Chapter 10: Characterization and Testing of Nonwovens With Emphasis on Absorbency

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Introduction

In view of the increasing success and demand of nonwovens in the wide variety of applications and end uses, the characterization and testing of nonwoven materials have become of a paramount importance. Needless to say, the results, which are obtained by the various testing methods and/or techniques, provide a great deal of technical information which will help the producers of the nonwovens in improving their quality, producing new and developed products, and in predicting the overall performance of their products.

Generally speaking, the subject of product characterization and testing, as applied in its broad term, can be covered by answering the following questions:

1. Why do we test?
2. What do we test?
3. What test method or technique should we use?
4. When do we test?
5. Who does the testing?

In this chapter, an attempt will be made to answer the above questions. Also a brief introduction will be given to the various mechanical and physical properties. The chapter is divided into two parts:

Part (A): Testing Methods and Techniques will address the different standard test methods, procedures, and techniques for characterization of nonwoven products. These standards are applied by INDA, ASTM, TAPPI, and AATCC.

Part (B): Absorbency Characteristics of Nonwoven Fabrics will introduce the most popular absorbency characteristics and the methods by which they could be measured.

Objectives of product characterization and testing

The various objectives of testing could summarize the answer as to why we test. It may be difficult to classify the reasons for testing because of overlapping. Nevertheless, some type of classification may be helpful in getting a broad view of the objectives of testing.

Process control

When processing goes out of control, the amount of waste and defective product increases, cost goes up, and very often tempers, too. A plan of production requires certain standard levels to which materials in process must conform. Also, for maximum effectiveness, the process control test should be close to the processing machinery. Quick answers are required to prevent excessive amounts of faulty material from getting through before detection, e.g., weight, thickness, strength, etc.

Process development

Process development may be considered as a form of applied research. The experimental work involved may be carried out in pilot plants in the R & D Department or perhaps on the actual processing machinery. In each case, investigations into better, cheaper, and quicker methods for manipulating the raw materials are made. Most trials in these directions require the testing of the material produced, and it is important to be clear which properties are to be measured to avoid unnecessary waste of time and money.

Product testing or "quality control"

If we could be absolutely certain that our choice of raw materials was right and that our system of process control had maintained the stipulated standard levels, then we could pack the end products into cases with confidence, knowing that they would fulfill their intended purposes satisfactorily. It is only by a good testing and well placed quality control program that we could be able to achieve this confidence and the required level of quality.

Research

The road along which a research worker travels is characterized by crossroads, fork roads, bridges, and cul-de-sacs. At each stage, there is a choice of direction. The results of testing in research will help the researchers to decide which route to follow next. What appears to be a sound theory is often disproved by experiment.

Specifications and "test quality"

Another important role which testing plays, is in the area of determining the required specifications for different products as well as in the operation of a "tested quality" scheme. In these cases, the materials tested are usually in the finished state or in the made-up state just as the eventual customer buys them.

Characterization of nonwoven products

The characterization of the nonwoven products encompasses the determination and measurement of the various properties which are relevant for any particular objective. The properties of the nonwoven material could be classified according to the two main types namely:

A. The physical properties, and

B. The mechanical properties.

These are defined as follows:

A. **Physical properties:**

The physical properties could be defined as the properties by which the material will be characterized in terms of its dimensions, weight, density, and other properties which do not relate to its response to load (stress) or extension (strain). Some of the properties which characterize the physical properties of textile materials are:

a. Dimension, length, width, and thickness

b. Density

c. Absorption

d. Swelling

e. Electrical properties, dielectric properties, electrical resistance, and static electricity

f. Optical properties

g. Thermal properties

h. Frictional properties

B. **Mechanical properties:**

The mechanical properties of textile material characterize the response of the material to applied forces and deformations. These have always been looked upon as the most important properties technically as they contribute both to the behavior of the material during processing as well as to the performance of the final product during end use.

The following are some of the mechanical properties which would be of interest:

a. Tensile properties, tenacity, breaking elongation.

b. Toughness (work to rupture)

c. Elastic properties (Initial or Young's Modulus)

d. Elastic recovery

e. Relaxation

f. Creep (Delayed deformation)

g. Resiliency

h. Flexural rigidity

Part A

Testing methods and techniques

Test methods and techniques are intended to provide uniform, orderly procedures for the determination of certain properties of nonwovens and the web structure which comprise them. Several standard test methods have been established and are being adopted by the industry.

The principal use of these standard tests is in the buying and selling of nonwovens and their component webs. Therefore, they are chosen so as to provide sufficient precision and reliability that they may be used to establish contractual specifications and judge compliance of the goods there to. Whenever possible, the Standard Tests designate and recommend the use of proven methods published by, and obtainable from, established standards organizations, such as INDA, ASTM, TAPPI, AATCC, ANSI, etc. In order that these existing methods be consistent, for example, with regard to test atmosphere or metric reporting, and be specifically applicable to nonwoven fabrics, certain modifications and adaptations of the published methods have been found to be necessary. These exceptions are not to be construed as in any way impugning the validity of the general method as published.

