



# Standard Test Method for Calculation of True Vapor Pressures of Petroleum Distillate Fuels<sup>1</sup>

This standard is issued under the fixed designation D2889; 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.

## 1. Scope

1.1 This test method describes the calculation of true vapor pressures of petroleum distillate fuels for which distillation data may be obtained in accordance with Test Method **D86** without reaching a decomposition point prior to obtaining 90 volume % distilled.

1.2 The test method may be used to calculate vapor pressures at temperatures between the 0 % equilibrium flash temperature and the critical temperature of the fuel. Provision is included for obtaining a calculated critical temperature for fuels for which it is not known.

1.3 Critical pressure-temperature data are usually not available for petroleum fuels. However, if both the critical pressure and critical temperature are known, the values shall be used as the coordinates in **Fig. 1** to establish a critical point to be used instead of the focal point established as described in **6.5.4**; and the calculations described in **6.5** through **6.5.4** are not required. If either a determined true boiling point or determined equilibrium flash vaporization temperature at 0 % distilled at atmospheric pressure is known, the determined value shall be used to establish the lower limit of the bubble-point line referred to in **6.4**.

1.4 The method is not reliable for distillate fuels having a boiling range of less than 100 °F (38 °C) between the Test Method **D86** 10 volume % and 90 volume % distilled temperatures.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 *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.*

<sup>1</sup> This test method is under jurisdiction of ASTM Committee **D02** on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee **D02.04.0K** on Correlative Methods.

Current edition approved Oct. 1, 2015. Published December 2015. Originally approved in 1970. Last previous edition approved in 2010 as D2889 – 95 (2010). DOI: 10.1520/D2889-95R15.

## 2. Referenced Documents

### 2.1 *ASTM Standards*:<sup>2</sup>

**D86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure**

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

### 2.2 *ASTM Adjuncts*:

Temperature Pressure Conversion Chart (16 by 20 in. drawings)<sup>3</sup>

## 3. Summary of Test Method

3.1 Equilibrium flash vaporization (EFV) temperatures are calculated from distillation data (Test Method **D86**) determined on the sample. The distillation data, calculated EFV data, and API gravity of the sample are used with a graphical correlation procedure to obtain two pairs of temperature-pressure coordinates through which the bubble-point line of the phase diagram for the sample may be drawn. The calculated true vapor pressure at a specified temperature is obtained by reading the pressure at the intersection of the bubble-point line and specified temperature.

NOTE 1—Details of the procedure and data substantiating its validity for establishing equilibrium flash vaporization temperatures have been published.<sup>4</sup>

## 4. Significance and Use

4.1 The true vapor pressure of a distillate fuel is a relative measurement, both of the tendency of the most volatile portion of the fuel to gasify, and of the restraining pressure required to prevent gasification of the most volatile portion. Thus the measurement is of importance when a fuel is to be utilized in applications where no gasification may be tolerated, and

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from ASTM International Headquarters. Order Adjunct No. **ADJD2889**. Original adjunct produced in 1987.

<sup>4</sup> Edmister, W. C., and Okamoto, K. K., "Applied Hydrocarbon Thermodynamics, Part 12: Equilibrium Flash Vaporization Correlations for Petroleum Fractions," *Petroleum Refiner*, PEREA, Vol 38, No. 8, 1959, p. 117.

