Designation: D2140 – 08 (Reapproved 2017)

Standard Practice for Calculating Carbon-Type Composition of Insulating Oils of Petroleum Origin[1]

This standard is issued under the fixed designation D2140; 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 practice may be used to determine the carbon-type composition of mineral insulating oils by correlation with basic physical properties. For routine analytical purposes it eliminates the necessity for complex fractional separation and purification procedures. The practice is applicable to oils having average molecular weights from 200 to above 600, and 0 to 50 aromatic carbon atoms.

1.2 Carbon-type composition is expressed as percentage of aromatic carbons, percentage of naphthenic carbons, and percentage of paraffinic carbons. These values can be obtained from the correlation chart, Fig. 1, if both the viscosity-gravity constant (VGC) and refractivity intercept (r_i) of the oil are known. Viscosity, density and relative density (specific gravity), and refractive index are the only experimental data required for use of this test method.

1.3 This practice is useful for determining the carbon-type composition of electrical insulating oils of the types commonly used in electric power transformers and transmission cables. It is primarily intended for use with new oils, either inhibited or uninhibited.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D129 Test Method for Sulfur in Petroleum Products (General High Pressure Decomposition Device Method)

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

D923 Practices for Sampling Electrical Insulating Liquids

D1218 Test Method for Refractive Index and Refractive Dispersion of Hydrocarbon Liquids

D1481 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Lipkin Bicapillary Pycnometer

D2007 Test Method for Characteristic Groups in Rubber Extender and Processing Oils and Other Petroleum-Derived Oils by the Clay-Gel Absorption Chromatographic Method

D2501 Test Method for Calculation of Viscosity-Gravity Constant (VGC) of Petroleum Oils

D3238 Test Method for Calculation of Carbon Distribution and Structural Group Analysis of Petroleum Oils by the n-d-M Method

D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter

3. Terminology

3.1 *Definitions:*

3.1.1 *percent of aromatic carbons (% C_A)*—the weight percent of the total carbon atoms present in an oil that are combined in aromatic ring-type structures.

3.1.2 *percent of naphthenic carbons (% C_N)*—the weight percent of the total carbon atoms present in an oil that are combined in naphthenic ring-type structures.

3.1.3 *percent of paraffinic carbons (% C_P)*—the weight percent of the total carbon atoms present in an oil that are combined in paraffinic chain-type structures.

[1] This practice is under the jurisdiction of ASTM Committee D27 on Electrical Insulating Liquids and Gases and is the direct responsibility of Subcommittee D27.07 on Physical Test.

