Designation: D 6651 – 01

Standard Test Method for
Determining The Rate of Sorption and Sorptive Capacity Of Nonwoven Fabrics[1]

This standard is issued under the fixed designation D 6651; 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 test method covers the quantifying of the rate of sorption of textile fabrics.

1.2 This test method applies to all textile fabrics used as wiping materials for spill removal. For additional literature see the International Nonwovens Journal[2,3].

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as the standard. Within the text, the inch-pound units are shown in parentheses. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

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 123 Terminology Relating to Textiles[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *extrinsic rate of sorption*, *n*—in textile fabrics, the rate at which a specified liquid is sorbed by a fabric on a per-unit-area basis under specified conditions.

3.1.1.1 *Discussion*—While extrinsic sorptive capacity is expressed in terms of volume per unit area, intrinsic capacity (below) has been used to describe capacity in terms of volume per unit mass. By way of example, if a fabric exhibited an intrinsic capacity of 5 mL/g, that mass of fabric would hold 5 mL whether is was part of a 50 g/m^2 or a 200 g/m^2 fabric. The extrinsic sorptive capacity would, however, be four (4) times higher for the 200 g/m^2 fabric than for the lighter weight material.

3.1.2 *intrinsic rate of sorption*, *n*—in textile fabrics, the rate at which a specified liquid is sorbed by a fabric on a per-unit-mass basis under specified conditions.

3.1.3 *sorption*, *n*—in textile fabrics, a process in which liquid molecules are taken up either by absorption or adsorption, or both.

3.1.4 *sorptive capacity*, *n*—in textile fabrics, the maximum amount of liquid absorbed and adsorbed under specified conditions.

3.1.5 *wiper*, *n*—in textile fabrics, fabric swatches used for housekeeping, cleaning, polishing, spill clean-up or removal.

3.2 For definitions of terms used in this test method refer to Terminology D 123.

4. Summary of Test Method

4.1 A stack of wiping material squares of known mass and dimensions is placed on the surface of a thermostatically controlled tank of liquid. The time required for the stack to wet out is recorded. From these measurements and from the mass of the wetted stack of wipers, a rate of sorption through the plane of the wiper can be calculated.

5. Significance and Use

5.1 This test method can be used for acceptance testing of commercial shipments, but comparisons should be made with caution because information on estimates of between-laboratory precision is limited as noted in the precision and bias section of this test method.

5.1.1 If there are differences of practical significance between reported test results for two laboratories (or more), comparative tests should be performed to determine if there is a statistical bias between them, using competent statistical assistance. As a minimum, samples used for such comparative tests should be as homogeneous as possible, drawn from the same lot of material as the samples that resulted in disparate results during initial testing, and randomly assigned in equal numbers to each laboratory. Other fabrics with established test values may also be used for these comparative tests. The test results from the laboratories involved should be compared using a statistical test for unpaired data, at a probability level chosen prior to the testing series. If bias is found, either its cause must be found and corrected, or future test results must

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[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.64 on Nonwovens.

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[2] C. F. Mattina and J. M. Oathout, "A New Method for Determining the Rate of Sorption of Wiping Materials," Cleanrooms, 8 (4), 18–24 (1994) and *International Nonwovens Journal*, 7(1), 48 (1995).

[3] J. M. Oathout and C. F. Mattina, "A Comparison of Selected Industrial and Household Wiping Materials for Rate of Sorption, Sorptive Capacity and Strength," *International Nonwovens Journal*, 7(1), 58 (1995).

[4] *Annual Book of ASTM Standards*, Vol 07.01.

be adjusted in consideration of the known bias.

5.2 When the rate is calculated as a flux on a per-unit-area basis, it is termed the extrinsic rate of sorption, R_e[mL/m^2/s]. The rate calculated on a per-unit-mass basis is termed the intrinsic rate of sorption, R_i[mL/g/s]. If basis weight (mass per unit area) is given in units of grams per square meter, then the two rates of sorption are related via the equation ($R_e = R_i \times$ basis weight).

5.3 This test method rests primarily on three hypotheses: that the rate of sorption is independent of the area of the specimens, that the rate of sorption is independent of the number of plies used to do the test, and that the sorptive capacity of the wiper is independent of the number of plies used to do the test. These hypotheses have been shown to be valid in most cases within the limits described in this test method. However, in certain cases, ply dependency on rate of sorption may exist, in particular, for materials that are slow absorbers, which generally are not considered superior wipers. (See 10.11).