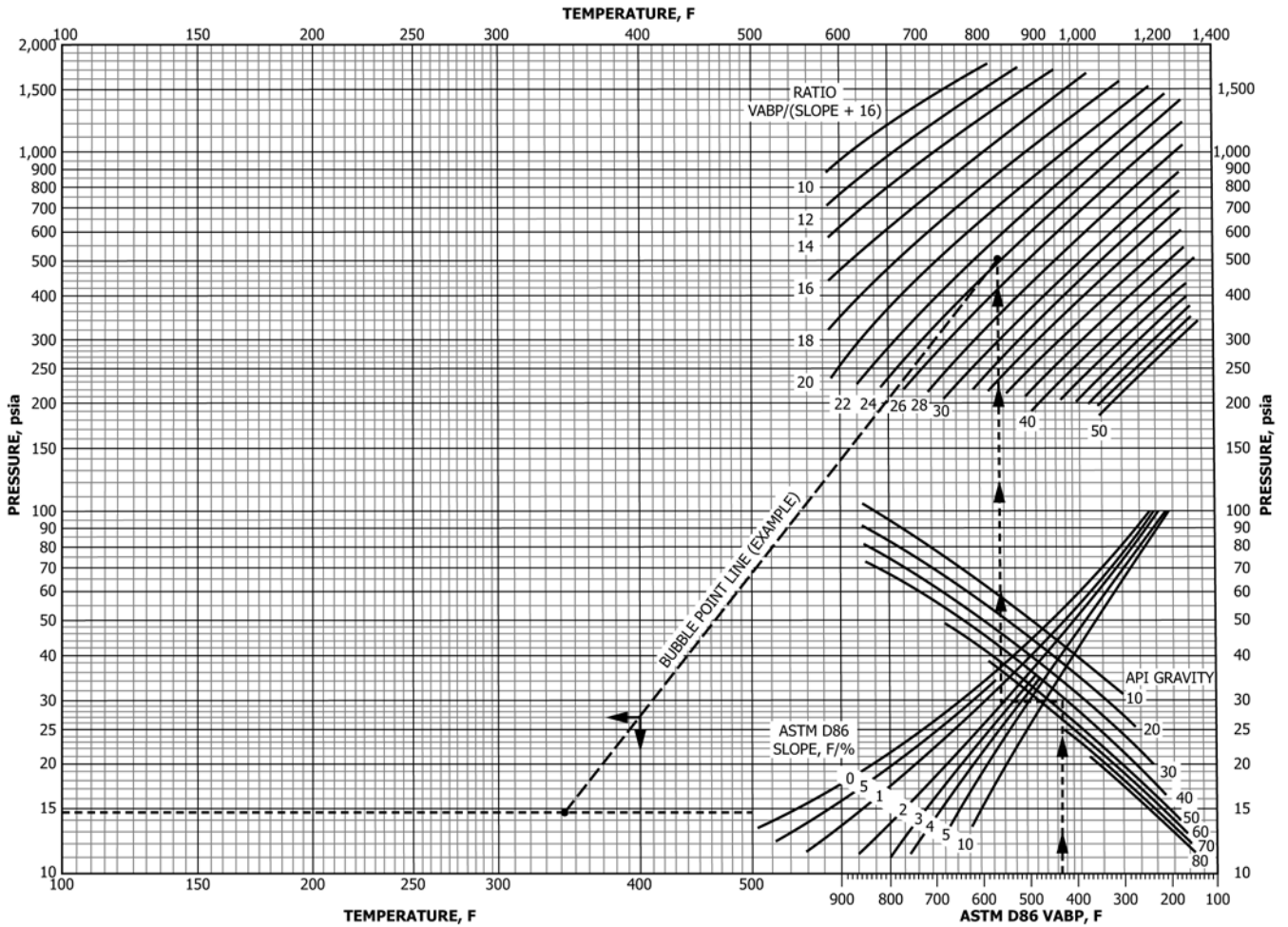


FIG. 1 Test Method D86 Distillation Temperature and Equalization Flash Vaporization Temperature Pressure Conversion Chart

temperature-pressure conditions are expected to be near the true vapor pressure of the fuel.

5. Data Requirements

5.1 Distillation temperatures at the initial boiling point (IBP) and 10 volume %, 30 volume %, 50 volume %, 70 volume %, and 90 volume % distilled obtained in accordance with Test Method D86.

5.2 API gravity determined in accordance with Test Method D287, or a method of equivalent accuracy.

6. Procedure

6.1 Calculate the 10/70 slope, °F/%, of the Test Method D86 distillation using the 10 volume % and 70 volume % distilled temperature. Using this slope and the Test Method D86 50 volume % distilled temperature, obtain to the nearest ±1 °F a temperature difference, °F, from Fig. 2. Add °F to the Method D86 50 volume % temperature to obtain the equilibrium flash vaporization (EFV) 50 volume % temperature.

