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Standard Test Methods for Testing Polyurethane Raw Materials: Determination of Hydroxyl Numbers of Polyols¹

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1. Scope*

1.1 These test methods measure the hydroxyl groups in polyester and polyether polyols containing primary and secondary hydroxyl groups. They also apply to many other hydroxyl-containing substances.

1.1.1 *Test Method A—Acetic Anhydride Pressure Bottle*, recommended for polyesters.

1.1.2 *Test Method B—Phthalic Anhydride Pressure Bottle*, recommended for polyethers and polyesters.

1.1.3 *Test Method C—Phthalic Anhydride Reflux*, recommended for polyethers and polyesters.

1.1.4 *Test Method D—Imidazole-Catalyzed Phthalic Anhydride Pressure Bottle*, recommended for polyethers, polyesters, polymer polyols, and amine-initiated polyols.

1.1.5 *Test Method E—Imidazole-Catalyzed Pyromellitic Dianhydride Esterification*, recommended for polyols used for flexible and rigid polyurethane foams and urethane elastomers. It is recommended for polyester polyols, polyether polyols, amine-started polyols, and polymer polyols (polyacrylonitrile/copolystyrene-based).

~~1.2 Other ASTM test methods for measuring hydroxyl groups are Test Methods D1957 and~~

~~1.2 Another ASTM test method for measuring hydroxyl groups is Test Method E222(see Note 1).~~

~~NOTE 1—Test Method C is essentially similar to ISO 6796-1981, but there are some differences in the concentrations used and some procedural details. There are currently no data available for comparing the results of Test Method C to those of ISO 6796-1981.~~

1.3 The values stated in 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.*

NOTE 1—This standard and ISO 6796 address the same subject matter, but differ in technical content.

2. Referenced Documents

2.1 *ASTM Standards:*²

D883 [Terminology Relating to Plastics](#)

~~D1193 Specification for Reagent Water~~ ~~D1957 Test Method for Hydroxyl Value of Fatty Oils and Acids~~

E180 [Practice for Determining the Precision of ASTM Methods for Analysis and Testing of Industrial and Specialty Chemicals](#)

E200 [Practice for Preparation, Standardization, and Storage of Standard and Reagent Solutions for Chemical Analysis](#)

E203 [Test Method for Water Using Volumetric Karl Fischer Titration](#)

E222 [Test Methods for Hydroxyl Groups Using Acetic Anhydride Acetylation](#)

E691 [Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method](#)

2.2 *ISO Standard:*³

~~ISO 6796-1981~~ [ISO 6796 Polyglycols for Industrial Use—Determination of Hydroxyl Number—Phthalic Anhydride Esterification Method](#)

¹ These test methods are under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.22 on Cellular Materials—Plastics and Elastomers.

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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.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

*A Summary of Changes section appears at the end of this standard.

3. Terminology

3.1 *Definitions*—The terminology in these test methods follows the standard terminology defined in Terminology D883.

3.2 *Definitions of Terms Specific to This Standard*—There are no terms in these test methods that require new or other than dictionary definitions.

4. Summary of Test Methods

4.1 *Test Method A*—The sample is acetylated with a solution of acetic anhydride in pyridine in a pressure bottle at 98°C. The excess reagent is hydrolyzed with water and the acetic acid is titrated with standard sodium hydroxide solution. The hydroxyl content is calculated from the difference in titration of the blank and sample solutions. (**Warning**—Acetic anhydride and pyridine are toxic and flammable. In addition, acetic anhydride is corrosive. Proper precautions must be taken in handling these reagents.)

4.2 *Test Method B*—The hydroxyl group is esterified with a solution of phthalic anhydride in pyridine in a pressure bottle at 98°C. The excess reagent is titrated with standard sodium hydroxide solution.

4.3 *Test Method C*—The hydroxyl group is esterified with a solution of phthalic anhydride in pyridine under reflux conditions at 115°C. The excess reagent is titrated with standard sodium hydroxide solution.

4.4 *Test Method D*—The hydroxyl group is esterified by reaction with phthalic anhydride in a pyridine medium at approximately 100°C. The esterification reaction is catalyzed by imidazole. The excess anhydride is hydrolyzed with water, and the phthalic acid formed is titrated to the phenolphthalein end point with standard sodium hydroxide solution. The hydroxyl content is calculated from the difference in titration of the blank and the sample solution.

