Designation: D 2140 – ~~97~~03

Standard Test Method for Carbon-Type Composition of Insulating Oils of Petroleum Origin [1]

This standard is issued under the fixed designation D 2140; 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] This test method is under the jurisdiction of ASTM Committee D-27 on Electrical Insulating Liquids and Gases and is the direct responsibility of Subcommittee D27.07 on Physical Tests.

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1. Scope

1.1 This test method 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 test method 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 test method 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 *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:*

D 129 Test Method for Sulfur in Petroleum Products (General Bomb Method)[2]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[2]

D ~~923 Test Method~~ 923 Practices for Sampling Electrical Insulating Liquids[3]

D 1218 Test Method for Refractive Index and Refractive Dispersion of Hydrocarbon Liquids[2]

D 1481 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Lipkin Bicapillary Pycnometer[2]

D 2007 Test Method for Characteristic Groups in Rubber Extender and Processing Oils and Other Petroleum Derived Oils by the Clay Gel Absorption Chromatographic Method[2]

D 2501 Test Method for Calculation of Viscosity-Gravity Constant (VGC) of Petroleum Oils[2]

D 3238 Test Method for Calculation of Carbon Distribution and Structural Group Analysis of Petroleum Oils by the ~~N-D-M~~ n-d-M Method[4]

D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter[4]

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.

[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 10.03.

[4] *Annual Book of ASTM Standards*, Vol 05.02.

