash point values, and limits stated in Table A4.1 were developed in an ASTM interlaboratory program to

TABLE A4.1 D 93 Typical Flash Point Values and Typical Limits for CRM

NOTE—Supporting data for the interlaboratory study to generate the flash point in Table A4.1 can be found in research report RR:S15-1010.

Hydrocarbon	Purity, mole %	Flash Point, °C	Limits, °C
<i>n</i> -decane	99+	52.8	±2.3
<i>n</i> -undecane	99+	68.7	±3.0
<i>n</i> -tetradecane	99+	109.3	±4.8
<i>n</i> -hexadecane	99+	133.9	±5.9

determine suitability of use for verification fluids in flash point test methods. Other materials, purities, flash point values, and limits can be suitable when produced according to the practices of ASTM RR:D02-1007 or ISO Guides 34 and 35. Certificates of performance of such

materials should be consulted before use, as the flashpoint value will vary dependent on the composition of each CRM batch.

A4.2 Secondary Working Standard (SWS)—SWS is a stable, pure (99+ mole % purity) hydrocarbon, or other petroleum product whose composition is known to remain appreciably stable.

A4.2.1 Establish the mean flash point and the statistical control limits (3σ) for the SWS using standard statistical techniques. See ASTM MNL 7).¹⁰

¹⁰ *Manual on Presentation of Data and Control Chart Analysis*, ASTM MNL, 6th ed., ASTM, 1990.

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