4.5 *Test Method E*—The hydroxyl group is esterified with a solution of imidazole (IMDA) and pyromellitic dianhydride (PMDA) in dimethylformamide in an iodine flask at 70 to 80°C. The excess reagent is titrated with standard sodium hydroxide solution.

5. Significance and Use

5.1 These test methods are suitable for research and as quality control and specification tests. It is necessary to know the hydroxyl contents of polyols in order to formulate polyurethane systems.

6. Reagents

6.1 *Purity of Reagents*—Use reagent-grade chemicals in all tests. Unless otherwise indicated, all reagents must conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.⁴ Other grades can be used, provided they are pure enough to be used without lowering accuracy.

6.2 *Purity of Water*—Unless otherwise indicated, use Type II water conforming to Specification D1193.

7. Sampling

7.1 Polyesters and polyethers usually contain molecules covering an appreciable range of molecular weights. These have a tendency to fractionate during solidification. Unless the material is a finely-ground solid it is necessary to melt (using no higher temperature than necessary) and mix the resin well before removing a sample for analysis. Many polyols are hygroscopic, and care is to be taken to provide minimum exposure to atmospheric moisture during the sampling.

TEST METHOD A—ACETYLATION

8. Interferences

8.1 Dry the sample if it contains more than 0.2 % water. More than that will interfere by destroying the esterification reagents.

8.2 Primary and secondary amines and long-chain fatty acids react with the reagent to form stable compounds that would be included in the analysis.

9. Apparatus

9.1 *Bottle*, pressure, heat-resistant, approximately 350 mL.

9.2 *Bag*, heavy fabric with draw string to hold bottle. As an alternative, a stainless steel mesh jacket fitted to cover the bottle can be used.

9.3 *Buret*, 100-mL total capacity, range of graduated portion 50 mL, 0.1-mL graduations.

NOTE 2—As a substitute, if the 100-mL buret is not available, the first 50 mL of titrant can be added by pipet (uniform drainage time for all aliquots) and the titration completed with a 50-mL buret.

9.4 *Water Bath*, 98 ± 2°C, containing enough water to cover the liquid in the sample bottles. The water level must be as prescribed, and the temperature must be within the prescribed range and uniform throughout the bath.

⁴ “Reagent Chemicals, American Chemical Society Specifications,” Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see “Reagent Chemicals and Standards,” by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the “United States Pharmacopeia.”

10. Reagents

10.1 *Acetic Anhydride*.

10.2 *Acetylation Reagent*—Mix 127 mL of acetic anhydride with 1000 mL of pyridine (10.5). Prepare the reagent fresh daily and keep it in a dark bottle. Do not use it if it is darker than pale yellow.

10.3 *Hydrochloric Acid, Standard (0.5 N)*—Prepare and standardize in accordance with Sections 20 to 24 of Practice E200. Determine and record the temperature at which the standardization was performed. The concentration of the solution shall be corrected to the temperature at which the determination is performed as described in 10.6. The factor for the thermal expansion of this solution is 0.00014. This solution is required only if a correction is to be applied for the presence of strong base in the sample being analyzed.

10.4 *Phenolphthalein Indicator Solution*—Dissolve 1 g of phenolphthalein in 100 mL of pyridine.

10.5 *Pyridine*, containing from 0.30 to 0.45 % water. Determine the water content of the pyridine using Test Method E203. Add the required amount of water. The volume of water to add, mL , per litre of pyridine can be calculated as follows:

$$\text{Water to add} = 4.0 - 9A \quad (1)$$

where A = percent of water in pyridine.

10.6 *Sodium Hydroxide, Standard Solution (0.5 N)*—Prepare and standardize in accordance with Sections 14 to 19 of Practice E200. Determine and record the temperature at which the standardization was performed. The factor for thermal expansion of this solution is 0.00014. For calculation of the hydroxyl content, the normality of the solution shall be corrected to the temperature at which the determination is performed by the following:

$$Nt_2 = Nt_1 + (t_1 - t_2)(F) \quad (2)$$

where:

Nt_1 = normality when standardized,

Nt_2 = normality during analysis of samples,

t_1 = temperature of solution during standardization, °C,

t_2 = temperature of solution during analysis of samples, °C, and

F = factor to correct for thermal expansion of the solution (see each solution for appropriate factor).

11. Procedure

11.1 Pipet 20.0 mL of the acetylation reagent to each pressure bottle for the blank and sample determinations (in duplicate). Use the same drainage time for each aliquot.