In the following section, the standard test methods established by the different organizations are summarized and presented to provide the scope of the test and the recommended methods. For the actual performance of the test, reference should be made to the actual test method for the full details of sampling, apparatus to be used, test procedure, calculations, and reporting of results.

INDA — Standard methods of testing nonwoven fabrics

In reference to INDA publication on the subject of testing entitled "IST — INDA STANDARD TESTS," INDA recommends the use of certain test methods by its members.

Table 10.1 shows an alphabetical listing of INDA standard tests showing the description of the test, the reference number, the year the test was adopted, and the year the test was revised. A summary of each test will be given in the same alphabetical order showing the scope of the test and the recommended or equivalent methods that could be used to perform the test.

Table 10.1. INDA standard tests

Description	1st number
Absorption	10.0-70 (R82)
Liquid absorbency time	10.1-70 (R82)
Liquid absorptive capacity	10.2-70 (R82)
Liquid wicking rate	10.3-70 (R82)
Abrasion resistance	20.0-70 (R82)
Oscillatory cylinder method	20.3-70 (R82)
Uniform abrasion method	20.5-70 (R82)
Bursting strength	30.0-70 (R82)
Electrostatic properties	40.0-70 (R82)
Surface resistivity	40.1-70 (R82)
Charge decay	40.2-70 (R82)
Spark energy	40.3-70 (R82)
Flammability	50.0-71 (R82)
Motor vehicle interior fabric flammability	50.3-86
Optical properties	60.0-70 (R82)
Opacity	60.1-70 (R82)
Brightness	60.2-70 (R82)
Permeability	70.0-70 (R82)
Air permeability	70.1-70 (R82)
Water vapor transmission	70.2-70 (R82)
Repellency	80.0-70 (R82)
Surface wetting spray test	80.1-70 (R82)
Internal wetting (tumble jar test)	80.2-70 (R82)
Internal wetting (static immersion)	80.3-70 (R82)
Penetration by water (rain test)	80.4-70 (R82)
Penetration by water (impact test)	80.5-70 (R82)
Penetration by water (hydrostatic test)	80.6-70 (R82)
Oil repellency	80.8-70 (R82)

Table 10.1 INDA standard tests (continued)

Description	1st number
Saline repellency	80.7-70 (R82)
Resistance to penetration of bacteria	80.7A-82
Alcohol repellency	80.9-74 (R82)
Handle-o-meter stiffness	90.0-75 (R82)
Cantilever stiffness	90.1-86
Gurley stiffness test	90.2-86
Tear strength	100.0-70 (R82)
Internal (Elmendorf) tear	100.1-70 (R82)
Edge tear	100.2-70 (R82)
Trapezoid tear	100.3-70 (R82)
Breaking load/elongation	110.0-70 (R82)
Seam breaking strength	110.1-82
Bond strength of laminates	110.2-82
Internal bond strength	110.3-84
Thickness	120.0-70 (R82)
Weight (grammage)	130.0-70 (R82)
Coefficient of friction	140.0-82
Resistance to dry cleaning and laundering	150.0-82
Resistance to linting	160.0-83
Web uniformity test	170.0-84

Table 10.1 INDA standard tests (continued)

Description	1st number
Geotextile fabric tests	180.0-84
Sampling procedure	180.1-84
Breaking load and elongation	180.2-84
Trapezoid tearing strength	180.3-84
Puncture strength	180.4-84
Diaphragm bursting strength	180.5-84
Apparent maximum opening size	180.6-84
Permittivity	180.7-84
Asphalt retention and area change	180.8-84
Extraction tests	190.0-86

Absorption [IST 10.0-70 (R82)

Scope

This test method covers the evaluation of the behavior of absorbent nonwovens in the presence of liquids. This evaluation is done by testing for liquid absorbency time, liquid absorptive capacity, and liquid wicking rate.

Specific property/procedures

10.1: Liquid absorbency time is the time required for a sample of absorbent material to become completely wet by the test liquid. It is the time required for a material to imbibe a liquid into its interior structure.

10.2: Liquid absorptive capacity measures the percent by weight of liquid that is absorbed by the test material.

10.3: Liquid wicking rate measures the capillarity of the test material.

Recommended methods

10.1: Liquid absorbency time: "Testing Nonwoven Fabrics," ASTM D1117-80 (Section 5).

10.2: Liquid absorptive capacity: "Testing Nonwoven Fabrics," ASTMD1117-80 (Section 5).