6.2 Calculate the differences between the Test Method D86 IBP and 10 volume %, the 10 volume % and 30 volume %, and the 30 volume % and 50 volume % temperatures. Using these

differences, obtain to the nearest 1 °F, the temperature differences between corresponding EFV percentages from Fig. 3.

6.3 Calculate the EFV zero volume percent temperature by subtracting the sum of the three differences obtained from Fig. 3, from the EFV 50 volume % temperature calculated in accordance with 6.1.

6.4 Plot a point on Fig. 1<sup>3,5</sup> at the coordinates, 14.7 psia and the calculated EFV 0 % temperature. This point establishes the lower end of the phase boundary line commonly referred to as the bubble-point line. If the EFV 0 % temperature at atmospheric pressure has been measured, use the measured value instead of the calculated value.

6.5 Use the following procedure and the curves on the right portion of Fig. 1 to obtain coordinates for the upper end, or focal point, of the bubble-point line. If both the critical temperature and critical pressure of the fuel are known, the calculations described in 6.5.1 through 6.5.4 are not carried out. The critical temperature and critical pressure are used as

<sup>5</sup> Precision of the test method as given in Section 6 was obtained using 8½ by 11-in. charts and should be improved using the 16 by 20-in. charts.

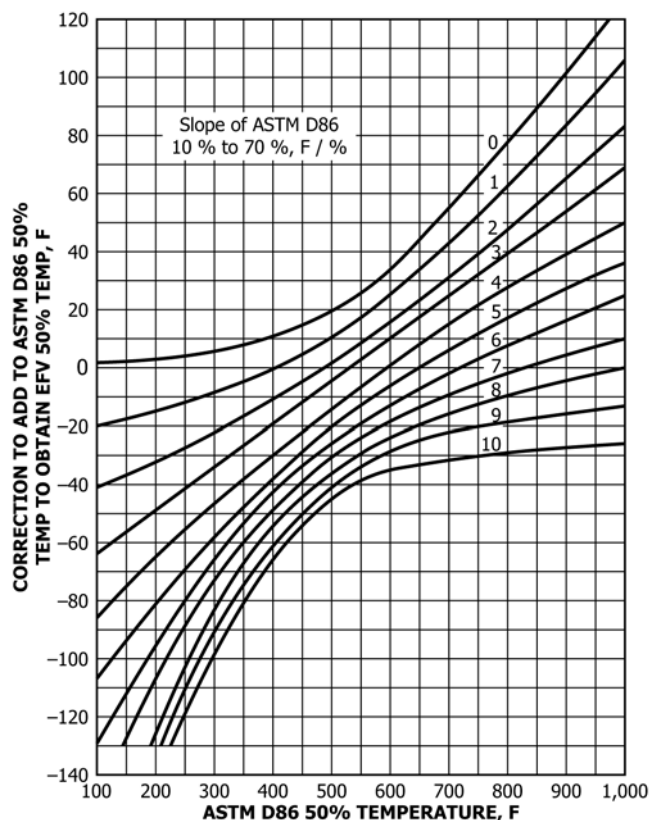


FIG. 2 Test Method D86 50 % Distilled Temperature versus Equilibrium Flash Vaporization 50 % Temperature

the coordinates in Fig. 1 to define a critical point to be used instead of the focal point.

6.5.1 Calculate to the nearest 0.1 unit the 10/90 slope of the Test Method D86 distillation curve, °F/volume %, as the difference between 10 volume % and 90 volume % distilled temperatures divided by 80.

6.5.2 Calculate to the nearest 1 °F, the volumetric average boiling point (VABP) as the sum of the Test Method D86 10 volume %, 30 volume %, 50 volume %, 70 volume %, and 90 volume % distilled temperatures divided by 5.

6.5.3 Calculate to the nearest 0.1 unit the ratio:

$$VABP / (10/90 \text{ Slope} + 16.0) \quad (1)$$

6.5.4 Enter Fig. 1 on the lower right scale at the Test Method D86 VABP temperature. From the intersection of the VABP temperature and the line of constant API gravity corresponding to the gravity of the sample, proceed horizontally to the point of intersection with the line corresponding to the 10/90 slope of the Test Method D86 distillation. From this point proceed vertically to the intersection with the ratio calculated for the sample according to the previous section. This point of intersection establishes the upper end, or focal point of the bubble-point line.