5.4 This test method is useful to select fabrics with superior cleaning and drying properties that can minimize the costs for spill removal. It can also be used to research fabrics for improved spill removal and for production control.

5.5 In addition to the measurement of rate of sorption and sorptive capacity, this method also permits the determination of basis weight (mass per unit area).

6. Apparatus and Materials[5]

6.1 *Balance*, top loading, with a sensitivity of at least 0.01g.

6.2 *Water Bath*, thermostatically controllable to 25 ± 1 °C (77 ± 2 °F), having dimensions of at least 400 mm (16 in.) by 300 mm (12 in.) and deep enough so that the topmost ply of a stack of fully wetted wiper specimens is at least 25 mm (1.0 in.) below the surface of the liquid.

6.2.1 Alternatively, any suitable container with dimensions of at least 400 mm × 300 mm × 200 mm, (16 in. × 12 in. × 8 in.) filled with liquid and fitted with a temperature controller can be used. The thermostat should be controllable to 25 ± 1 °C (77 ± 2 °F) and of sufficient depth that the topmost ply of a stack of fully wetted wipers is at least 25 mm (1.0 in.) below the surface of the liquid.

6.3 *Liquid*, usually tap water, or other liquid when specified.

6.4 *Measuring Rule*, metal, graduated in 1 mm (0.05 in.).

6.5 *Stopwatch*, digital electronic capable of reading to 0.01 s.

6.5.1 As an option, the stopwatch can be operated by a foot-switch, thereby allowing both hands to be free to handle the test specimen during the test.

6.6 *Die Cutter*, or equivalent, to meet the test specimen size requirements of 7.3.

6.7 *Utility Knife*.

7. Sampling and Test Specimens

7.1 *Primary Sampling Unit*—Consider rolls, bolts, or pre-packaged pieces of fabric to be the primary sampling unit, as applicable.

7.2 *Laboratory Sampling Unit*—As a laboratory sampling unit, use the primary sampling unit, as a source of test specimens and prepare the test specimens as directed in 7.3 and 7.4.

7.2.1 For primary sampling units having narrow widths or short lengths, use a sufficient number of pieces to prepare the test specimen stacks as described in 7.3 and 7.4.

7.3 *Test Specimen Size*—From each laboratory sampling unit, cut square or rectangular test swatches, such that the specimen area is no less than 25600 mm^2 (39 in.^{2}) and no greater than 64500 mm^2 (100 in.^{2}) with no side less than 160 mm (6.3 in.) nor greater than 250 mm (10 in.).

7.3.1 In any event, the specimen side length-width aspect ratio must not be greater than 2:1.

NOTE 1—Specimen swatches having smaller dimensions than specified in 7.3 may have an edge effect and may lead to erroneous results. Specimen swatches having larger dimensions than specified in 7.3 are cumbersome to handle and may lead to erroneous results.

7.4 *Number of Swatches Per Test Specimen Stack and Number of Test Specimen Stacks*—The number of swatches (fabric layers) can vary. As a minimum, prepare two specimen stacks, each with 10 fabric layers, two specimen stacks, each with fewer layers, such as 5, and two specimen stacks, each with more layers, such as 15. This will help to establish whether there is any ply dependency on the rate of sorption.

7.4.1 Primary sampling units may consist of pre-packaged wiping material that are nominally 229 mm by 229 mm (9.00 in. by 9.00 in.) material squares. In those cases, use the entire square as the test specimen.

7.4.2 If prepackaged wiping material squares are quarter-folded or C-folded, unfold them and place in stacks. If the stack of material squares do not lie flat after stacking, apply modest compression. When necessary, bend previously folded creases backward to flatten.

7.4.3 Prepare specimen stacks, such that the same fabric surface is facing up for all stacks so they can be identified when testing.

7.4.4 Ensure specimens are free of folds, creases, or wrinkles. Avoid getting oil, grease, etc. on the specimens when handling.

7.5 *Test Specimen Preparation*—Select test specimens as follows:

7.5.1 *For Prepackaged Wipes, Nominal 229 by 229 mm (9.00 by 9.00 in.)*—Open the package. Select a stack of wipes that is sufficient to provide the necessary number of layers needed for each test specimen set. Use the entire square as the test specimen.