10.3: Liquid wicking rate: "Capillarity Test of Paper," TAPPI Useful Methods 451 (UM 451).

Abrasion resistance [IST 20.0-70 (R82)]

Scope

This test method covers the evaluation of the behavior of nonwovens when subjected to abrasive action. This evaluation is done by any of six test procedures.

Specific property/procedure

The subjective and/or objective determination of the effects of abrading nonwovens with machines which:

20.1: Rub specimens, held in position with an inflated rubber diaphragm, against an abradant.

20.2: Unidirectionally fold and rub specimens over a bar under known conditions of pressure and tension.

20.3: Rub specimens unidirectionally under specified conditions of pressure, tension and abrasive action—Oscillatory Cylinder Method.

20.4: Subject specimens to rotary rubbing action under controlled pressure and abrasive action.

20.5: Rub specimens uniformly in all directions in the plane of the surface about every point in it—Uniform Abrasion Method.

20.6: Subject specimens to flexing, rubbing, shock, compression, stretching, and other forces during a test.

Recommended methods

"Abrasion Resistance of Textile Fabrics," ASTM D1175-77.

(Section 18) and ASTM D1175-80)

Alternate methods

20.1: "Inflated Diaphragm," FTMS No. 191, Method 5302.1-1974.

20.2: "Flexing and Abrasion," ASTM D3885-80.

20.3: "Oscillating Cylinder," FTMS No. 191, Method 5304-1968.

20.4: "Rotary Platform," ASTM D3884-80.

20.5: "Uniform Abrasion," FTMS No. 191, Method 5308.1-1970.

20.6: "Accelerator Method (Impeller Tumbler)," AATCC Test Method 93-1989.

Bursting strength [IST 30.0-70 (R77)]

Scope

This test method covers the evaluation of the behavior of nonwovens when subjected to bursting stress. It is not intended for use in testing materials that tend to cut the thin rubber diaphragm.

Specific property/procedure

Bursting strength is the hydrostatic pressure, in kilopascals (or pounds-force per square inch), required to produce rupture in the material when the pressure is applied at a controlled increasing rate through a rubber diaphragm to a circular area 30.5 mm (1.200 in.) in diameter, the area of the material under test being initially flat and held rigidly at the circumference, but free to bulge under the increasing pressure during the test.

Recommended methods

"Bursting Strength of Paper," ASTM D3786-80

Equivalent methods

"Bursting Strength of Paper," TAPPI Test Method T 403 os-76.

"Bursting Strength," SCAN-P24:68.

Electrostatic properties [IST 40.0-79 (R82)]

Scope

These test methods evaluate the ability of a material to be free of electrostatic hazards in the presence of incendive medical gases under specified conditions of relative humidity and temperature. These procedures cover the measurement of the surface resistivity, charge decay times, and the spark energy.

Specific property/procedures

40.1: Surface Resistivity: The ratio of the potential gradient parallel to the current along its surface to the current per unit width of the surface as measured by the Surface Resistivity Test.

40.2: Charge Decay: The time required for 90% of an induced charge on the surface of a material to dissipate as measured by the Charge Decay Test.

40.3: Spark Energy: The energy contained in a spark drawn from a material as measured by the Spark Energy Test.

Recommended methods

40.1: "Electrical Resistivity of Fabrics" AATCC 76-1972.

40.2: "Electrostatic Properties of Materials" Fed. Test Method Std. No. 101B, Method 4046.

40.3: "Spark Energy" IST 40.3 - 79 (R82).

Equivalent methods

40.1: ASTM D257.

ANSI C59.3 - 1968.

Flammability [IST 50.0-71 (R82)]

Scope

This test method covers the evaluation of the behavior of nonwovens when exposed to specific ignition procedures.

Specific property/ procedures

50.1: The time of flame spread of nonwovens held at a 45 degree angle and ignited by a one-second surface impingement of a standard flame. (This is the general test procedure referenced in the Flammable Fabrics Act as amended in 1967.)

50.2: The time of flame spread of plain surfaced nonwovens held at a 45 degree angle and continuously ignited (up to 20 seconds) at the lower edge of the specimen by a standard flame.

Recommended methods

50.1: Commercial Standard 191-53 (Revised).

50.2: "Wearing Apparel Flammability 1975," NFPA No. 702, Chapter 4.

Equivalent methods

50.1: ASTM D1230-72.

FTMS 191, Method 5908.1-1974.

AATCC Method 33-1962.

Motor vehicle interior fabric flammability [IST 50.0-86]

Scope

This test determines the horizontal burning rate of single layer or composite materials composing the first 1/2 inch adjacent to the passenger compartments of all roadway motor vehicles.

Principle

The specimen is held in a horizontal plane in a metal cabinet, ignited with a flame for 15 seconds and the burning rate is determined, after ignition, for a 10-inch length.

