



# Standard Test Method for Estimating Apparent Vapor Pressures and Molecular Weights of Lubricating Oils<sup>1</sup>

This standard is issued under the fixed designation D 2878; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>e1</sup> NOTE—Warning notes were placed in the text editorially in November 2000.

## 1. Scope

1.1 This test method provides a calculation procedure for converting data obtained by Test Method D 972 to apparent vapor pressures and molecular weights. It has been demonstrated to be applicable to petroleum-based and synthetic ester lubricating oils,<sup>2</sup> at temperatures of 395 to 535K (250 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.<sup>3</sup>

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 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 or regulatory limitations prior to use. For specific hazard statements, see 6.2, 7.1, and 8.2.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels<sup>3</sup>
- D 92 Test Method for Flash and Fire Points by Cleveland Open Cup<sup>4</sup>
- D 972 Test Method for Evaporation Loss of Lubricating Greases and Oils<sup>4</sup>

- D 2503 Test Method for Molecular Weight (Relative Molecular Mass) of Hydrocarbons by Thermoelectric Measurement of Vapor Pressure<sup>4</sup>
- D 2595 Test Method for Evaporation Loss of Lubricating Greases over Wide Temperature Range<sup>4</sup>
- D 2883 Test Method for Reaction Threshold Temperature of Liquid and Solid Materials<sup>4</sup>
- E 1 Specification for ASTM Thermometers<sup>5</sup>
- E 659 Test Method for Autoignition Temperature of Liquid Chemicals<sup>6</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

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

3.1.1.1 *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.<sup>6</sup> Unless stated, this average shall cover the range 0 to  $5 \pm 1$  %.

3.1.2 *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.

$$k = 22.41 PW/VpM \quad (1)$$

where:

- $k$  = call constant
- $P$  = ambient atmospheric pressure, torr
- $W$  = mass of lubricant evaporated, g
- $V$  = volume of gas passed through all litres at 273K 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

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<sup>2</sup> Coburn, J. F., "Lubricant Vapor Pressure Derived from Evaporation Loss," *Transactions*, American Society of Lubricating Engineers, ASLTA, Vol 12, 1969, pp. 129–134.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 05.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 14.03.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 14.02.

$$k = 0.1266 - 12.60/(T - 273) \quad (2)$$

and that the cell constant is independent of the composition of the lubricant.<sup>6</sup>

3.1.3 Test Method D 972 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  $5 \pm 1\%$  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 ( $\pm 0.5\text{K}$  ( $1^\circ\text{F}$ )).

6.4 *Thermometers*—ASTM thermometers graduated in either Celsius or Fahrenheit degrees and having a range from  $-5$  to  $400^\circ\text{C}$  ( $20$  to  $760^\circ\text{F}$ ) and conforming to the requirements for Thermometers 3C or 3F, respectively, as described in Specification E 1.

6.5 *Flowmeter*<sup>7</sup>—A rotameter calibrated to deliver air at a rate of  $2.583 \pm 0.02$  g/min between 289 and 302K ( $60$  and  $85^\circ\text{F}$ ) ( $2$  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 D 972 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.<sup>8</sup> The following two points shall be determined:

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

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 D 2595 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,  $10.00 \pm 0.05$  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  $\pm 0.5\text{K}$  ( $\pm 1^\circ\text{F}$ )) 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  $\frac{1}{2}$  h before beginning the test. During this period, allow clean 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,  $2.583 \pm 0.02$  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 E 659 or Test Method D 2883, or both.)

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 D 2503 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 477K ( $400^\circ\text{F}$ ). The proper test time

<sup>7</sup> The Flowrater meter manufactured by Fisher and Porter Co., Hatboro, PA, has been found satisfactory.

<sup>8</sup> Santowax, M., Monsanto Chemical Co., St. Louis, MO, has proved satisfactory.