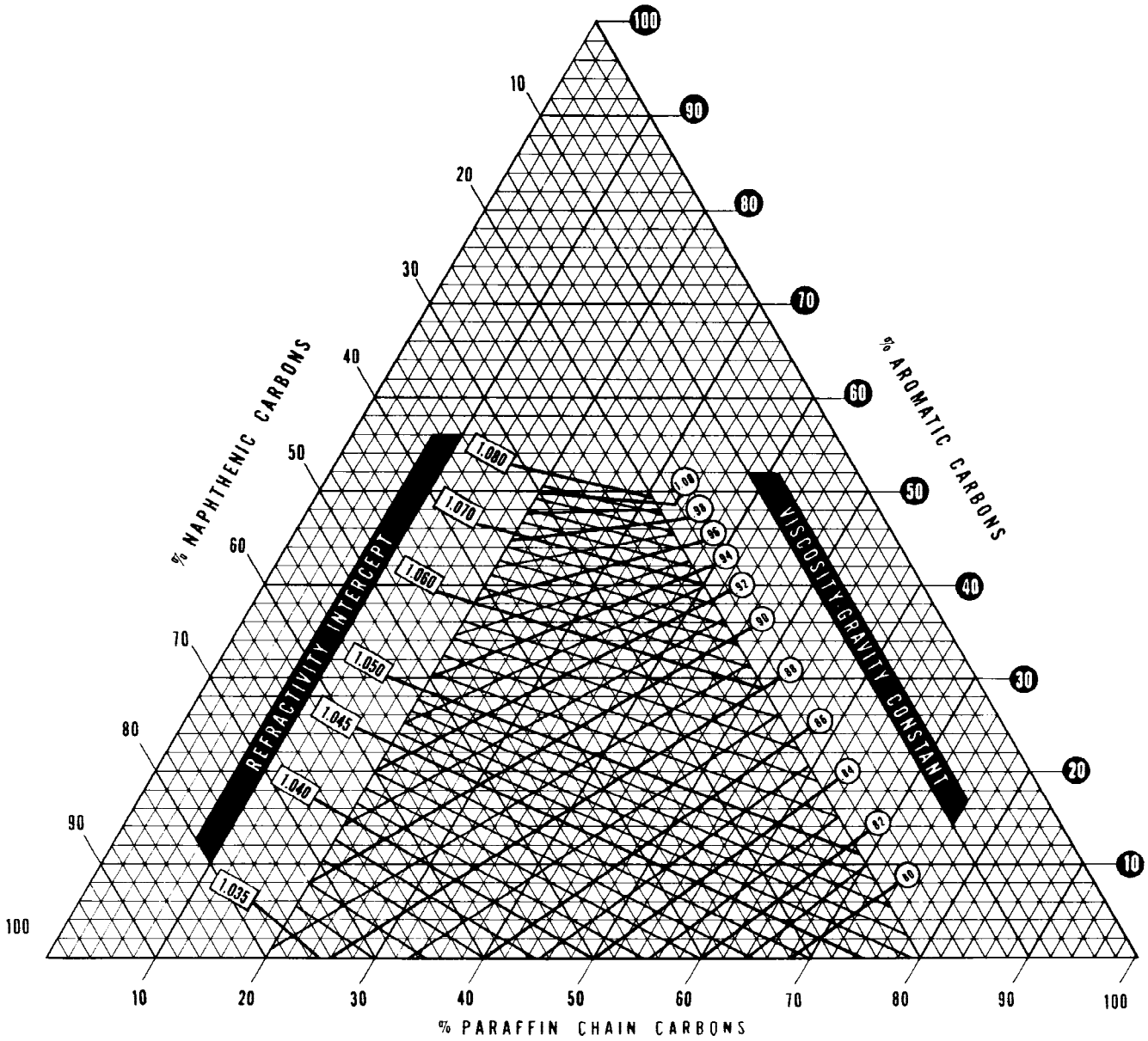

FIG. 1 Correlation Chart for Determining % C_A, % C_N, and % C_P ~~(See Appendix)~~

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.

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 Test Method

4.1 A sample of the oil to be analyzed by this method is first 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 test method 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, ~~acid treatment, etc.~~ 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 method are similar to, but not identical with, results obtained from Test Method D 3238. The relationship between the two methods and the equations used in deriving Fig. 1 are discussed in the literature.[5]

5.3 Although this test method tends to give consistent results, it may not compare with direct measurement test methods such as Test Method D 2007.

6. Apparatus

6.1 No specific apparatus is required for use by this test method. 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 other 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 ~~Test Method~~ Practices D 923.

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 D 445.

7.2.2 *Density and Relative Density (Specific Gravity)*—See Test Method D 1481 or D 4052.

7.2.3 *Refractive Index*— See Test Method D 1218.

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.[6] Accurate VGC data may be obtained using other equations and other measurement temperatures. Test Method D 2501 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 test method may be improved by applying a sulfur correction. This may be done by use of the following equations (Note 4):

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

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

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

[5] 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, pp 1928–1936 (1956).

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

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 D 129.[6]

9. Report

9.1 Report the following information:
9.1.1 Designation of test method used (D 2140),
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. Precision and Bias

10.1 *Precision*—The precision of this test method has not been the subject of an interlaboratory test. This procedure involves calculations based on three experimentally observed values whose precisions are given in their respective methods. The precision of this test method (without the sulfur correction), calculated from the precisions of these values and using the equations of ~~Appendix X1 to avoid errors in reading Fig. 1,~~ Section 8, is as follows:

10.1.1 *Repeatability*— The difference between successive results obtained by the same operator with the same apparatus under constant operating conditions on identical test material should, in the long run, in the normal and correct operation of the test method exceed the following values only in 1 case in 20:

	C_A = 0 %	C_A = 25 %	C_A = 50 %
C_A	0.2	0.1	0.1
C_N	0.3	0.2	0.5
C_P	0.2	0.2	0.5

10.1.2 *Reproducibility*— The difference between two single and independent results obtained by different operators working in different laboratories on identical test material should, in the long run, exceed the following values only in 1 case in 20:

	C_A = 0 %	C_A = 25 %	C_A = 50 %
C_A	0.2	0.2	0.2
C_N	0.7	0.4	1.0
C_P	0.5	0.4	1.1

NOTE 6—The precision of the carbon-type composition calculation varies with position on the C_A–C_N–C_P plane of Fig. 1. Sensitivity to experimental error for the C_N and C_P values is greatest at high C_A values. The precision values given above do not apply if routine test methods, rather than the precision methods specified, are used for determining density and refractive index.

10.2 *Bias*—Since there is no accepted reference material suitable for determining the bias of this test method, no statement on bias is being made. A comparison of results from this test method and a complex separation and purification procedure has been reported[7] for petroleum fractions, with agreement between the two methods being dependent on the viscosity-gravity constant of the fraction.

11. Keywords

11.1 carbon type; composition; electrical oils; mineral oils; oils

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~~APPENDIX~~

[7] Stout, W. J., et al, "Adsorption and Physical Property Methods." *Symposium on Composition of Petroleum Oils, ASTM STP 224*, ASTM, 1957, p. 230.

~~**(Nonmandatory Information)**~~

~~**X1. COMPUTER PROGRAM FOR CARBON-TYPE COMPOSITION CALCULATION**~~

~~X1.1 Because of the difficulty in reading Fig. 1 accurately, as well as the necessity of calculating viscosity-gravity constant and refractivity intercept, a computer program that calculates these values and the carbon-type composition analytically may be convenient. A FORTRAN IV subroutine that does this calculation is as follows in Fig. X1.1:~~