Referenced method

Motor Vehicle Safety Standard No. 302, part 571, revised 1975.

Optical properties [IST 60.0-70 (R77)]

Scope

This test method covers the evaluation of the optical properties of nonwovens. The evaluation is done by testing for opacity and brightness.

Principle

60.1: Opacity: The essential principle of this contrast-ratio method for determining the opacity of nonwovens is as follows: The reflectance of nonwovens when combined with a white backing is higher than that of nonwovens when combined with a black backing because, in the former case, light transmitted through the imperfectly opaque sheet is largely reflected by the white backing, and a portion of the light thus reflected is transmitted through the nonwovens a second time. Contrast ratio, C0.89, is defined as 100 times the ratio of the diffuse reflectance, Rb, of a specimen backed with black of not more than 0.005 reflectance, to the diffuse reflectance, Rw, of the same specimen backed with a white body having an absolute reflectance of 0.89; C0.89=100

Rb/Rw). These reflectances are absolute: The absolute diffuse reflectance for magnesium oxide being very nearly 0.98. Accordingly, the contrast ratio is 100 percent for perfectly opaque nonwovens, and is only a few percentage points for a perfectly transparent sheet.

Recommended methods

60.1: "Opacity of Paper," (15 Diffuse Illuminant A, 89% Reflectance Backing and Paper Backing)" TAPPI T 425 om-81.

60.2: "Brightness of Paper and Paperboard, " TAPPI T 452 os-58.

Permeability [IST 70.0-70 (R82)]

Scope

This test method covers the evaluation of the air permeability and water vapor transmission of nonwovens.

Specific property/ procedures

70.1: Air Permeability: The resistance of a nonwoven fabric to the passage of air at a known pressure differential.

70.2: Water Vapor Transmission (WVT): the rate of passage of water vapor through nonwovens under a know temperature and relative humidity differential.

Recommended methods

70.1: "Air Permeability of Textile Fabrics"-ASTM D737-75.

70.2: "Water Vapor Transmission of Materials in Sheet Form" ASTM E96-66(R72).

Equivalent methods

70.1: FTMS 191, Method 5450.1-1970

Repellency [IST 80.0 - 70 (R82)]

Scope

This test method evaluates the ability of nonabsorbent nonwovens to resist wetting and/or penetration by liquids. These procedures cover the evaluation of resistance to surface wetting, internal wetting, penetration by water, penetration by aqueous sodium chloride under hydrostatic pressure in contact with a flat surface, and resistance to wetting by a selected series of liquid hydrocarbons.

Specific property/procedures

80.1: Surface Wetting: Wetting resistance as measured by the Spray Test.

80.2: Internal Wetting: Resistance to absorption as measured by the Dynamic Absorption Test (Tumble-jar Method).

80.3: Internal Wetting: Resistance to absorption as measured by the Static (Immersion) Absorption Test.

80.4: Penetration by Water: Resistance to penetration as measured by the Rain Test.

80.5: Penetration by Water: Resistance to penetration as measured by the Impact Penetration Test.

80.6: Penetration by Water: Resistance to penetration as measured by the Hydrostatic Pressure Test.

80.7: Saline Repellency: Resistance to penetration by aqueous sodium chloride under hydrostatic pressure in contact with a flat surface. (See separate test method.)

80.7A: Bacteria Repellency: Resistance to penetration by bacteria in aqueous sodium chloride solution under hydrostatic pressure. (See separate test method).

80.8: Oil Repellency: The index of resistance to staining by oily substances.

80.9: Alcohol Repellency: Resistance to penetration by water/alcohol solutions. (See separate test method.)

Recommended methods

80.1: "Water Repellency: Spray Test," AATCC 22-1974.

80.2: "Water Repellency Tumble Jar Dynamic Absorption Test," AATCC 70-1975.

80.3: "Water Repellency Static Absorption Test," AATCC 21-1977.

80.4: "Water Resistance Rain Test," AATCC 35-1974.

80.5: "Water Resistance Impact Penetration Test," AATCC 42-1974.

80.6: "Water Resistance Hydrostatic Pressure Test," AATCC 127-1974.

80.8: "Oil Repellency Hydrocarbon Resistance Test," AATCC 118-1975.

Saline repellency of nonwovens [IST 80.7-70 (R82)]

Scope

To measure the resistance of nonwovens to the penetration by an aqueous sodium chloride solution under a hydrostatic pressure. This procedure is applicable to the determination of water repellency of nonwovens and, in particular, those used for surgical applications.

Principle

The nonwoven to be tested is used to seal an inverted vented Mason jar containing a saline solution, and the penetration of the solution through the nonwoven is noted.

