



Designation: **D 2493 – 95a01**

## Standard Viscosity-Temperature Chart for Asphalts<sup>1</sup>

This standard is issued under the fixed designation D 2493; 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 The viscosity-temperature chart covered by this standard is a convenient means of plotting data for estimating the viscosity of asphalts at any temperature within a limited range. Conversely, the chart may be used to ascertain the temperature at which a desired viscosity is attained.

1.2 The chart is suitable for original asphalt cements and for asphalts recovered from laboratory aging tests or extracted from pavements.

1.3 The chart is based on a viscosity-temperature relationship that can be plotted using any appropriate set of units. For convenience, charts based on both conventional and SI units are provided.

1.4 The range of the chart is sufficient for roofing asphalts.

1.45 The range of the chart is sufficient for liquid asphalts (bitumens) whose viscosity exceeds 0.1 poise (10 centipoise).

### 2. Referenced Documents

2.1 *ASTM Standards:*

D 341 Viscosity-Temperature Charts for Liquid Petroleum Products<sup>2</sup>

<sup>1</sup> This chart is under the jurisdiction of ASTM Committee ~~D-4~~ D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.44 on Rheological Tests.

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- D 2170 Test Method for Kinematic Viscosity of Asphalts (Bitumens)<sup>3</sup>
- D 2171 Test Method for Viscosity of Asphalts by Vacuum Capillary Viscometer<sup>3</sup>
- D 3205 Test Method for Viscosity of Asphalt with Cone and Plate Viscometer<sup>3</sup>
- D 4957 Test Method for Apparent Viscosity of Asphalt Emulsion Residues and Non-Newtonian Bitumens by Vacuum Capillary Viscometer<sup>3</sup>

**3. Significance and Use**

3.1 The viscosity-temperature chart is a convenient means of plotting the viscosity data for estimating the viscosity of asphalts, recovered asphalts, and roofing asphalts at any temperature within a limited range. It is also a convenient means to estimate the temperature at which a desired viscosity is attained.

3.2 Kinematic viscosity-temperature charts are described in Charts D 341.

**4. Description**

4.1 For Fig. 1, the chart coordinates are logarithm of the logarithm of the viscosity in centipoise as the ordinate, and logarithm of the absolute temperature in Degrees Rankine (degrees F + 459.7) as the abscissa. However, the viscosity in poise and the temperature in degrees Fahrenheit is shown in the chart for convenience.<sup>4</sup>

4.1.1 The range of the chart is 10<sup>-1</sup> to 10<sup>24</sup> poise and 0 to 400°F, as shown in Fig. 1. Its size is 16 by 17 in. (406 by 432 mm).

4.2 For Fig. 2, the chart coordinates are logarithm of the logarithm of the viscosity in mPa.s as the ordinate, and logarithm of the absolute temperature in degrees Kelvin (degrees C + 273.2) as the abscissa. However, viscosity in Pascal-seconds, and the temperature in degrees Celsius is shown in the chart for convenience.

<sup>2</sup> Annual Book of ASTM Standards, Vol 05.01.

<sup>3</sup> Annual Book of ASTM Standards, Vol 04.03.

<sup>4</sup> The chart is available at a nominal charge. Contact ASTM International Headquarters at 100 Barr Harbor Drive, West Conshohosken, PA 19428. Request Adjunct No. ADJD2493.