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

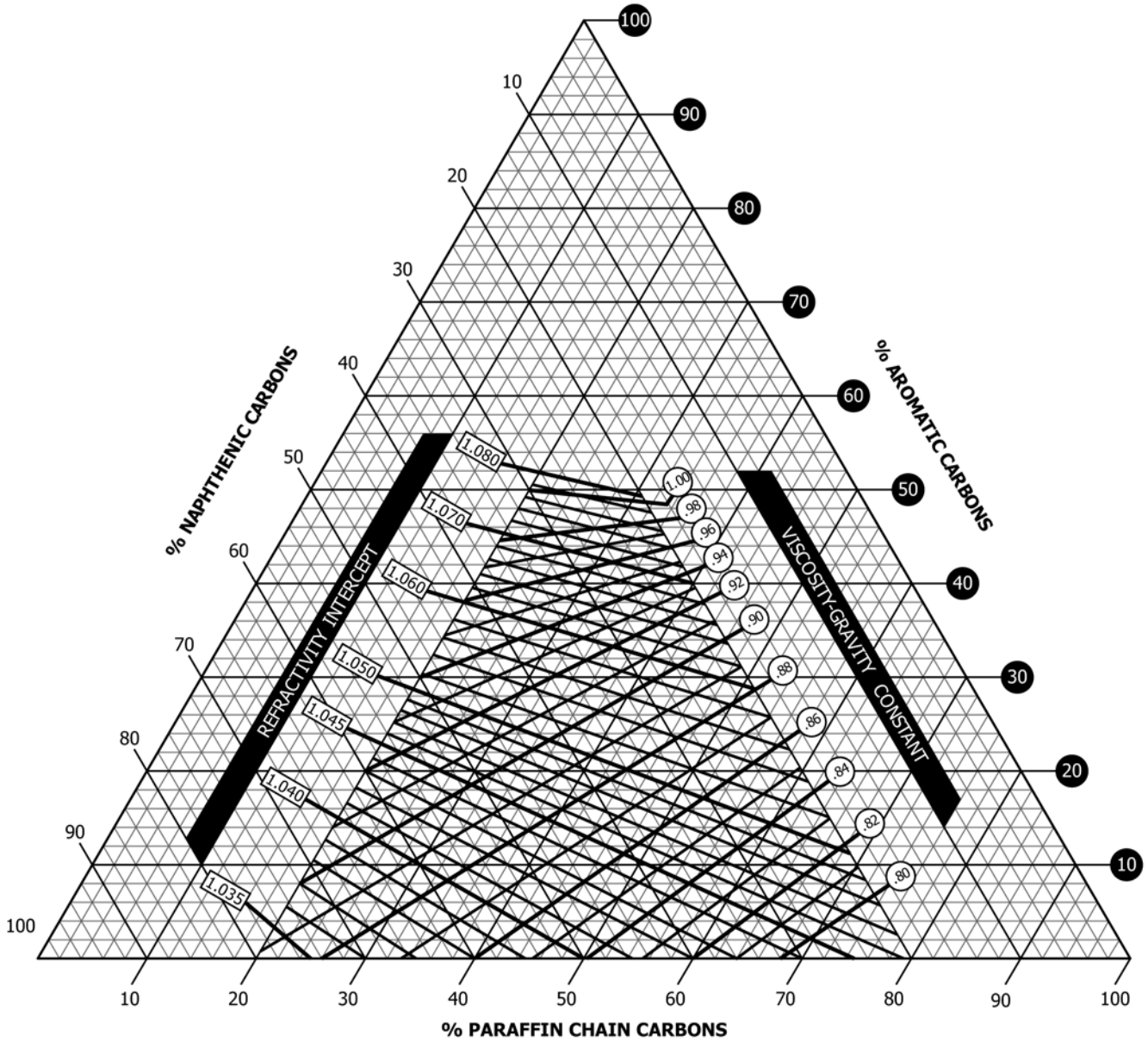

FIG. 1 Correlation Chart for Determining % C_A, % C_N, and % C_P

NOTE 1—The resolution of carbon atoms into structural classifications is independent of whether the structures exist as separate molecules or are combined with other structural forms in a molecule. For example, a paraffinic chain may be either an aliphatic hydrocarbon molecule, or may be an alkyl group attached to an aromatic or naphthenic ring.

4. Summary of Practice

4.1 A sample of the oil is tested to determine its viscosity, density and relative density (specific gravity), and refractive index. From these measured properties the viscosity-gravity constant (VGC) and refractivity intercept (r_i) are obtained by calculation, using the equations given. The calculated values of VGC and r_i are used with Fig. 1, to correlate those parameters with carbon-type composition. The composition in terms of % C_A, % C_N, and % C_P may be read directly from Fig. 1.

NOTE 2—Fig. 1 is a form of correlation chart that has been found satisfactory for use with this method. Other chart forms may be devised and used in preference to Fig. 1 if it is determined that the data obtained are consistent with similar data from Fig. 1. In addition, some users will find it convenient to develop a computer program or spreadsheet which will provide a consistent evaluation of the data.

5. Significance and Use

5.1 The primary purpose of this practice is to characterize the carbon-type composition of an oil. It is also applicable in observing the effect on oil constitution, of various refining processes such as hydrotreating, solvent extraction, and so forth. It has secondary application in relating the chemical nature of an oil to other phenomena that have been demonstrated to be related to oil composition.