7.5.2 *For Rolls or Bolts of Fabric, (Preferred)*—Using a utility knife, cut a suitable number of plugs, approximately 300 by 300 mm (12 by 12 in.) and about 25 mm (1.0 in.) deep from the roll or bolt to provide fabric layers for the necessary specimen stacks. Using the die cutter, or equivalent, cut through the plugs to provide the specimen stacks necessary to meet the requirements of 7.3 and 7.4.

7.5.2.1 Alternately, a full-width piece of fabric that is of sufficient length along the machine direction can be taken from the primary sampling unit to prepare the test specimens after removing a first 1 m (1 yd) length from the roll or bolt.

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[5] Apparatus and materials are commercially available.

7.5.2.2 Take no specimens closer than 25 mm (1.0 in.) from the machine direction edge, except as noted in 7.3.1.

8. Conditioning

8.1 No conditioning is required unless otherwise specified in a material specification or contract order.

9. Preparation of Test Apparatus and Calibration

9.1 Verify that the balance is within calibration.

9.2 Verify that the liquid bath thermostats are within calibration and liquid is at the required temperature.

9.2.1 The liquid depth should be at least 25 mm (1.0 in.) greater than the specimen stack.

9.3 If bubbles or foam are observed on the surface of the liquid bath, this is usually a sign the liquid has been contaminated by surfactants from previous specimens. When this occurs, change the liquid and bring it to the required temperature.

10. Procedure

10.1 Measure and record the length (L) and width (W) of one specimen stack of 10 layers to the nearest 1-mm (0.05 in.).

10.2 Place the specimen stack on the balance and measure and record the mass (M_d) to the nearest 0.01 g.

10.3 While holding the specimen stack with the top-surface face up and horizontal, gently place it on the surface of the liquid in the liquid bath with one continuous motion and simultaneously start the timer.

NOTE 2—If the optional foot switch is not used, it is convenient to first start the stopwatch, then, using both hands, place the stack in the liquid at a predetermined time interval. The predetermined time interval is then subtracted from the time recorded in 10.4.

10.3.1 Ensure the specimen stack is flat, to minimize any concavity or convexity that might provide for air pockets and influence the result.

10.4 Stop the timer when all dryness has disappeared from the top-most ply of the stack and record the time (t_n) to the nearest 0.01 s.

10.5 Grasp the specimen stack by adjacent corners while holding vertically at a slight angle to the horizontal and lift it out of the liquid so that the liquid drains from the lowest corner.

10.6 Allowed the specimen stack to drain for 60 ± 2 seconds.

10.7 Place the wet specimen stack on the balance and determine the mass to the nearest 0.01 g, (m_w).

10.8 Take the second specimen stack of 10 and repeat 10.1-10.7 except reverse the specimen such that the opposite surface is down.

NOTE 3—The first specimen stack of a set is tested with the bottom-most surface of the fabric placed to the surface of the liquid. The second specimen stack of the set is reversed and tested with the upper-most surface of the fabric placed to the surface of the liquid.

10.9 Continue as directed in 10.1-10.8 using the specimen stacks with the greater number of layers, such as 15.

10.10 Continue as directed in 10.1-10.8 using the specimen stacks with the fewer number of layers, such as 5.

10.11 Establish and report whether the sorption rate is dependent on the number of plies in the stack by comparing the sorption rate per ply between the ten-ply stack and a higher and lower number of plies in a stack. For example, if a ten-ply stack takes approximately twice as long to wet-out as a five-ply stack, there is no number-of-ply dependency. However, if the sorption rate per ply between stacks with different numbers of plies is more than 15 percent, then it is likely that the number of plies in a stack influence the sorption rate per ply which then must be determined as directed in 11.3.

11. Calculations

11.1 Calculate the basis weight (mass per unit area), extrinsic and intrinsic sorptive capacity, extrinsic and intrinsic rate of sorption for individual specimen using Eq 1-5, as applicable.

11.1.1 Before using Eq 1-5, convert millimetres (mm) to metres (m) by dividing millimetres (mm) by 1000; and convert inches (in.) to meters (m) by multiplying inches (in.) by 0.0254, as applicable.

$$bw = m_d/[n \times L \times W] \tag{1}$$

$$A_e = [(m_w - m_d)/D]/[n \times L \times W] \tag{2}$$

$$A_i = A_e/bw \tag{3}$$

$$R_e = [(m_w - m_d)/D]/[L \times W]/t_n \tag{4}$$

$$R_i = R_e/bw \tag{5}$$

where:

n = number of layers in the test specimen stack,
bw = basis weight (mass per unit area), g/m^2,
A_e = extrinsic sorptive capacity, mL/m^2,
A_i = intrinsic sorptive capacity, mL/g,
R_e = extrinsic rate of sorption, mL/m^2/s,
R_i = intrinsic rate of sorption, mL/g/s,
D = density of liquid (for water, 0.997 g/mL at 25 °C),
L = length of specimen, m,
W = width of specimen, m,
m_w = mass of the test specimen after wetting, g (from 10.7),
m_d = mass of the test specimen before wetting, g (from 10.2), and
t_n = time to wet-out specimen stack.