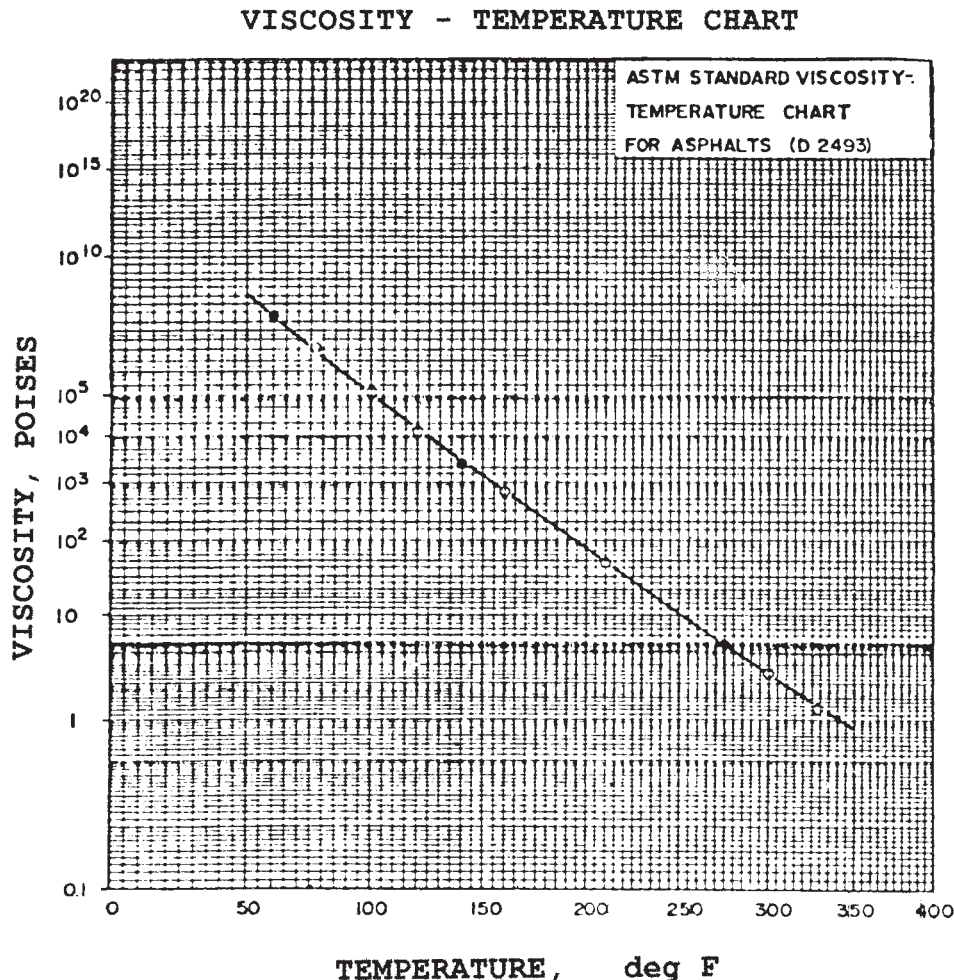


FIG. 1 Facsimile of Viscosity-Temperature Chart on Which a Typical Experimental Curve Has Been Plotted

