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T _____ 479 _____

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WORKING GROUP
CHAIRMAN _____ Holly Martin _____

SUBJECT
CATEGORY _____ Physical Properties _____

RELATED
METHODS _____ See "Additional Information" _____

CAUTION:

This Test Method may include safety precautions which are believed to be appropriate at the time of publication of the method. The intent of these is to alert the user of the method to safety issues related to such use. The user is responsible for determining that the safety precautions are complete and are appropriate to their use of the method, and for ensuring that suitable safety practices have not changed since publication of the method. This method may require the use, disposal, or both, of chemicals which may present serious health hazards to humans. Procedures for the handling of such substances are set forth on Material Safety Data Sheets which must be developed by all manufacturers and importers of potentially hazardous chemicals and maintained by all distributors of potentially hazardous chemicals. Prior to the use of this method, the user must determine whether any of the chemicals to be used or disposed of are potentially hazardous and, if so, must follow strictly the procedures specified by both the manufacturer, as well as local, state, and federal authorities for safe use and disposal of these chemicals.

**Smoothness of paper (Bekk method)
(Reaffirmation of T 479 cm-09 as a Classical Method)
(The ballot 2 reconfirmed this Standard as a Classical Method)**

1. Scope

This method is for determining the smoothness of individual surfaces of paper when under a clamping pressure of approximately 100 kN/m² and using an anvil with an effective area of 10.00 ± 0.05 cm².

2. Summary

The specimen is clamped with a pressure of one atmosphere between a plain, circular anvil having a small hole in its center and a soft rubber pad. The time required to draw 10 mL of air radially between the anvil and the specimen is measured, when a decreasing suction averaging 49.3 kPa (370 mm of mercury) is applied to the hole.

3. Significance

This test is an indirect measure of smoothness when the paper is under moderate pressure. At other pressures, such as the higher pressure used in some printing presses, the ranking of papers may be changed, depending upon the relative compressibilities of the papers being compared (1). With some papers, radial air leakage may affect the result (2).

4. Apparatus

4.1 *Testing instrument*¹ having:

4.1.1 An anvil with a circular, plain, glass surface, with a small hole (1-2 mm diameter) in its center, the surface having an effective area of $10.00 \pm 0.05 \text{ cm}^2$. A capillary connected to a suction chamber having a volume such that the addition of 10 mL of air at 23°C and normal pressure causes its negative pressure to fall from 50.7 to 48.0 kPa (380 to 360 mm Hg).

4.1.2 A 4-mm-thick pad of soft butyl or EPDM rubber about 50 mm across with smooth surfaces and a Shore Durometer hardness of 39 ± 5 units (A scale).

4.1.3 A platen (pressure disk) with means of applying a load² of $100 \pm 5N$, including the disk and rubber pad, to the specimen on the anvil.

NOTE 1: Some instruments are supplied with a small chamber, one-tenth the volume that is specified, or with inserts that can be placed in the chamber to reduce its volume to one-half or one-quarter of the normal volume. The one-tenth volume chamber reduces the measurement to one-tenth, and the one-half or one-quarter inserts reduce the measurement to one-half and one-quarter, respectively. They are for use with very smooth papers when the time for test with the standard chamber exceed 300 s.

4.2 *Stopwatch or timer*

5. Calibration

5.1 Check the instrument frequently for leakage. By means of a vacuum pump, raise the mercury level, turn the stopcock to the closed or “0” position, and allow the instrument to remain in this state for at least 5 h. If the

¹Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list, available as part of the CD or printed set of Standards, or on the TAPPI website general Standards page.

²A 10-kgf is within the allowable tolerance shown of $100 \pm 5 N$ force.

drop in the mercury column is found to be over 5 mm, tighten all gaskets. If air leakage continues, remove the stopcocks and the regulating valve pin, clean them, and apply a thin film of stopcock grease to the polished surfaces. Make certain that the nut holding the plain glass block in place is tight.

5.2 It is particularly important that the capillary be kept clean. A jerky movement of the mercury column or adherence to the glass is an indication that the capillary is dirty. In this case, carefully remove and clean the capillary by washing it alternatively with nitric acid and a solution of potassium dichromate in concentrated sulfuric acid. Remove all the cleaning solution by flushing with distilled water and rinsing with alcohol. (Do not use ether.) Dry the tube thoroughly by letting it stand in a warm room or by blowing filtered warm air through it. The mercury and reservoir should be cleaned at the same time. Before inserting the capillary, it is recommended that a layer, approximately 2 mm in height, of pure benzyl salicylate be poured onto the surface of the mercury in the reservoir to lubricate the capillary walls.

5.3 Whenever the instrument is not being used, protect the polished glass surface with a dust cap. Keep the surface of this block and the rubber pad clean at all times. Handle the rubber pad by the edges to prevent grease from fingertips from accumulating on the surface of the pad. When the pad hardens beyond the specified limits, discard it.

6. Sampling and test specimens

6.1 Obtain a sample of the paper in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product," being careful not to expose the sample to dampness.

6.2 From each test unit of the sample select 10 representative specimens (i.e., 5 for each side) at least 50 mm square.

7. Procedure

7.1 Condition the specimens and test them in an atmosphere in accordance with TAPPI T 402 "Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products." Ensure that the apparatus is not subjected to any vibration during the test.

7.2 Set the stopcock of the tester to position "P". With gentle strokes of the vacuum pump, raise the mercury column to slightly above 380 mm and turn the stopcock to position "0".