Resistance to penetration of bacteria in saline solution [IST 80.7A-82]

Scope

There is substantial evidence that bacteria in a liquid will not migrate through a fabric without some liquid penetration, as measured by IST 80.7; however, where a test with bacteria is desired, the following test procedure may be used to measure the resistance of nonwovens to the penetration of microorganism suspensions under a hydrostatic pressure.

This procedure is applicable to the determination of the bacterial barrier properties of nonwovens that are used for surgical applications.

Principle

The nonwoven to be tested is used to seal an inverted vented mason jar containing an aqueous solution of microorganisms. The inverted jar is placed in a sterile petri dish for a specified time after which it may be removed and placed in a second sterile petri dish and the test continued. Agar is poured into the first dish, covered and incubated for at least 72 hours. At the end of a specified time, the jar is removed from the second petri dish and this dish is treated as the first. After 48 and 72 hours of incubation, the dishes are checked for microorganism growth. If growth is observed, the organisms are identified and colonies counted. The results are reported versus a given time and hydrostatic head.

The procedure is to be carried out in a sterile environment by individuals skilled in microbiological techniques.

Alcohol repellency of nonwovens [IST 80.9-74 (R82)]

Scope

This test is designed to measure the resistance of nonwoven fabrics to penetration by water/alcohol solutions.

Limitation

This test provides a rough index of alcohol repellency of nonwoven fabrics in that, generally, the higher the Alcohol Repellency Rating, the better resistance to penetration by water/alcohol-containing solutions. This is particularly applicable when comparing various finishes on a given fabric.

Principle

Drops of standard test liquids, consisting of a selected series of water/alcohol solutions, are placed on the fabric surface and observed for penetration. The Alcohol Repellency Rating is the highest numbered test liquid which does not penetrate the fabric.

Handle-o-meter stiffness* [IST 90.0-75 (R82)]

Scope

This test method covers the evaluation of the stiffness of nonwovens.

Principle

The nonwoven to be tested is deformed through a restricted opening by a plunger, and the required force is measured. This force is a measure of both flexibility and surface friction of the nonwoven.

Recommended method

"Handle-O-Meter Stiffness Test" TAPPI T 498 su-66.

Alternative methods

1. Ring and Rod Softness. Reference: Mendoza and Harrington, "Total Softness Measurement of Nonwovens:, INDA Technical Symposium Paper, 1973. Developed by The Dexter Corp.; marketed by Instron Corp.
2. Handfeel Comparator. No published references. Developed by Scott Paper Co.
3. Loop Softness. Reference: Noll and Teeple, "Instrument Test for Softness," *Modern Packaging*, July 1963. Developed by American Can Co.; marketed by Custom Scientific Instruments, Inc.

Cantilever stiffness [IST 90.1-86]

Scope

This test method evaluates the stiffness of nonwoven fabrics using very simple inexpensive equipment. It is not recommended for fabrics that are very limp or have a tendency to curl.

Principle

A nonwoven fabric strip is moved slowly in a horizontal direction parallel to its length, so that an end overhanging the edge of the horizontal surface bends downward. When the tip of the fabric strip has dropped under its own weight to intersect a line from the upper edge of the horizontal surface, a line making a 41.5 degree angle with the surface, the length of the fabric that has been pushed over the edge is read off a scale and recorded. This length and the unit area weight of the fabric is used to calculate its flexural rigidity.

In INDA's "Softness Hand Research Study" the average MD-CD flexural rigidity was found to correlate better with the results of six independent panels on 14 different fabrics than did the average bending length alone.

Referenced method

ASTM D-1388.

FTMS 191-5206.

INDA's Softness Hand Research Study 1971-1974 (published pamphlet).

Gurley stiffness test [IST 90.2-86]

Scope

This test method is useful in evaluating the stiffness of heavier and stiffer nonwoven fabrics; it is not recommended for heavy limp fabrics.

Principle

The fabric specimen clamped in a motor driven arm overlaps the end of a pendulum by 1/4 inch and deflects the pendulum an amount depending upon the stiffness of the fabric, before it slips past the end of the pendulum. The deflection of the pendulum is noted and used to calculate the stiffness.

Referenced method

TAPPI T 543 pm-84.

Tear [IST 100.0-70 (R82)]

Scope

This test method covers the evaluation of the resistance of nonwovens to both internal and edge tearing.

Specific property/procedures

100.1: Internal Tear Resistance: The standard method covers the internal tearing resistance of nonwovens using a rectangular or constant radius testing specimen.

100.2: Edge Tear: This procedure measures the resistance of nonwovens to the initiation of tear at the edge of the test specimen.

100.3: Trapezoid Tearing Strength: this is an alternative method to IST100.1 for measuring internal tear resistance.

Recommended methods

100.1: "Propagation Tear Resistance of Plastic Film and Thin Sheeting," ASTM D 1922 (Reapproved 1978).