VISCOSITY - TEMPERATURE CHART

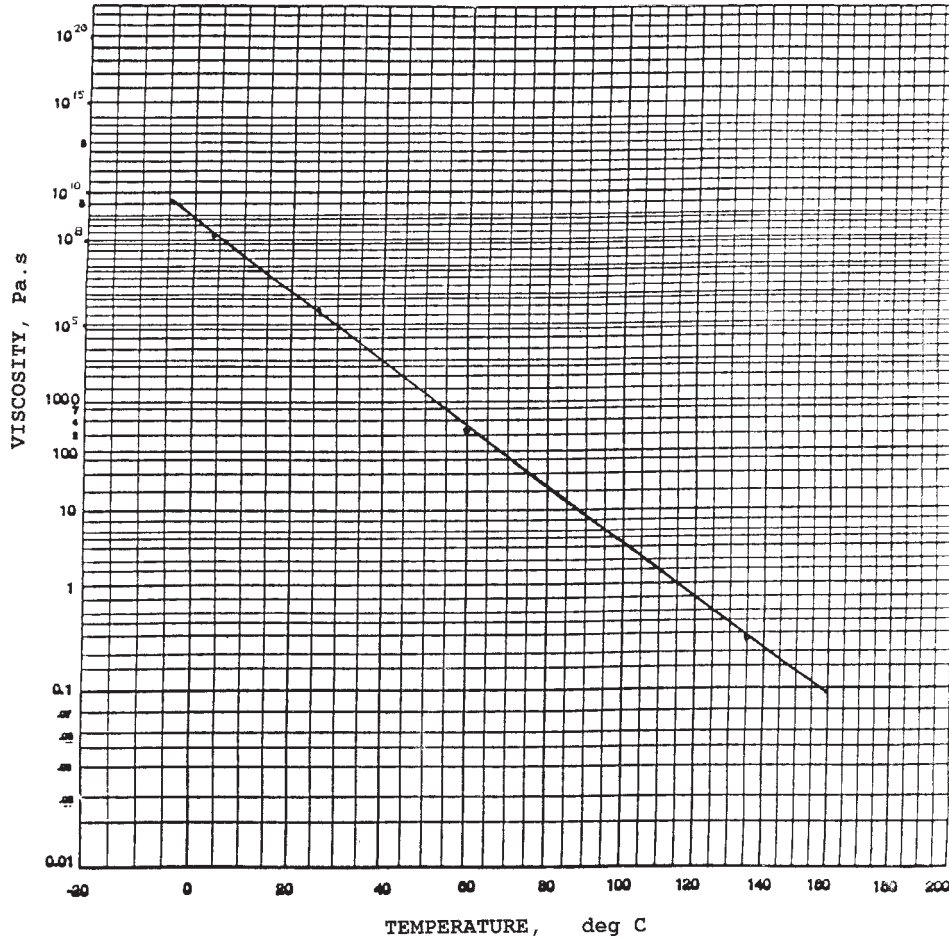


FIG. 2 Viscosity-Temperature Chart for Asphalts on Which a Typical Experimental Curve has Been Plotted

$$(1 \text{ Pa.s} = \text{mPa.s} \times 10^3) \tag{1}$$

4.2.1 The range of the chart is 10<sup>-2</sup> to 10<sup>23</sup> Pa.s and -20 to 200°C, as shown in Fig. 2.

4.3 The temperature range of the charts may be extended to lower temperatures by renumbering the temperature scale of a second chart, according to Table 1, discarding the portion above 230°F (110°C), and placing the 230°F (110°C) axis along the 0°F (-17.8°C) axis of an original chart.

**5. Procedure**

5.1 For temperatures above 140°F (60°C) 60°C (140°F), plot two viscosity-temperature points and carefully draw a straight line through the points. Plot at least three viscosity-temperature points if the included temperature range is below 60°C (140°F). Carefully draw a straight line or curve through the points. A point on this line, within the temperature range of the points plotted, shows the viscosity at the corresponding desired temperature.

**TABLE 1 Low-Temperature Substitutes**

NOTE 1—Standards for determining the viscosity of asphalts at very low temperatures have not been developed. The significance of extrapolated viscosities at very low temperatures is not known.

Column A	Column B
Temperature Printed on Chart, °F (°C)	Low-Temperature Substitute, °F (°C)
+ 170 (76.7)	-40 (-40)
+ 185 (84.9)	-30 (-34.4)
+ 200 (93.3)	-20 (-28.9)
+ 215 (102.8)	-10 (-23.3)
+ 230 (110.0)	0 (-17.8)

**NOTE 1**—These charts are appropriate for use at higher temperatures, where asphalts are primarily viscous. At lower temperatures most asphalts become viscoelastic. When this occurs, viscosity alone is insufficient to describe an asphalt's flow properties. Most asphalts are primarily viscous at temperatures above 60°C (140°F). Caution should be used when applying this standard below that temperature.

5.2 Some asphalts have viscosity-temperature relationships too complex to be represented by only three points, as shown in Fig. 1. In this case determine the viscosity at sufficient temperatures to produce a curve adequate for the purpose intended.

5.3 If the viscosities are not known they should be determined in accordance with Test Methods D 2170, D 2171, D 3205, and D 4957. Viscosities determined at temperatures other than the temperatures specified in each of these test methods may be used.