11.1.2 If liquids other than water are used, substitute the appropriate density (D) in Eq 1.

11.2 Calculate the average basis weight (mass per unit area), extrinsic and intrinsic sorptive capacity, extrinsic and intrinsic rate of sorption to three significant figures for the laboratory sample and for the lot.

11.3 For specimen stacks showing a number-of-plies dependency, plot the rate of sorption versus number of plies in a given stack and extrapolate the curve to estimate the rate of sorption for one ply.

11.4 If the rate of sorption is different between two stacks in a specimen set is greater than 15 percent, then consider the material top and bottom surface to have an influence on the sorbency rate of the material.

12. Report

12.1 Report that the basis weight (mass per unit area), extrinsic and intrinsic sorptive capacity, extrinsic and intrinsic rate of sorption was determined as directed in Test Method D 6651. Describe the material or product sampled and the method of sampling used.

12.2 Report the following information for the laboratory-sampling unit and for the lot as applicable to a material specification or contract order.

12.2.1 Basis weight (mass per unit area).

12.2.2 Extrinsic sorptive capacity.

12.2.3 Intrinsic sorptive capacity.

12.2.4 Extrinsic rate of sorption.

12.2.5 Intrinsic rate of sorption.

12.2.6 Identification of liquid used.

12.2.7 Number of plies in the specimen stacks.

12.2.8 Whether any ply effect on Rate of Sorption.

12.2.9 Whether any material top or bottom effect on Rate of Sorption.

13. Precision and Bias

13.1 *Summary*—Limited information from one laboratory shown in Table 1 illustrates what was found when all the observations were taken by the same well-trained operator using the same piece of equipment and specimens randomly drawn from the sample of material. For this laboratory, in comparing two averages for this fabric, the critical differences are not expected to exceed values shown in Table 1 in 95 out of 100 cases when the number of observations in the average is two. Differences for other fabrics or other laboratories may be larger or smaller.

TABLE 1 Average Value, Standard Deviation and Maximum Property Critical Differences When Comparing Averages for N Equals 2 (Single-Operator Precision)

Property	Average	Standard Deviation	Critical Differences[A], Expressed As Standard Deviation N=2
Basis Weight, g/m^2	66.5	1.27	2.50
Extrinsic Sorptive Capacity, mL/m^2	277	5.43	10.6
Intrinsic Sorptive Capacity, mL/g	4.16	0.014	0.03
Extrinsic Rate of Sorption, mL/m^2/s	2570	203	398
Intrinsic Rate of Sorption, mL/g/s	38.7	3.50	6.85

[A] The critical differences were calculated using t = 1.960, which is based on infinite degrees of freedom.

13.2 *Single-laboratory Test Data*—A single-laboratory test was run in 1999 in which a randomly-drawn fabric was tested. One operator in the laboratory tested ten 20-layer stacks from the material as directed in this test method. The test specimens were tested over several days. The fabric was of nonwoven (hydroentangled) construction, having a basis weight (mass per unit area) of 70.6 g/m^2, and composed of 55 % woodpulp (cellulose) and 45 % poly-(ethylene)-terephthalate and was white in color without apparent patterning.

13.3 *Precision*—Before a meaningful statement can be made about two specific laboratories, the amount of statistical bias, if any, between them must be established, with each comparison being based on recent data obtained on specimens taken from a lot of material of the type being evaluated so as to be as nearly homogeneous as possible and then randomly assigned in equal numbers to each of the laboratories. (See 5.1). Interlaboratory testing will continue to provide between-laboratory precision statements.

13.4 *Bias*—The procedure of this test method produces a test value that can be defined only in terms of a test method. There is no independent, referee method by which bias may be determined. This test method has no known bias.

14. Keywords

14.1 basis weight; extrinsic rate of sorption; extrinsic sorptive capacity; intrinsic rate of sorption; intrinsic sorptive capacity; nonwoven fabric; sorption