100.2: "Edge Tearing Strength of Paper," ASTM D 827-67 (Reapproved 1971).

100.3: "Trapezoid Tearing Strength," ASTM D 1117-77, Section 14.

Equivalent methods

100.1: SCAN-P11:64.
100.2: TAPPI T 470 os-66.
100.3: EDANA-70.0.75.

Breaking load/elongation [IST 110.0-70 (82)]

Scope

This test method covers the behavior of nonwovens when subjected to tensile stress.

Specific property/procedures

Values for the breaking load and elongation of a specified width of material are determined by longitudinal application of increasing load at a specified rate within a specified time as measured by grab, raveled strip, or cut strip methods.

Recommended methods

"Breaking Load and Elongation of Textile Fabrics," ASTM D-1117-77, Section 7.

Seam breaking test [IST 110.1-82]

Scope

This test method is designed to determine the breaking load of sewn seams when the load is applied perpendicularly to the seam, using the Grab Test Method.

This method requires a straight seam. The seam line should be parallel to the machine direction or cross direction, which must be noted. Specimens may be taken from previously sewn articles or prepared from fabric samples.

Seam preparation and fabric samples may vary according to specifications established by the seller and the purchaser and will not be part of the general instructions.

Definition

Grab Test—a test in which only part of the width of the specimen is gripped in the clamps. For example, if the specimen is 100 mm (4 in.) wide and the width of the jaw faces is 25 mm (1 in.), then the specimen is gripped centrally in the clamps.

Recommended methods

"Seam Breaking Strength (load) of Woven Textile Fabrics," ASTM D 1683-78 (Reapproved 1973).

Bond strength of laminates [IST 110.2-82]

Scope

This procedure provides a method for measuring the force required to separate a nonwoven from any flexible substrate, whether another nonwoven or other material to which it has been laminated.

This method may also be used for measuring the adhesive forces between a nonwoven and other material following various treatments, such as washing and dry cleaning. (See IST 150.0.)

Specific property/procedure

Bond Strength: The resistance of a laminate containing at least one ply of a nonwoven, to separation forces applied at a specific and constant rate and at 180° angle.

Recommended method

ASTM D-2724-79 P 13.3 "Bonded and Laminated Apparel Fabrics."

Internal bond strength [IST 110.3-84]

Scope

This test method determines the intra fabric (internal bond) strength of a nonwoven fabric by measuring the energy required to separate the nonwoven into two plies. This strength is important in considering the suitability of nonwovens used in wall coverings and such.

Principle

The nonwoven specimen is bonded on both sides with double-sided adhesive tape to metal test fixtures. The right angle arm of the upper test fixture is impacted with a pendulum and the energy determined to separate the nonwoven into two plies is determined.

Referenced method

TAPPI-RC308, Test of Interfiber Bond Using the Internal Bond Strength Tester.

Definition of tensile properties

To define the different tensile properties, it could be achieved by understanding the typical stress/strain diagram for a material and the information it contains. A typical stress/strain curve is given in Fig. 10.1 and the basic tensile properties are given in Table 10.2.

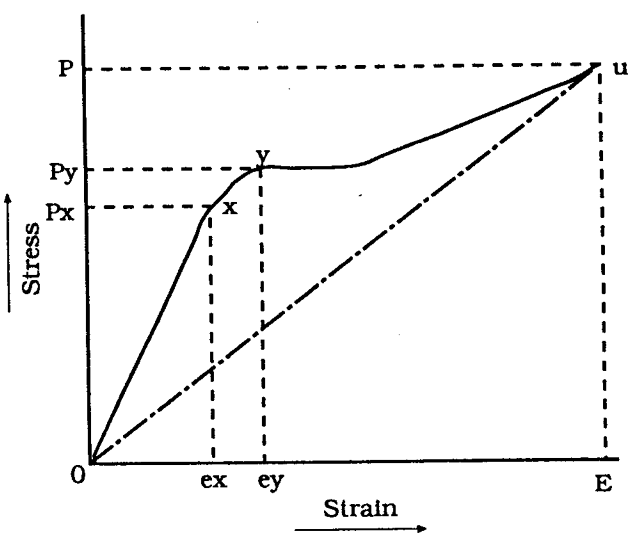


Fig. 10.1. General form of stress–strain curve

Table 10.2. Basic tensile properties of materials

Quality	Service Rendered	Criterion
A. Strength	To carry a dead load.	Ultimate strength.
B.Stiffness	To carry a load with the ability to return to original shape when load is removed.	Modulus of elasticity.
C. Elasticity	To undergo deformation and return to original shape upon cessation of deforming forces.	Elastic limit.
D. Resilience	To absorb shock without permanent deformation.	Modulus of resilience.
E. Toughness	To endure large, permanent deformations without rupture.	Ultimate resilience.

