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Standard Test Method for Acid and Base Number by Color-Indicator Titration¹

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This test method has been adopted for use by government agencies to replace Method 5105 of Federal Test Method Standard No. 791b.

1. Scope

1.1 This test method covers the determination of acidic or basic constituents (Note 1) in petroleum products² and lubricants soluble or nearly soluble in mixtures of toluene and isopropyl alcohol. It is applicable for the determination of acids or bases whose dissociation constants in water are larger than 10^{-9} ; extremely weak acids or bases whose dissociation constants are smaller than 10^{-9} do not interfere. Salts react if their hydrolysis constants are larger than 10^{-9} .

NOTE 1—In new and used oils, the constituents considered to have acidic characteristics include organic and inorganic acids, esters, phenolic compounds, lactones, resins, salts of heavy metals, and addition agents such as inhibitors and detergents. Similarly, constituents considered to have basic properties include organic and inorganic bases, amino compounds, salts of weak acids (soaps), basic salts of polyacidic bases, salts of heavy metals, and addition agents such as inhibitors and detergents.

NOTE 2—This test method is not suitable for measuring the basic constituents of many basic additive-type lubricating oils. Test Method D 4739 can be used for this purpose.

1.2 This test method can be used to indicate relative changes that occur in an oil during use under oxidizing conditions. Although the titration is made under definite equilibrium conditions, the method does not measure an absolute acidic or basic property that can be used to predict performance of an oil under service conditions. No general relationship between bearing corrosion and acid or base numbers is known.

NOTE 3—Oils, such as many cutting oils, rustproofing oils, and similar compounded oils, or excessively dark-colored oils, that cannot be analyzed for acid number by this test method due to obscurity of the color-indicator end point, can be analyzed by Test Method D 664. The acid numbers obtained by this color-indicator test method need not be

numerically the same as those obtained by Test Method D 664, the base numbers obtained by this color indicator test method need not be numerically the same as those obtained by Test Method D 4739, but they are generally of the same order of magnitude.

1.3 The values stated in acceptable SI units are to be regarded as the standard.

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 117 Guide to Sampling Test Methods, Standard Practices, and Guides for Electrical Insulating Oils of Petroleum Origin³

D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration⁴

D 1193 Specification for Reagent Water⁵

D 4175 Terminology Relating to Petroleum, Petroleum Products, and Lubricants⁶

D 4739 Test Method for Base Number Determination by Potentiometric Titration⁶

3. Terminology

3.1 Definitions:

3.1.1 *acid number, n*—the quantity of base, expressed in milligrams of potassium hydroxide per gram of sample that is required to titrate a sample to a specified end point.

3.1.1.1 *Discussion*—In this test method, the indicator is *p*-naphtholbenzein titrated to a green/green-brown end point in a toluene-water-isopropanol solvent.

3.1.2 *base number, n*—the quantity of acid, expressed in milligrams of potassium hydroxide per gram of sample that is required to titrate a sample to a specified end point.

¹ This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.06 on Analysis of Lubricants.

In the IP, this test method is under the jurisdiction of the Standardization Committee. This test method was adopted as a joint ASTM-IP standard in 1965.

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² Statements defining this test method, its modification, and its significance when applied to electrical insulating oils of mineral origin will be found in Guide D 117.

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

⁴ *Annual Book of ASTM Standards*, Vol 05.01.

⁵ *Annual Book of ASTM Standards*, Vol 11.01.

⁶ *Annual Book of ASTM Standards*, Vol 05.02.

3.1.2.1 *Discussion*—In this test method, the indicator is *p*-naphtholbenzein titrated to an orange end point in a toluene-water-isopropanol solvent.

3.1.3 *used oil, n*—any oil that has been in a piece of equipment (for example, an engine, gearbox, transformer, or turbine) whether operated or not. (D 4175)

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *strong acid number, n*—the quantity of base, expressed in milligrams of potassium hydroxide per gram of sample, that is required to titrate a hot water extract of the sample to a golden-brown end point using methyl orange solution.

4. Summary of Test Method

4.1 To determine the acid or base number, the sample is dissolved in a mixture of toluene and isopropyl alcohol containing a small amount of water, and the resulting single-phase solution is titrated at room temperature with standard alcoholic base or alcoholic acid solution, respectively, to the end point indicated by the color change of the added *p*-naphtholbenzein solution (orange in acid and green-brown in base). To determine the strong acid number, a separate portion of the sample is extracted with hot water and the aqueous extract is titrated with potassium hydroxide solution, using methyl orange as an indicator.

5. Significance and Use

5.1 New and used petroleum products can contain basic or acidic constituents that are present as additives or as degradation products formed during service, such as oxidation products. The relative amount of these materials can be determined by titrating with acids or bases. This number, whether expressed as *acid number* or *base number*, is a measure of this amount of acidic or basic substances, respectively, in the oil—always under the conditions of the test. This number is used as a guide in the quality control of lubricating oil formulations. It is also sometimes used as a measure of lubricant degradation in service; however, any condemning limits must be empirically established.