6.6 Draw the bubble-point line on Fig. 1 by connecting the two points (6.4 and 6.5.4) with a straight line.

6.7 Obtain the calculated true vapor pressure psia, at any specified temperature below the critical temperature by reading

the vertical pressure scale of Fig. 1 at the intersection of the bubble-point line with the specified temperature.

6.7.1 If either a determined critical temperature or determined critical pressure is known, the point of its intersection with the bubble-point line defines the maximum vapor pressure to be reported.

6.7.2 If neither the critical temperature nor critical pressure is known, obtain a calculated approximate critical temperature from Fig. 4.<sup>6</sup> The point of intersection of the calculated critical temperature with the bubble-point line defines the maximum vapor pressure to be reported.

## 7. Report

7.1 Report the results as indicated in the following tabulation:

Vapor Pressure Range, psia:	Report to the Nearest:
100 and below	1
100 to 200	2
200 to 500	5
Above 500	10

7.2 The calculated true vapor pressure psia may be converted to the International System of Units (SI) of kilopascals (kPa) by multiplying the results obtained in 7.1 by the conversion factor 6.894757 and then rounding to the appropriate number of significant digits.

## 8. Precision and Bias

8.1 Precision—The precision of this test method as determined by statistical examination of interlaboratory results is as follows:

8.1.1 Repeatability—The difference between successive test 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 value only in one case in twenty: the larger of 2 psia (14 kPa) or 4 % of the mean of the two results.

8.1.2 Reproducibility—The difference between two, single and independent results, obtained by different operators working in different laboratories on identical test material, would, in the normal and correct operation of the test method, exceed the following value only 1 case in 20: the larger of 2 psia (14 kPa) or 8 % of the mean of the two results.

NOTE 2—The preceding repeatability and reproducibility were obtained from results submitted by seven laboratories that cooperatively tested four turbine fuels with initial boiling points in the range 320 °F to 400 °F (160 °C to 204 °C), and end points in the range 430 °F to 534 °F (221 °C to 279 °C). Each laboratory determined the required distillation and gravity data in duplicate, and performed the calculations required for this procedure once for each of the two sets of determined data for each sample. Vapor pressures were not determined during the cooperative program.

8.2 Bias—The bias of the true vapor pressures obtained by this test method has not been evaluated. Determined true vapor pressures were not known for the fuels cooperatively tested.

<sup>6</sup> Technical Data Book-Petroleum Refining, American Petroleum Institute, 2101 L St. NW, Washington, DC 20037. Fig. 4 is a modified version of Fig. 4 A1.2, Chapter 4.

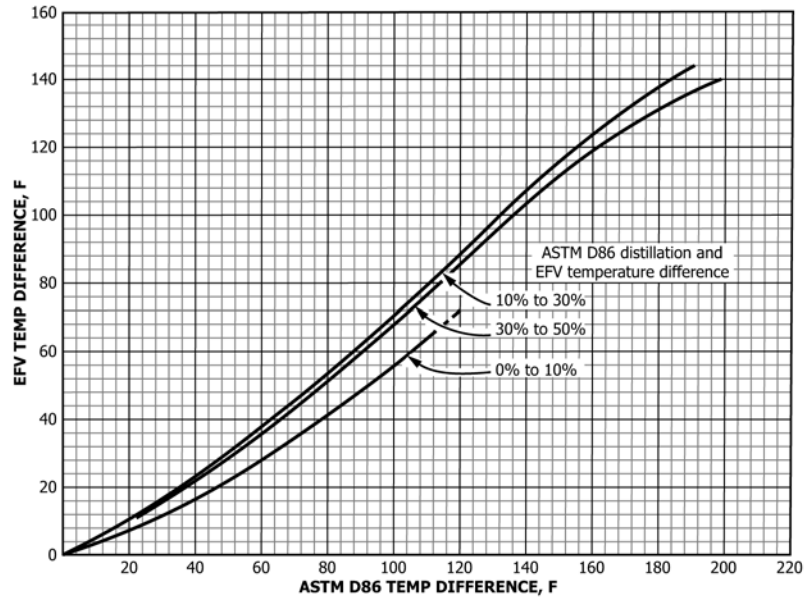


FIG. 3 Test Method D86 Distillation Temperature Differences Versus Equilibrium Flash Vaporization Temperature Differences