The slope of the line (Ox) is Initial modules or stiffness. The point (x) represents the amount of stress that the material can take reproducibly since (x) is the elastic limit of the material. At point (u), the material breaks and then (OP) is its strength and (OE) is its elongation. The area under the curve (oyeyo) is "resilience." The area under the curve oxyuEo is "toughness." (See Figure 10.1)

By examining the curves for various nonwovens, it is easy to recognize specific material characteristics that can be used to improve desired products.

Other uses of the stress/strain curve are to determine wet vs. dry performance and also to determine product performance under cyclic loading conditions. Once fibrous web is placed into a polymer matrix as occurs in bonded nonwovens, the new structure takes on physical responses that represents a hybrid of the properties of both the fiber and the matrix. In regular composite where fibers are totally surrounded by a polymer matrix in woven structures, the fiber properties normally represent between 65-80% of the final composite behavior. With nonwovens, where bonding is more sporadic, the relationship is more individualistic. In a study of binder concentration on stress/strain behavior for both rayon and nylon webs bonded with natural latex rubber, the following results were reported, as shown in Fig. 10.2.

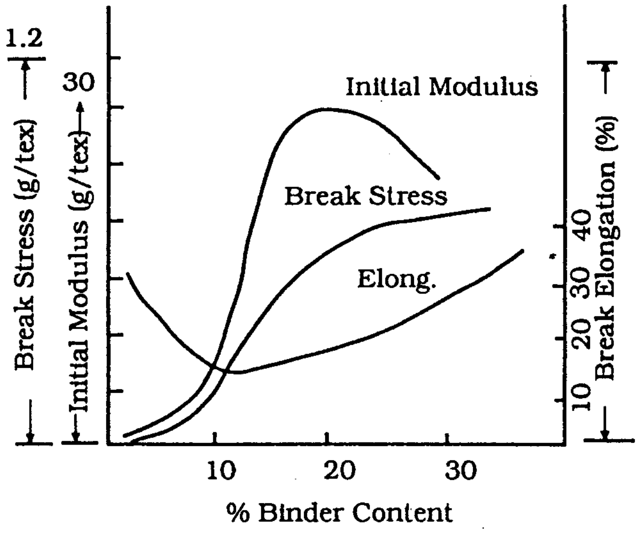


Fig. 10.2. Nonwoven properties vs. binder content

Modulus increased fairly rapidly and then fell. Strength increased and then leveled off. Elongation dropped significantly and then rose. About 20% binder seemed to be the level of maximum binder effect.

Thickness [IST 120.0-70 (R82)]

Scope

This test method covers the measurement of the thickness of nonwovens when subjected to compressive loading.

Specific property/procedures

Thickness is evaluated by determining the distance under specified pressure between one surface and its opposite.

Recommended methods

"Measuring Thickness of Textile Materials," ASTM D-1777-64 (reapproved 1975).

Weight (grammage) [IST 130.0-70 (R82)]

Scope

This test method covers the measurement of the weight per unit area of nonwovens.

Specific property/procedures

Weight (grammage) is measured by determining the grams per square meter (ounces per square yard or other weight per unit area).

Recommended methods

"Construction Characteristics of Woven Fabrics," ASTM D-1910-64 (reapproved 1975) (paragraphs 35-41).

Federal Test Method Standard 191, Methods 5040 & 5041.

Coefficient of friction of nonwovens [IST 140.0-82]

Scope

This method covers the determination of the coefficient of dynamic (kinetic) friction of a nonwoven textile when sliding over itself or a polished metal surface.

Specific property/procedures

The measurement of the relative difficulty with which the surface of one material will slide over another is achieved by an assembly of apparatus attached to a Constant-Rate-Of-Speed-Tensile Tester.

The coefficients of friction are useful indexes of performance relating to the sewability of nonwovens.

Recommended method

"Coefficient of Friction Plastic Film" ASTM D1894-78.

Resistance to dry cleaning and laundering [IST 150.0-82]

Scope

This procedure defines methods for subjecting nonwovens or bonded laminates of nonwovens to other nonwovens, wovens, or other substrates to standardized dry cleaning and machine laundering treatments. It further characterizes the effect of the treatment with respect to tensile strength, delamination, shrinkage, and bond strength.

Recommended methods

ASTM D-2724-79
AATCC 158-1978

Resistance to linting [IST 160.0-83]

Scope

These test methods are applicable for determining the relative linting properties of fabrics for developmental studies. The tests may require some modifications to make them sufficiently reproducible for quality acceptance criteria.

Principle

These tests are designed to determine the relative number of particles released from a fabric sample when subject to continuous twisting flexure. The particles may originate as airborne debris (dust) or as fragments from fibers, binders, or process treatments. The results may be used to assess the initial cleanliness and the lint generating potential of fabrics and fabric composites.