5.2 Since a variety of oxidation products contribute to the acid number and the organic acids vary widely in corrosive properties, the test cannot be used to predict corrosiveness of an oil under service conditions. No general correlation is known between acid number and the corrosive tendency of oils toward metals. Compounded engine oils can and usually do have both acid and base numbers in this test method.

6. Apparatus

6.1 *Buret*—A 50-mL buret graduated in 0.1-mL subdivisions, or a 10-mL buret graduated in 0.05-mL subdivisions.

NOTE 4—An automated buret capable of delivering titrant amounts in 0.05-mL or smaller increments can be used but the stated precision data were obtained using manual burets only.

7. Reagents

7.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society,

where such specifications are available.⁷ Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 *Purity of Water*—References to water shall be understood to mean reagent water as defined by Type III of Specification D 1193.

7.3 *Isopropyl Alcohol*, anhydrous (less than 0.9 % water). (**Warning**—Flammable.).

7.4 *Hydrochloric Acid Solution, Standard Alcoholic* —(0.1 M)—Mix 9 mL of concentrated hydrochloric acid (**Warning**—Corrosive, fumes cause irritation.) (HCl, sp gr 1.19) with 1000 mL of anhydrous isopropyl alcohol (2-propanol) (**Warning**—See 7.3). Standardize frequently enough to detect molarity changes of 0.0005 (Note 6), preferably by electrometric titration of approximately 8 mL (accurately measured) of the 0.1 M alcoholic KOH solution diluted with 125 mL of carbon dioxide-free water. When an electrometric titration is used for the standardization, the end point shall be a well-defined inflection point closest to the cell voltage for the acidic buffer solution. When a colorimetric titration is used for the standardization, titrate to the first stable appearance of the orange color with methyl orange indicator.

NOTE 5—Commercially available reagents may be used in place of the laboratory preparations when they are certified to be in accordance with 7.1.

NOTE 6—To simplify calculations, both the standard KOH and HCl solutions can be adjusted so that 1.00 mL is equivalent to 5.00 mg of KOH. Sodium hydroxide (NaOH) and sulfuric acid (H₂SO₄) can be substituted for KOH and HCl, respectively.

7.5 *Methyl Orange Indicator Solution*—Dissolve 0.1 g of methyl orange in 100 mL of water.

7.6 *p-Naphtholbenzein Indicator*⁸ *Solution*—The *p*-naphtholbenzein must meet the specifications given in Annex A1. Prepare a solution of *p*-naphtholbenzein in titration solvent equal to 10 ± 0.01 g/L.

7.7 *Potassium Hydroxide Solution, Standard Alcoholic* (0.1 M)—Add 6 g of solid KOH (**Warning**—Highly corrosive to all body tissue.) to approximately 1 L of anhydrous isopropyl alcohol (containing less than 0.9 % water) in a 2-L Erlenmeyer flask. Boil the mixture gently for 10 to 15 min, stirring to prevent the solids from forming a cake on the bottom. Add at least 2 g of barium hydroxide (Ba(OH)₂) (**Warning**—Poisonous if ingested, strongly alkaline, causes severe irritation producing dermatitis.) and again boil gently for 5 to 10 min. Cool to room temperature, allow to stand for several hours, and filter the supernatant liquid through a fine sintered-glass or porcelain filtering funnel; avoid unnecessary exposure to carbon dioxide (CO₂) during filtration. Store the solution in a chemically resistant dispensing bottle out of contact with cork,

⁷ *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

⁸ In a 1992 study, only Kodak, Fisher, and Baker (Mallinkrodt) *p*-naphtholbenzein were found to meet the specifications in Annex A1. However, Kodak brand is no longer available.

rubber, or saponifiable stopcock lubricant and protected by a guard tube containing soda lime or soda nonfibrous silicate absorbent (Ascarite, Carbosorb, or Indecarb).

7.7.1 Standardization of Potassium Hydroxide Solution—Standardize frequently enough to detect changes of 0.0005 *N*. One way to do this is as follows: Weigh, to the nearest 0.1 mg approximately 0.2 g of potassium acid phthalate, which has been dried for at least 1 h at $110 \pm 1^\circ\text{C}$ and dissolve in 40 ± 1 mL of water, free of CO_2 . Titrate with the potassium hydroxide alcoholic solution to either of the following end points: (a) When the titration is electrometric, titrate to a well-defined inflection point at the voltage that corresponds to the voltage of the basic buffer solution, or (b) When titration is colorimetric, add six drops of phenolphthalein indicator solution and titrate to the appearance of a permanent pink color. Perform the blank titration on the water used to dissolve the potassium acid phthalate. Calculate the normality using the following equation:

$$\text{Normality} = \frac{W_p}{204.23} \times \frac{1000}{V - V_b} \quad (1)$$

where:

- W_p = weight of the potassium acid phthalate, g,
- 204.23 = molecular weight of the potassium acid phthalate,
- V = volume of titrant used to titrate the salt to the specific end point, mL, and
- V_b = volume of titrant used to titrate the blank, mL.

