ASTM INTERNATIONAL

Designation: D2878 − 21

Standard Test Method for
Estimating Apparent Vapor Pressures and Molecular Weights of Lubricating Oils[1]

This standard is issued under the fixed designation D2878; 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.

1. Scope*

1.1 This test method covers a calculation procedure for converting data obtained by Test Method D972 to apparent vapor pressures and molecular weights. It has been demonstrated to be applicable to petroleum-based and synthetic ester lubricating oils,[2] at temperatures of 395 K to 535 K (250 °F to 500 °F). However, its applicability to lubricating greases has not been established.

NOTE 1—Most lubricants boil over a fairly wide temperature range, a fact recognized in discussion of their vapor pressures. For example, the apparent vapor pressure over the range 0 % to 0.1 % evaporated may be as much as 100 times that over the range 4.9 % to 5.0 % evaporated.

1.2 The values stated in SI units are to be regarded as the standard. In cases in which materials, products, or equipment are available in inch-pound units only, SI units are omitted.

1.3 **WARNING**—Mercury has been designated by many regulatory agencies as a hazardous substance that can cause serious medical issues. Mercury, or its vapor, has been demonstrated to be hazardous to health and corrosive to materials. Use caution when handling mercury and mercury-containing products. See the applicable product Safety Data Sheet (SDS) for additional information. The potential exists that selling mercury or mercury-containing products, or both, is prohibited by local or national law. Users must determine legality of sales in their location.

1.4 *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 or regulatory limitations prior to use. For specific warning statements, see* 6.2, 7.1, 8.2, *and* Annex A2.

1.5 *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:*[3]

A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester

D972 Test Method for Evaporation Loss of Lubricating Greases and Oils

D2503 Test Method for Relative Molecular Mass (Molecular Weight) of Hydrocarbons by Thermoelectric Measurement of Vapor Pressure

D2595 Test Method for Evaporation Loss of Lubricating Greases Over Wide-Temperature Range

D2883 Test Method for Reaction Threshold Temperature of Liquid and Solid Materials (Withdrawn 2016)[4]

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

E659 Test Method for Autoignition Temperature of Chemicals

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 For definitions of terms used in this test method, refer to Terminology D4175.

3.1.2 *apparent vapor pressure (p), n*—the time-averaged value of the vapor pressure from the start to the end of the evaporation test.

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

3.1.2.1 *Discussion*—While this may include some effects of differences in nonideality of the vapor, heat of vaporization, surface tension, and viscosity between the *m*-terphenyl and the lubricating oil, these factors have been demonstrated to be negligible. Unless stated, this average shall cover the range 0 % to 5 % ± 1 %.

3.1.3 *cell constant (k), n*—the ratio of the amount of *m*-terphenyl or lubricating oil carried off per unit volume of gas to that predicted by Dalton's law.

$$k = 22.41 \ PW/VpM \tag{1}$$

where:
k = call constant
P = ambient atmospheric pressure, torr
W = mass of lubricant evaporated, g
V = volume of gas passed through all litres at 273 K and 101.3 kPa (760 torr)
p = apparent vapor pressure, torr
M = mole average molecular weight of lubricant vapor, g/mole
T = test temperature, K

It has been empirically determined that for *m*-terphenyl in air

$$k = 0.1266 - 12.60/(T - 273) \tag{2}$$

and that the cell constant is independent of the composition of the lubricant.

3.1.4 Test Method D972 is normally run with air, which may cause changes in easily oxidized fluids. In such cases, use of common reactive gas nitrogen and recalibration to obtain a slightly different cell constant (k') is mandatory.

4. Summary of Test Method

4.1 The test is run at the selected temperature for a sufficient time to give the selected amount of evaporation, which is 5 % ± 1 % unless otherwise specified. This evaporation rate is compared with a standard value for pure *m*-terphenyl to yield the apparent vapor pressure and molecular weight of the lubricating oil as defined in Section 3.

5. Significance and Use

5.1 The vapor pressure of a substance as determined by measurement of evaporation reflects a property of the bulk sample. Little weight is given by the procedure to the presence of low concentrations of volatile impurities.

5.2 Vapor pressure, *per se*, is a thermodynamic property that is dependent only upon composition and temperature for stable systems. In the present method, composition changes occur during the course of the test so that the contribution of minor amounts of volatile impurities is minimized.