11.2 Reserve two of the bottles for the blank determinations; weigh samples to the nearest 0.1 mg into the other bottles. Determine the sample weight, g, as follows:

$$\text{Sample weight} = (561 \times 0.98) / \text{approximate hydroxyl number} \quad (3)$$

Since the calculated weight will be near the maximum permitted by the test method, adhere closely to the indicated weight.

11.3 Stopper the bottle and swirl it until the sample is completely dissolved. Enclose each bottle in a fabric bag and place all bottles as close together as possible in the water bath at $98 \pm 2^\circ\text{C}$ for 2 h. Keep enough water in the bath to cover the level of liquid in the bottles.

11.4 Remove the bottles from the bath and allow them to cool to room temperature. Untie the bags, uncap the bottles to release any pressure, and then remove the bags.

11.5 Carefully rinse any liquid on the stopper into the bottle and rinse the walls of the flask with 20 to 30 mL of water. Add clean crushed ice to each of the bottles until about half full.

11.6 Add 1 mL of the phenolphthalein indicator solution and titrate immediately with the 0.5 N NaOH solution to the first faint pink end point that persists for 15 s. The solution is to be swirled during the titration, with vigorous swirling as the end point is reached. Record the volume of titrant to 0.02 mL (Note 3). Record the temperature of the NaOH solution.

NOTE 3—If the volume of 0.5 N NaOH solution required for the sample is less than 80 % of that required for the blank, the sample was too large and the analysis must be repeated with a smaller sample.

11.7 *Acidity or Alkalinity Correction*—If the sample contains significant acidity or alkalinity, correct the result as follows. Weigh into a 400-mL Erlenmeyer flask the same amount of sample used before for the hydroxyl determination. Add to the flask 75 mL of redistilled pyridine, 75 mL of distilled water, and 0.5 mL of phenolphthalein indicator solution.

11.8 *Acidity Correction*—If the solution is colorless, titrate with standard 0.1 N NaOH to a pink end point that persists for at least 15 s. Make a blank titration on the reagent mixture described in 11.7, omitting the sample. The acidity correction, mg KOH/g, is calculated as follows:

$$\text{Acidity correction} = [(A - B)N \times 56.1] / W \quad (4)$$

W

where:

- A = NaOH solution required for titration of the ~~blank~~, sample, mL,
- B = NaOH solution required for titration of the blank, mL,
- N = normality of the NaOH solution, and
- W = sample used, g.

56.1 = Eq weight of KOH, mg/meq

11.9 *Alkalinity Correction*—If the solution in 11.7 is pink, titrate to the disappearance of the pink color with 0.1 N HCl, and then add 1.0 mL excess. Back-titrate with standard 0.1 N NaOH to a pink end point that persists for at least 15 s. Titrate with standard 0.1 N NaOH a blank containing exactly the same amount of added 0.1 N HCl and the reagent mixture described in 11.7 omitting the sample. The alkalinity correction, mg KOH/g, is calculated as follows:

$$\text{Alkalinity correction} = [(B - A)N \times 56.1]/W \quad (5)$$

where the terms are as defined as in 11.8.

12. Calculation

12.1 Calculate the hydroxyl number, mg KOH/g, of sample as follows:

$$\text{Hydroxyl number} = [(B - A)N \times 56.1]/W \quad (6)$$

where:

- A = NaOH required for titration of the sample, mL,
- B = NaOH required for titration of the blank, mL,
- N = normality of the NaOH, and
- W = sample used, g.

12.2 If the sample contains free acidity or alkalinity as measured in 11.7-11.9, the result in 12.1 must be corrected as follows:

$$\text{Hydroxyl number (corrected)} = \text{hydroxyl number} + \text{acidity, or} \quad (7)$$

$$\text{Hydroxyl number (corrected)} = \text{hydroxyl number} - \text{alkalinity} \quad (8)$$

13. Report

13.1 Report the corrected hydroxyl number to the nearest 0.1.

14. Precision and Bias ⁵

14.1 *Precision*—Attempts to develop a precision and bias statement for this test method have not been successful. For this reason, data on precision and bias cannot be given. Contact the Chairman, Subcommittee D20.22, ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 to participate in the development of precision and bias data.

14.2 It is estimated that duplicate results by the same analyst are to be considered suspect if they differ by more than 1 unit (where the measured hydroxyl number <120) or by more than 1 % relative (measured hydroxyl Number >120).

14.3 *Bias*—There are no recognized standards on which to base an estimate of bias for this test method.