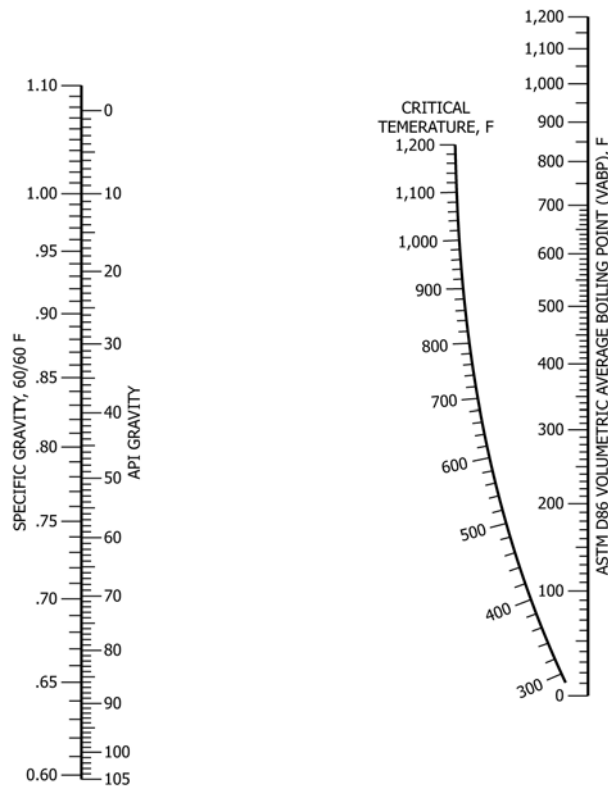


FIG. 4 Critical Temperature, Gravity, and Test Method D86 Volumetric Average Boiling Point °F

## 9. Keywords

9.1 API gravity; D86 distillation; true vapor pressure



**APPENDIX**
**(Nonmandatory Information)**
**X1. EXAMPLE OF TRUE VAPOR PRESSURE CALCULATION**

X1.1 Calculate the true vapor pressure at 400 °F, for a fuel for which the following data have been determined:

API gravity	40.0
Method <b>D86</b> distillation, °F (IBP)-IP 123	
0 %	275
10 %	345
30 %	404
50 %	436
70 %	465
90 %	505

X1.1.1 From **Fig. 2**, using the 10/70 slope of 2.0 % and the 50 % distillation temperature, a value of -6 is obtained as the increment to add to the 50 % distillation temperature to obtain the EFV 50 % temperature. Thus the calculated 50 % temperature is 436 - 6, or 430 °F.

X1.1.2 From **Fig. 3**, using ASTM temperature differences of 70 for 0 % to 10 %, 59 for 10 % to 30 %, and 32 for 30 % to 50 %, EFV temperature differences of 34, 37, and 17, respectively, were obtained and their sum determined to be 88. Thus the calculated EFV 0 % temperature is 430 - 88, or

342 °F. The coordinates for the lower end of the bubble-point line are 342 °F and 14.7 psia (distillation pressure), as plotted on **Fig. 1**.

X1.1.3 The slope of the Test Method **D86** distillation curve from 10 % to 90 % is equal to  $(505 - 345)/80$ , or 2.0 °F/%.

X1.1.4 The volumetric average boiling point is equal to  $(345 + 404 + 436 + 465 + 505)/5$ , or 431 °F.

X1.1.5 The ratio,  $VABP/(10/90 \text{ Slope} + 16.0)$  is  $431/(2.0 + 16.0)$ , or 23.9.

X1.1.6 The results of the calculations, **X1.1.1** to **X1.1.5** are shown in **Fig. 1**. The first datum entered in **Fig. 1** was the VABP, 431 °F, on the lower right scale, and other data were used as required and indicated by the heavy broken line to establish the focal point. The bubble-point line then was drawn by connecting the focal point and the point obtained as explained in **X1.1.2**.

X1.1.7 The calculated true vapor pressure at 400 °F, as read from the bubble-point line is 27 psia.

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