5.4 Viscosities determined by extrapolation of data may be unreliable.

5.5 The viscosity values represented by the data points may have been obtained at different shear rates. This chart does not reflect the shear rate at which the viscosities were determined.

## 6. Keywords

6.1 asphalt; rheology; viscosity; viscosity-temperature chart

## APPENDIX

### (Nonmandatory Information)

#### X1. SUGGESTIONS FOR DATA ANALYSIS

X1.1 The chart in Fig. 1 includes the region where the viscosity of asphalts depends not only on the temperature, but also on the shearing conditions. Therefore, the data plotted on the viscosity-temperature chart must be obtained under standardized shearing conditions, for example, at the same shear rate, or the same shear stress. Constant shearing conditions also implies the use of the same viscometer, or viscometers of the same type and size, to avoid differences in viscosity values caused by differences in the extent of breakdown of the micellar structure of the asphalt due to shearing in the measurement process.

X1.2 Asphalt viscosities are often reported at an arbitrary shear rate of 0.05 s<sup>-1</sup>. Interpolation or extrapolation of measured viscosity data is often required to obtain values for this shear rate. A useful model for interpolating or extrapolating asphalt rheological measurements is the empirical "Power Law" relationship:

$$\tau = \eta_1 \dot{\gamma}^c \quad (X1.1)$$

where:

$\tau$  = the shearing stress,

$\dot{\gamma}$  = the rate of shear,

$\eta_1$  = the apparent viscosity at a shear rate of 1 s<sup>-1</sup>, and

$c$  = the slope of a plot of log  $\tau$  versus log  $\dot{\gamma}$ .

The parameter  $c$  is called the Complex Flow Index, and is an indicator of the rheological character of the material. For Newtonian liquids, whose viscosity does not vary with shear rate,  $c = 1$ . If  $c < 1$ , the apparent viscosity decreases with increasing shear rate, and if  $c > 1$ , the apparent viscosity increases with shear rate.

X1.3 Because a small error in the value of  $c$  can cause a large error in an extrapolated viscosity value, it is recommended that the Power Law slope be determined using replicate tests on the material. The average value of  $c$  can be determined by regression analysis of the log  $\tau$  versus log  $\dot{\gamma}$  data. If the data for replicate tests do not superimpose on a plot of all the data on the same chart, the calibration and operating procedure for the viscometer should be checked before proceeding further with the data analysis. If there are a small number of outliers, these can be discarded, and the remainder of the data used in the regression analysis. Fig. X1.1 shows an example of data containing outliers that should be ignored.

X1.3.1 The objective of screening for outliers should be to retain all data that legitimately belong in the population of results characteristic of the test method used, and to eliminate only those that differ so drastically that their inclusion distorts the shear stress versus shear rate relationship. Therefore, the criterion for rejecting data should be conservative. If a statistical technique is used, the significance level of the test should be no greater than one percent.

X1.4 Large extrapolations of rheological data to obtain values at constant shear rate are often unavoidable because most viscometers allow a limited range of shear stress, and the large variation in viscosity over a range of temperatures results in large differences in observed shear rate at different test temperatures. A procedure which circumvents this problem is to plot the apparent viscosity at constant power input per unit volume as a function of temperature. This avoids long extrapolations of the shear stress/shear rate relationships. H. E. Schwyer and others have recommended that apparent viscosities at a constant power input of 100 W/m<sup>3</sup> be used. However, this value has no theoretical significance, and may not be appropriate for all viscometers. A value which minimizes the amount of extrapolation needed to estimate the apparent viscosities in the temperature range of interest should be selected.