TEST METHOD B—PRESSURE-BOTTLE PHTHALATION

15. Interferences

15.1 Excessive amounts of water in the sample will interfere by destruction of the esterification reagent. Dry the sample if it contains more than 0.2 % water.

15.2 Primary and secondary amines and long-chain fatty acids react with the reagent to form stable compounds and would be included in the analysis.

16. Apparatus

16.1 *Bottles*, pressure or storage, borosilicate glass.

16.2 *Pressure Bottle Bags*. ⁶

16.3 *Buret*, Normax, bulb, 100-mL capacity.

17. Reagents

17.1 *Pyridine*—Distill from phthalic anhydride, discarding the fraction boiling below 114 to 115°C. Store in brown glass bottles.

⁵ The sole source of supply of the apparatus known to the committee at this time is Flaherty Filter Media, Inc., 16 Passaic Ave., P.O. Box 357, Spring Lake, NJ 07762.

⁶ Supporting data are available from ASTM Headquarters. Request RR:D20-1089.

17.2 *Phthalic Anhydride (Pyridine Reagent)*—Weigh 111 to 116 g of phthalic anhydride into a 1-qt brown bottle. Add 700 mL of pyridine, which has been distilled from phthalic anhydride (see 17.1), and shake vigorously until dissolved. The reagent must stand overnight before use. Reagent that develops a color is to be discarded. In the blank titration as described in the following procedure, exactly 25 mL of this reagent must consume between 95 and 100 mL of 0.500 *N* sodium hydroxide.

17.3 *Phenolphthalein Indicator Solution (10 g/L)*—Prepare a solution of 1 g of phenolphthalein in 100 mL of pyridine.

17.4 *Potassium Acid Phthalate*—Use material that is traceable to the National Institute of Standards and Technology.

17.5 *Sodium Hydroxide, Standard Solution (0.5 N)*— Prepare a 0.5 *N* solution of sodium hydroxide (NaOH) and standardize as follows:

17.5.1 Crush (do not grind) about 10 g of potassium acid phthalate ($\text{KHC}_8\text{H}_4\text{O}_4$) to approximately 100 mesh and dry it for 1 to 2 h at 100°C. Place in a glass-stoppered container and cool in a desiccator. Accurately weigh 4 to 5 g of the dried potassium acid phthalate and transfer it to a 500-mL flask that has been swept free of carbon dioxide. Add 200 mL of water that is free of carbon dioxide, stopper the flask, and swirl it gently until the sample is dissolved. Add phenolphthalein indicator and titrate to a pink end point with the 0.5 *N* NaOH solution using a 50-mL buret.

17.5.2 Calculate the normality of the NaOH as follows:

$$\text{Normality} = W/(V \times 0.2042) \quad (9)$$

V

where:

W = $\text{KHC}_8\text{H}_4\text{O}_4$, g, and

V = NaOH required for titration of the $\text{KHC}_8\text{H}_4\text{O}_4$, mL.

0.2042 = Eq/L potassium acid phthalate (204.2 g/eq divided by 1000 to convert mL to L).

18. Procedure

18.1 Prepare a sufficient number of clean, dry pressure bottles to make all blank and sample determinations in duplicate. Replace the rubber gaskets, if necessary, and make certain the caps can be fastened securely.

18.2 Accurately pipet 25 mL of the phthalic anhydride reagent into each of the bottles. Use the same pipet for both sample and blank determinations. Do not allow the reagent to contact the rubber gasket.

18.3 Reserve two of the bottles for the blank determination.

18.4 Introduce into each of the other bottles the amount of sample, g, calculated as follows, as weighed to the nearest 0.1 mg:

$$\text{Sample size} = 561/\text{estimated hydroxyl number} \quad (10)$$

Since the calculated weight will be near the maximum permitted by the method, adhere closely to the indicated weight. Weigh the sample from a hypodermic syringe. Swirl to dissolve completely.

18.5 Cap the bottles and enclose them in the pressure bottle bags. Keep the samples and blanks as close together as possible in a water bath, maintained at $98 \pm 2^\circ\text{C}$, for 2 h. Maintain sufficient water in the bath to just cover the liquid in the bottles.

18.6 Remove the bottles from the bath and allow them to cool to room temperature.

18.7 When the bottles have cooled, open the bags, uncap them carefully to release any pressure, and then remove the bags.

18.8 To each bottle, add 50 mL of redistilled pyridine and 0.5 mL of the phenolphthalein indicator solution, and titrate with standard 0.5 *N* NaOH solution to a pink end point that persists for at least 15 s. It is essential that the net titration (blank minus sample) be between 18 and 22 mL. If it is not, repeat the determination, adjusting the sample size accordingly.