7.3 Place a specimen with the side to be tested in contact with the polished glass surface. Lay the rubber pad on the paper and, on top of this, center the pressure disk.

7.4 Gently bring the pressure bar down to a horizontal position, with the leveling screw resting on the depression in the center of the disk. With the aid of the level, and by means of the leveling screw, bring the pressure bar to level position.

7.5 After a waiting period of 1 min., during which the paper rapidly compacts under the applied pressure, turn the stopcock to position “M”, and by gently manipulating the fine regulating vent at the base of the air chamber, permit the mercury column to drop to approximately 380 mm. Just before the mercury column reaches 380 mm, close the fine adjustment vent with a firm pushing-turning motion.

7.6 Various types of stopwatch or timing techniques or devices may be found in various models of instruments conforming with the method. Visual observation of the drop of the mercury column with manual timing with the stopwatch is described in 7.6.1. An electromechanical method utilizing electrodes placed in the capillary column at appropriate points to activate a solenoid which operates the stopwatch is described in 7.6.2. An optical sensing device which detects the dropping of the mercury column past the appropriate measurement points with its related timing device is described in 7.6.3.

7.6.1 *Visual / manual timing.* At the instant the 380-mm mark is reached, start the stopwatch and note the time required in seconds for the mercury column to drop from 380 to 360 mm.

7.6.2 *Electrode / electromechanical timing.* As the mercury column drops past the 380-mm mark, an electrical circuit is activated causing a solenoid to start the stopwatch. As the mercury column passes the 360-mm mark, an electrical circuit is activated and the solenoid is activated to stop the stopwatch.

7.6.3 *Optical / electrical timing.* At the instant that the mercury column drops past the 380-mm mark, a light beam/photocell device activates an electrical circuit which starts an electronic timer. At the instant the mercury column passes the 360-mm mark, another light beam/photocell device activates an electrical circuit which stops the timer.

7.6.4 The time referenced in 7.6.1, 7.6.2, and 7.6.3 represents the time necessary for 10 mL of air to pass between the plain surface and that of the test specimen.

7.7 Before removing the paper, turn the stopcock back to the “0” position.

7.8 If the time required for the 20-mm drop is over 300 s, instrument adaptations to change the cavity size may be used. If the instrument is equipped with a chamber one-tenth the standard size, turn the stopcock to the one-tenth position³, repeat the test on a separate specimen, and multiply the observed time by 10. If the instrument is equipped with chamber changing devices, insert either the one-half or one-quarter volume plugs and repeat the test on separate specimens, multiplying the observed time by either 2 or 4, respectively.

7.9 Use a separate specimen for each test, because the pressure on the test specimen slowly compacts the fibers.

7.10 Test five specimens each on the wire and on the felt sides, respectively.

8. Report

³Use of the one-tenth position may result in considerably different test results and suitable comment should be made in the test report.

8.1 For each test unit report as Bekk smoothness the average result in seconds, for each side of the paper, to three significant figures.

8.2 Include also the number of specimens tested and the standard deviation for each side.

9. Precision

The precision of this method has been studied on several occasions (2-4). Recent information from the TAPPI Collaborative Testing Program (5) indicates that variations in the machine and cross directions of the paper and the nature of the paper can have an appreciable effect on the precision of testing. For a very uniform paper, a repeatability of 5% or less may be expected. For most papers the repeatability is in the range 8-25% for test results, each of which is an average for five test specimens. It is reasonable to expect a reproducibility of the order of 20-30%, but occasionally a poorer reproducibility (40-90%) occurs with porous papers, possibly because of the use of inadequate backing material. The reader should be cautioned that this analysis on Collaborative Testing Program Data is based on actual mill/laboratory measurements with instruments or procedures that may not conform with this method. This information is given as a guide as to the potential variation in smoothness that may exist across the industry.

10. Additional information

10.1 Effective date of issue: To be assigned.

10.2 This method was first published in 1948 as a Suggested Method and was revised in 1971. In the 1981 revision, only the Bekk instrument was described. A waiting period of 1 min. was specified after the pressure is applied to the specimen in accordance with the specifications of the original manufacturer.

10.3 The mercury columns on some instruments are calibrated at positions representing pressures other than 380 and 360 mm. The use of pressure drops other than those specified in the method is contrary to the procedure described and should be avoided.

10.4 Additional information on the Bekk Smoothness instrument may be found in DIN 53 107. This method reports that the volume of air drawn into the Apparatus for the pressure differential of 380 to 360 mm. (-507 to -480 mm bar) is equal to 10 ± 0.2 mL (Method A).

10.5 In 1999, this method was made Classical by vote of the committee.

10.6 A diagram and description of the measuring principle is given in ISO 5627: 1995 "Paper and paper board - determination of smoothness (Bekk method)."

11. Keywords

Paper, Smoothness, Bekk testers

Literature cited

1. Lashof, T. W., Mandel, J., and Worthington, V., "Use of the Sensitivity Criterion for the Comparison of the Bekk and Sheffield Smoothness Testers," *Tappi* **39** (7): 532 (1956).
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4. Lashof, T.W., and Mandel, J., "Measurement of the Smoothness of Paper," *Tappi* **43** (5): 385 (1960).
5. TAPPI Collaborative Reference Program, Report No. 10, p. 15, National Bureau of Standards, October 1970.

Reference

Bekk, J., "Apparatus for Measuring Smoothness of Paper Surfaces," *Paper Trade J.* **104** (12): 62 (1937).

Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Standards Department. ■