6. Apparatus

6.1 *Evaporation Cell,* as described in Annex A1.

6.2 *Air Supply System,* capable of supplying to the cell the required flow of air free of entrained particles (**Warning**—Compressed gas under high pressure. Use with extreme caution in the presence of combustible material, since the autoignition temperatures of most organic compounds in air are drastically

reduced at elevated pressures. See Annex A2.1.). A 410 mm (16 in.) length of 1 in. diameter pipe packed with glass wool has been found satisfactory for filtering the air.

6.3 *Oil Bath,* as described in Annex A1.

Note 2—Other constant-temperature baths may be used if the exit air passing over the grease sample is at the test temperature (±0.5 K (1 °F)).

6.4 *Temperature Measuring Devices*—Resistance thermometers, thermocouples, or liquid-in-glass thermometers calibrated to accuracy within ±0.5 °C (±1.0 °F) may be used. The use of mercury-in-glass thermometers of equal accuracy is permitted, although it is discouraged.

6.5 *Flowmeter*[5]—A rotameter calibrated to deliver air at a rate of 2.583 g/min ± 0.02 g/min between 289 K and 302 K (60 °F and 85 °F) (2 L/min at standard temperature and pressure). It shall be furnished with a needle valve and mounted as shown in Fig. 1.

6.6 *Oil Sample Cup,* as described in Fig. 1 and A1.1.2.

7. Calibration of Equipment

7.1 It is assumed that equipment conforming to Test Method D972 in design and installation needs no calibration. If questions arise, carry out the procedure using *m*-terphenyl (**Warning**—Harmful or fatal if swallowed. See A2.2.) of good commercial quality. The following two points shall be determined:

Temperature		Time, h	Evaporation to Conform to Eq 2, g
K	°F		
395	250	22	0.267 ± 0.027
420	300	6.5	0.503 ± 0.050

If the data do not fall within the above ranges, check flow rate and temperature. If these are correct, prepare a substitute equation for k' similar to Eq 2 and use it in Section 10. When use of nonreactive gas is required, this calibration is necessary as standard cell constants are not valid for gases other than air.

7.2 If the apparatus specified in Test Method D2595 is to be used, it shall be calibrated as described in 7.1.

8. Procedure

8.1 Weigh the clean test specimen cup and hood to the nearest 1 mg. Transfer, by means of a pipet, 10.00 g ± 0.05 g of test specimen to the cup. Assemble the cup and hood, being careful not to splash oil on the underside of the hood. Weigh the assembly and record the net test specimen weight to the nearest 1 mg.

8.2 With cover in place, but without the hood and test specimen cup attached, allow the evaporation cell to acquire the temperature of the bath (controlled to ±0.5 K (±1 °F)) at which the test is to be made by immersing the cell in it, as shown in Fig. 1. Allow the cell to remain in the bath at least ½ h before beginning the test. During this period, allow clean