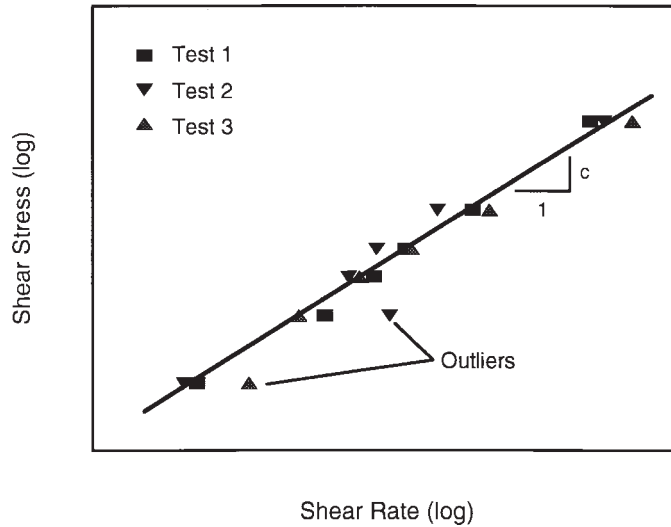


FIG. X1.1 Power Law Shear Stress versus Shear Rate Relationship

X1.5 To estimate the apparent viscosity at constant power input, first determine the Power Law constants  $\eta_1$  and  $c$  from a plot or regression analysis of log shear stress versus log shear rate. Calculate the apparent viscosity at power input  $P$  from:

$$\eta_P = \eta_1 \frac{P^{\frac{c-1}{c+1}}}{\eta_1} \tag{X1.2}$$

where:

- $\eta_P$  = apparent viscosity, Pa.s at power input  $P$ ,  $W/m^3$ ,
- $\eta_1$  = apparent viscosity, Pa.s at  $1 \text{ s}^{-1}$  shear rate, and
- $c$  = complex flow index.

X1.6 The effect of temperature on apparent viscosity can be shown by plotting the constant power input viscosities at two or more temperatures on the chart in Fig. 1. Because of the non-linearity of the scales on this chart, the viscosities must be plotted in the units shown. Many asphalts will have a straight line viscosity versus temperature relationship on the chart. However, a minimum of 3 points should be plotted, to ensure that the nature of the relationship is shown. Because of the possibility of curvature, particularly at very high viscosity levels, extrapolation is not recommended.

X1.7 Alternatively, a regression analysis of  $\log \log \eta$  versus  $\log T$  (absolute temperature) can be performed. To be consistent with Fig. 1, the viscosity values must be converted to mPa.s or cP before taking the logarithms. A straight regression line of this type is shown in Fig. X1.2.

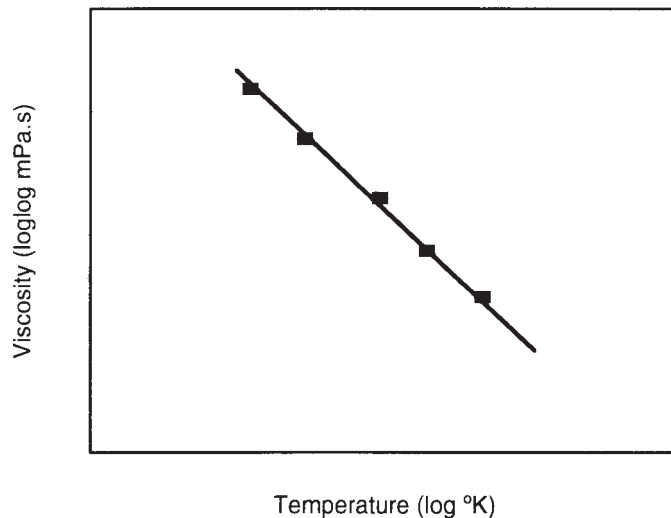


FIG. X1.2 Viscosity versus Temperature Relationship

X1.8 Lefebvre and Robertson<sup>5</sup> is suggested for additional reading, because it describes the application of these techniques.

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<sup>5</sup> Lefebvre, J. A. and Robertson, W. D., "Viscosity Characteristics of Two Canadian Asphalts," *Proceedings CTA* 15, Vol 101, 1970.

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