7.7.2 Phenolphthalein Indicator Solution—Dissolve 0.1 ± 0.01 g of pure solid phenolphthalein in 50 mL of water, free of CO_2 , and 50 mL of ethanol.

NOTE 7—Commercially available reagents may be used in place of the laboratory preparations.

NOTE 8—Because of the relatively large coefficient of cubic expansion of organic liquids, such as isopropyl alcohol, the standard alcoholic solutions should be standardized at temperatures close to those employed in the titrations of samples.

7.8 Titration Solvent—Add 500 mL of toluene (**Warning**—Flammable. Vapor harmful. Keep away from heat, sparks, and open flame.) and 5 mL of water to 495 mL of anhydrous isopropyl alcohol.

8. Preparation of Used Oil Samples

8.1 Strict observance of the sampling procedure described in 8.2 is necessary, since the sediment itself is acidic or basic or has adsorbed acidic or basic material from the sample. Failure to obtain a representative sample causes serious errors.

8.2 Heat the sample (Note 9) of used oil to $60 \pm 5^\circ\text{C}$ in the original container and agitate until all sediment is homogeneously suspended in the oil (Note 10). If the original container is of opaque material, or if it is more than three-fourths full, transfer the entire sample to a clear glass bottle having a capacity at least one third greater than the volume of the sample, and transfer all traces of sediment from the original container to the bottle by violent agitation of portions of the sample in the original container. After complete suspension of all sediment, strain the sample or a convenient aliquot through a 100-mesh screen for the removal of large contaminating particles (Note 9).

NOTE 9—When samples are visibly free of sediment, the heating

procedure described in 8.2 may be omitted. When samples are visibly free of sediment, the straining procedure may also be omitted.

NOTE 10—As used oil can change appreciably in storage, samples should be tested as soon as possible after removal from the lubricating system and the dates of sampling and testing should be noted.

9. Procedure for Acid Number

9.1 Into an appropriate size Erlenmeyer flask or a beaker, introduce a weighed quantity of the sample as given in Table 1. Add 100 mL of the titration solvent and 0.5 mL of the indicator solution, and without stoppering, swirl until the sample is entirely dissolved by the solvent. If the mixture assumes a yellow-orange color, proceed as directed in 9.2; if it becomes green or green-black, proceed as directed in Section 10.

NOTE 11—In routine analysis, the indicator may be pre-mixed with the titration solvent before adding to the sample.

9.2 Without delay, titrate at a temperature below 30°C (Note 14). Add 0.1 *M* KOH solution in increments and mix to disperse the KOH as necessary (see Note 12). Shake vigorously near the end point, but avoid dissolving carbon dioxide (CO_2) in the solvent. (In the case of acidic oils, the orange color changes to a green or green-brown as the end point is approached.) Consider the end point definite if the color change (Note 13) persists for 15 s or if it reverses with two drops of 0.1 *M* HCl.

NOTE 12—When acid numbers about or below one are expected, better precision can be obtained by substituting 0.01 or 0.05 *M* solutions in 9.2 and 9.3. This substitution was not included in the development of a precision statement.

NOTE 13—To observe the end point of dark-colored oil, shake the flask vigorously to produce momentarily a slight foam when the color change occurs as the last few drops of titrant are added and observe the titration under a white fluorescent lamp at bench top level.

NOTE 14—The temperature can be measured by any suitable temperature measuring device.

9.3 **Blank**—Perform a blank titration on 100 mL of the titration solvent and 0.5 mL of the indicator solution, adding 0.1-mL or less increments of the 0.1 *M* KOH solution.

9.3.1 The titration solvent usually contains weak acid impurities which react with the strongly basic components of the sample. To correct the base number for the sample, determine an *acid number* blank upon the solvent.

10. Procedure for Base Number

10.1 If the titration solvent containing the dissolved sample assumes a green or greenish-brown color after the indicator is added (9.1), carry out the titration as described in 9.2, but use 0.1 *M* HCl and titrate until the green-brown color changes to orange.

TABLE 1 Size of Sample^A

Acid Number or Base Number	Size of Sample, g	Sensitivity of Weighing, g
New or Light Oils		
0.0 to 3.0	20.0 ± 2.0	0.05
Over 3.0 to 25.0	2.0 ± 0.2	0.01
Over 25.0 to 250.0	0.2 ± 0.02	0.001
Used or Dark-Colored Oils		
0.0 to 25.0	2.0 ± 0.2	0.01
Over 25 to 250.0	0.2 ± 0.02	0.001

^A Light-colored samples of low acid number permit the use of 20-g samples to obtain more precise results. The sample size for dark-colored oils is limited to the quantity specified to minimize possible interference by the dark color.