[5] The sole source of supply of the apparatus known to the committee at this time is Flowrater meter, Fisher and Porter Co., Hatboro, PA. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.
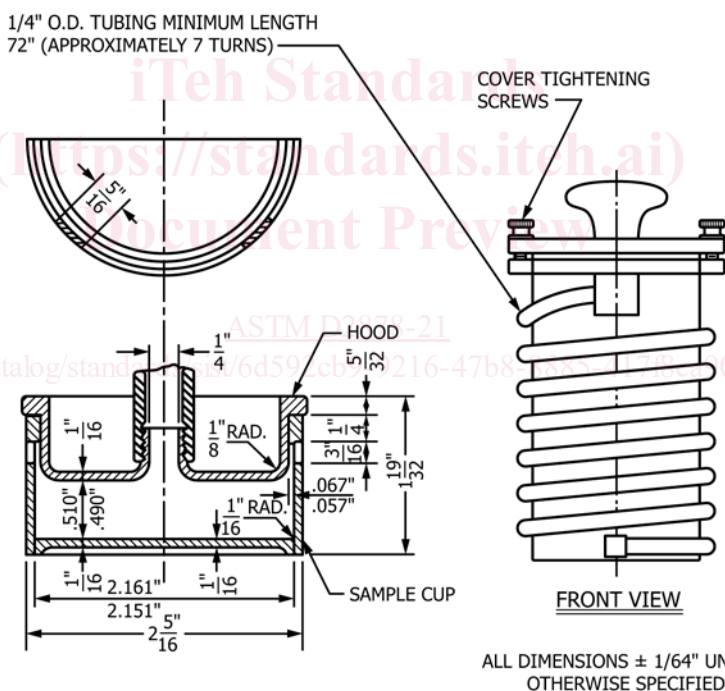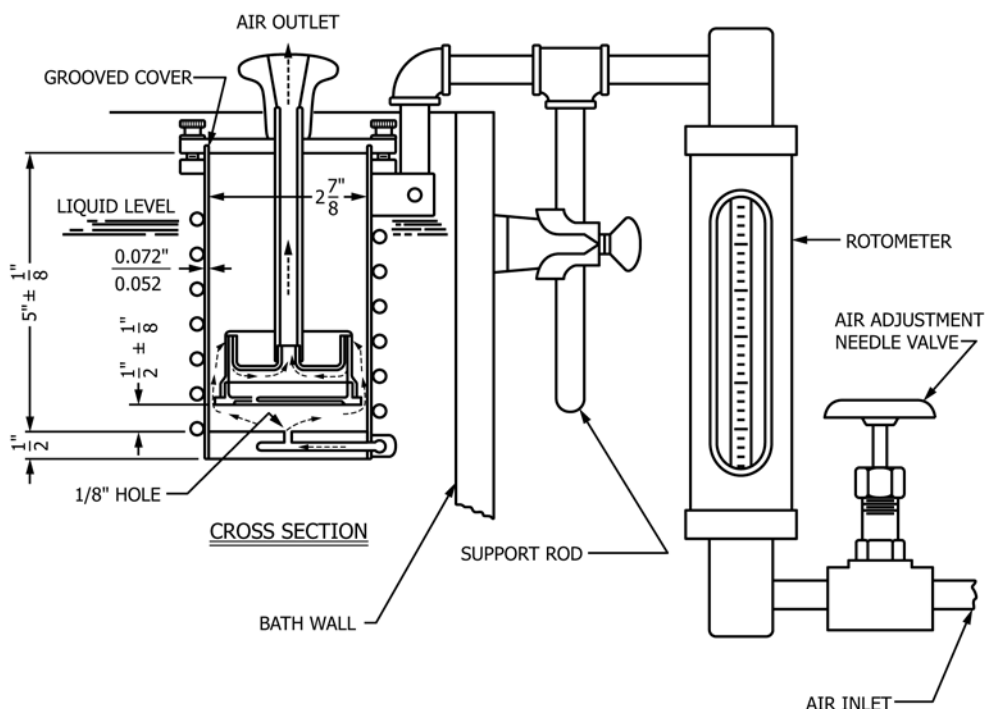
FIG. 1 Evaporation Test Cell

air (**Warning**—Compressed gas under high pressure. Use with extreme caution in the presence of combustible material, since the autoignition temperatures of most organic compounds in air are drastically reduced at elevated pressures. See Annex A2.1.) to flow through the cell at the prescribed rate, 2.583 g/min ± 0.02 g/min (2 L/min at standard temperature and pressure), as indicated by the rotameter. Then remove the cover, thread and

weighed hood and sample cup into place, and replace the cover. Tighten the three knurled cover-tightening screws securely to prevent air leakage under the cover. Pass clean air through the cell for the required period. (**Warning**—Do not perform this test with air at temperatures in excess of the autoignition temperature of the test specimen as determined by Test Method E659 or Test Method D2883, or both.)

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8.3 At the end of the test period, remove the assembled test specimen cup and hood from the cell, and allow to cool to room temperature. Determine the net weight of the sample to the nearest 1 mg.

9. Determination of Molecular Weight and Apparent Vapor Pressure

9.1 If a value of M is already available from Test Method D2503 or equivalent, 9.2 – 9.4 and 10.1 may be omitted, even though this value is for the whole lubricant instead of the part vaporized, as the calculation is not very sensitive to M error.

9.2 Conduct a test on the sample in accordance with the procedure in Section 7, at 477 K (400 °F). The proper test time to evaporate 5 % (0.500 g) may be estimated from the flash point of the lubricant as measured by Test Method D92, from Table 1.