5.2 Results obtained by this practice are similar to, but not identical with, results obtained from Test Method D3238. The relationship between the two and the equations used in deriving Fig. 1 are discussed in the literature.[3]

5.3 Although this practice tends to give consistent results, it may not compare with direct measurement test methods such as Test Method D2007.

6. Apparatus

6.1 No specific apparatus is required. However, to obtain the VGC and r_i parameters of Fig. 1, certain measurements of basic physical properties of the test oil must be made. The apparatus required for those measurements is as specified in ASTM test methods as detailed in Section 7.

7. Procedure

7.1 Obtain a uniform sample of the oil to be analyzed for carbon-type composition, using sampling procedures as specified in Practices D923.

7.2 Determine the viscosity, density and relative density (specific gravity), and refractive index of the sample experimentally by the procedures specified in the following test methods:

7.2.1 *Viscosity*—See Test Method D445.

7.2.2 *Density and Relative Density (Specific Gravity)*—See Test Method D1481 or D4052.

7.2.3 *Refractive Index*— See Test Method D1218.

8. Calculation

8.1 From the measured viscosity and specific gravity properties of the oil sample (7.2) calculate the viscosity-gravity constant, VGC, as follows (Note 3):

$$VGC = \frac{G + 0.0887 - 0.776 \log\log(10V - 4)}{1.082 - 0.72 \log\log(10V - 4)}$$

where:

G = relative density (specific gravity) at 15.6°C (60°F), and
V = viscosity, cSt at 37.8°C (100°F).

NOTE 3—This equation for VGC was devised by Moore and Kaye.[4] Accurate VGC data may be obtained using other equations and other measurement temperatures. Test Method D2501 gives some of these alternatives.

8.2 From the measured density and refractive index properties of the oil sample (7.2) calculate the refractivity intercept, r_i, as follows:

$$r_i = n_D^{\,20} - (d/2)$$

where:

$n_D^{\,20}$ = refractive index at 20°C (68°F) for D line of sodium, and
d = density at 20°C (68°F).

8.3 Enter the correlation chart, Fig. 1, with the values of VGC and r_i, from 8.1 and 8.2. Read from Fig. 1 the corresponding values of % C_A, % C_N, and % C_P.

8.4 For oils containing 0.8 % or more sulfur, the accuracy of this practice may be improved by applying a sulfur correction. This may be done by use of the following equations (Note 4):

$$\text{Sulfur correction for \% } C_N = -\text{weight \% } S/0.288$$

$$\text{Sulfur correction for \% } C_P = +\text{weight \% } S/0.216$$

$$\text{Sulfur correction for \% } C_A = 100 - (\text{corrected \% } C_N + \text{corrected \% } C_P)$$

NOTE 4—Commercially available oils of the types to which this method applies normally have sulfur contents of less than 0.8 %. Therefore it is unlikely that a sulfur correction will be necessary. For new or experimental oils, or whenever the true sulfur content is unknown, the determination of that quantity is recommended. A satisfactory method is described in Test Method D129.[4]

9. Report

9.1 Report the following information:

9.1.1 Designation of practice used (D2140),
9.1.2 Sample identification.
9.1.3 Percent of aromatic ring carbons (% C_A).
9.1.4 Percent of naphthenic ring carbons (% C_N), and
9.1.5 Percent of paraffinic chain carbons (% C_P).

NOTE 5—The total of 9.1.3, 9.1.4, and 9.1.5 should equal 100 %.

10. Keywords

10.1 carbon type; composition; electrical oils; mineral oils; oils

[3] Kurtz, S. S., King, R. W., Stout, W. J., Partikian, D. G., and Skrabek, E. A., "Relationship Between Carbon-Type Composition, Viscosity-Gravity Constant, and Refractivity Intercept of Viscous Fractions of Petroleum," *Analytical Chemistry*, Vol 28, 1956, pp 1928–1936.

[4] *Proc.*, 15th API Annual Meeting, November 1934, Section II, p. 7.