18.9 *Acidity or Alkalinity Correction*—If the sample contains significant acidity or alkalinity, the result must be corrected as follows.

18.9.1 Weigh into a 400-mL Erlenmeyer flask an amount of sample equal to that taken previously for the hydroxyl determination. Add to the flask 75 mL of redistilled pyridine, 75 mL of distilled water, and 0.5 mL of phenolphthalein indicator solution.

18.10 *Acidity Correction*—If the solution is colorless, titrate with standard 0.1 *N* NaOH solution to a pink end point that persists for at least 15 s. Make a blank titration on the reagent mixture described in 18.9.1, omitting the sample. The acidity correction, mg KOH/g, is calculated as follows:

$$\text{Acidity correction} = [(A - B)N \times 56.1]/W \quad (11)$$

W

where:

A = NaOH solution required for titration of the sample, mL,

B = NaOH solution required for titration of the blank, mL,

N = normality of the NaOH solution, and

W = sample used, g.

56.1 = Eq weight of KOH, mg/meq.

18.11 *Alkalinity Correction*—If the solution in 18.9.1 is pink, titrate to the disappearance of the pink color with 0.1 *N* HCl, and

then add 1.0 mL in excess. Back titrate with standard 0.1 *N* NaOH solution to a pink end point that persists for at least 15 s. Titrate with 0.1-*N* NaOH solution a blank containing exactly the same amount of added 0.1 *N* HCl and the reagent mixture described in 18.9.1, omitting the sample. The alkalinity correction, mg KOH/g, is calculated as follows:

$$\text{Alkalinity correction} = [(B - A)N \times 56.1] / W \quad (12)$$

where the terms are as defined as in 18.10.

19. Calculation

19.1 See Section 12.

20. Report

20.1 See Section 13.

21. Precision and Bias

21.1 See Section 14.

TEST METHOD C—REFLUX PHTHALATION

22. Interferences

22.1 Excessive amounts of water in the sample will interfere by destruction of the esterification reagents. If the water content of the sample exceeds 0.2 %, it is recommended that the sample be dried.

22.2 Primary and secondary amines and higher fatty acids react with the reagent to form stable compounds and would be included in the analysis.

23. Apparatus

23.1 *Soil Digestion Flasks*, 250-mL capacity, with standard-taper 24/40 joints and 24-in. air condensers.

23.2 *Oil Bath*, maintained at $115 \pm 2^\circ\text{C}$.

23.3 *Buret*, Normax, bulb, 100-mL capacity.

24. Reagents

24.1 *Pyridine*—See 17.1.

24.2 *Phthalic Anhydride (Pyridine Reagent)*—See 17.2.

24.3 *Phenolphthalein (10 g/L)*—See 17.3.

24.4 *Potassium Acid Phthalate*—See 17.4.

24.5 *Sodium Hydroxide, Standard Solution (0.5 N)*—See 17.5.

25. Procedure

25.1 Weigh into the flasks, by means of a hypodermic syringe or other suitable equipment, the amount of sample, g, calculated as follows, and weigh to the nearest 0.1 mg. No material must be allowed to touch the neck of the flask:

$$\text{Sample size} = 561 / \text{estimated hydroxyl number} \quad (13)$$

Since the calculated weight will be near the maximum permitted by the test method, adhere closely to the indicated weight.

25.2 Accurately pipet 25 mL of the phthalic anhydride-pyridine reagent into each flask. Swirl the flask to effect solution of the sample. Put the air condensers in place, and place the flasks in an oil bath, maintained at $115 \pm 2^\circ\text{C}$, for 1 h. Keep sufficient oil in the bath to cover approximately one half of the flask.

25.3 After the heating period, remove the assembly from the bath and cool to room temperature. Wash down the condenser with 50 mL of redistilled pyridine, and remove the condenser. Add 0.5 mL of phenolphthalein indicator solution and titrate with 0.5 *N* NaOH solution to a pink end point that persists for at least 15 s.

25.4 Run a blank in the same manner, omitting the sample. It is essential that the net titration (blank minus sample) be between 18 and 22 mL. If it is not, repeat the determination, adjusting the sample size accordingly.

25.5 *Acidity or Alkalinity Correction*—See 18.9.

26. Calculation

26.1 See Section 12.

27. Report

27.1 See Section 13.

28. Precision and Bias

28.1 See Section 14.