NOTE 3—The need for a run at 477 K (400 °F) is, created by lack of exact values for the first two constants in Eq 3, Eq 4, and Eq 5 for other temperatures.

9.3 For synthetic and redistilled petroleum oils, the variation of W/t with W is not great, and the 5 % point shall be approximated by linear interpolation of two points taken at different W values. For single-distilled petroleum or unknown oils, three points shall be plotted, representing the estimated time and also half and twice that time. These readings may all be obtained on one sample by stop and start operation of the apparatus.

9.4 When a single data point that does not fall within the 5 % ± 1 % evaporated range is used (as is often justifiable on synthetic oils) or the evaporation is measured at some other level of W, this fact shall be reported in Section 11.

9.5 The test for apparent vapor pressure is conducted in accordance with Section 8 for the estimated time at the selected temperature. If the 5 ± 1 % criterion is not met, proceed as in 9.3.

10. Calculations

10.1 *Calculation of Molecular Weight:*

10.1.1 Use the evaporation time, t, (in seconds) obtained in 9.3 to evaporate 5 % ± 1 %.

10.1.2 Calculate the molecular weights of lubricants in general as follows:

$$\log M = 3.028 - 0.164 \log(10\ 335\ PW/t) \tag{3}$$

10.1.3 For lubricants of known composition, slightly greater accuracy is obtained with special equations:

10.1.3.1 For polyol esters:

$$\log M = 3.181 - 0.207 \log(10\ 335\ PW/t) \tag{4}$$

10.1.3.2 For dibasic esters:

$$\log M = 3.089 - 0.190 \log(10\ 335\ PW/t) \tag{5}$$

10.1.3.3 For mineral oils:

$$\log M = 2.848 - 0.106 \log(10\ 335\ PW/t) \tag{6}$$

10.1.4 The molecular weight equations all contain the standard value of k at 477 K (400 °F) from Table 2. If a change greater than ±3 % in this value is caused by the calibration in Section 7, adjustments shall be made in the constant 10 335 by multiplying it by the factor (k/k').

10.2 *Calculation of Apparent Vapor Pressure:*

10.2.1 Use the molecular weight, M, as calculated in 10.1 or predetermined in 9.1 to calculate the vapor pressure as follows:

$$p = 672\ PW/tkM \tag{7}$$

where k is obtained from Table 2. Use Eq 2 to extend this table. If a special equation was required in 7.1, use it rather than Table 2 or Eq 2.

10.2.2 For the special case of lubricants run at 477 K (400 °F) for 6.5 h as required in several military aircraft engine oil specifications, with $P = 760$ torr:

$$\log p = 1.164 \log(10W) - 1.255 \tag{8}$$

where 10 W = percent evaporated from a 10 g sample.

10.2.3 These results may be converted to SI units by the equations:

$$p' = 133.32p \text{ and } P' = 133.32P \tag{9}$$

where:

p' = apparent vapor pressure, Pa
P' = ambient atmospheric pressure, Pa

11. Report

11.1 If the results are obtained in accordance with 9.1, 9.2, 9.3, and 9.5, and calculated by Eq 3, they shall be reported as "Apparent Vapor Pressure = _ _ torr at _ _ °C (_ _ °F), and Molecular Weight = _ _ ."

11.2 If the results are obtained in accordance with 9.1, 9.2, 9.3, and 9.5, and calculated by Eq 4, Eq 5, or Eq 6, they shall

TABLE 1 Estimated Time to Evaporate 5 %, h[A]

Flash Point		Test Temperature, K (°F)					
K	°F	394 (250)	422 (300)	450 (350)	477 (400)	505 (450)	533 (500)
422	300	2.7	0.9	0.3	0.1	...	...
450	350	8.1	2.7	0.9	0.3	0.1	...
477	400	24.3	8.1	2.7	0.9	0.3	0.1
505	450	72.9	24.3	8.1	2.7	0.9	0.3
533	500	...	72.9	24.3	8.1	2.7	0.9
561	550	...	...	72.9	24.3	8.1	2.7
589	600	...	...	...	72.9	24.3	8.1

[A] This table may be extended by means of equation:
Estimated Hours = 0.9 log^{-1} [0.0095($F - 1.8T + 460$)]