During the flexing, clean air is passed at a controlled rate through a chamber enclosing the sample. The number of particles above a minimum size, carried out of the chamber are counted for directly succeeding periods of time.

Recommended methods

A number of member companies have used two different available apparatus for flexing the fabrics. Both apparatus appear to give useful data; however, since the test conditions are not identical, the results obtained with one unit should not be compared directly with the results obtained with the other flexing equipment.

The primary test differences using the two apparatus are:

	160.1	160.2
Apparatus	Modified Gelbo Flex Unit	KC Flex Unit
Chamber Size	0.25 ft^3	1.0 ft^3
Air Flow Rate	15.0 ft^3/hour	1.0 ft^3/hour
Counting Period	60 secs	36 secs
Min. Particle Size	1.0 micron	0.5 microns
Twist and Stroke	440° & 6 in.	150° & 4.2 in.
Cycles/Min	45	70
Total Flex Time	10 min	6 min
Sample Size	9 x 10 in.	7 x 8 in.
Mounting Disc diameter	3-1/2 in.	3 in.

The significance of the minimum particle size counted will depend upon the intended end use of the nonwoven. For most applications, particle sizes 1-5 microns and larger are more significant than those less than 1 micron.

Web uniformity test [IST 170.0-84]

Scope

This test method evaluates and rates the uniformity of a nonwoven sheet.

Principle

This method measures the optical density at 100,000 points in approximately a 500 cm^2 area, counting as many as 64 variations in light transmission. Factors such as thickness, density, roughness, fiber distribution, color, and opacity will influence the results.

Referenced method

TAPPI Useful Method 432

Breaking load and elongation of geotextile [IST 180.2-84]

Scope

This method covers a procedure for determining the breaking load (grab tensile) and elongation (grab elongation) of geotextile fabrics using the Grab method.

Applicable documents

ASTM Standards:

D-76: Specification for Tensile Testing Machines for Textiles

D-123: Definitions of Terms Relating to Textiles

D-259: Specification for Woven Tapes

D-629: Quantitative Analysis of Textiles

D-1117: Testing Nonwoven Fabrics

D-1682: Breaking Load and Elongation of Textile Fabrics

D-461: Felt Testing

D-1776: Conditioning Textiles for Testing

Definitions

Grab Test-in Fabric Testing, a tension test in which only a part of the width of the specimen is gripped in the clamps.

Summary of method

A continually increasing load is applied longitudinally to the specimen, and the test is carried to rupture. Values for the breaking load and elongation of the test specimen are obtained from machine scales, dials, or autographic recording charts.

Geotextile fabric tests [IST 180.0-84]

Introduction

The following test methods were prepared by INDA's Geotextile Committee for determining pertinent physical properties of both woven and nonwoven fabrics used in geotextile applications.

These test methods have been reviewed and approved by Task Force 25, a subcommittee of the joint AASHTO-AGC-ARTBA committee for the Federal Highway Administration.

The tests include the following methods:

IST 180.1-84: Sampling Procedure

IST 180.2-84: Breaking Load and Elongation

IST 180.3-84: Trapezoid Tearing Strength

IST 180.4-84: Puncture Strength

IST 180.5-84: Diaphragm Bursting Strength

IST 180.6-84: Apparent Maximum Opening Size

IST 180.7-84: Permittivity

IST 180.8-84: Asphalt Retention and Area Change

Sampling of geotextile for testing [IST 180.1-84]

Scope

This practice covers a procedure for the use in the division of shipments of geotextiles into lots and the sampling of lots for testing.

Applicable documents

ASTM Standards:

D-123: Definitions of Terms Relating to Textiles

93-207: Practice for Writing Statements on Sampling in Test Methods for Textiles.

Definitions

Geotextile - n. - any permeable textile used with foundation, soil, rock, earth, or any other geotechnical material, as an integral part of a man-made product, structure, or system.

Production, Lot - n. - unit of production, or a group of other units or packages, taken for sampling or statistical examination, having one or more common properties and being readily separable from other similar units.

For definitions of other textile terms used in this practice, refer to Definitions ASTM-D123.

Trapezoid tearing strength of geotextiles [IST 180.3-84]

Scope

This procedure is used to measure the tearing strength and resistance to tear propagation of woven or nonwoven geotextiles by the trapezoid method.

This procedure is applicable to conditioned fabrics.

Applicable documents

ASTM Standards:

D-61-012: Definitions of terms and symbols relating to Geotextiles

D-76: Specification for Tensile Testing Machines for Textile Materials

D-123: Definitions of Terms Relating to Textiles

D-639: Quantitative Analysis of Textiles

D-1117: Standard Methods of Testing Nonwoven Fabrics

D-1776: Conditioning Textiles for Testing

Definition

Strength, Tearing - F_T (F), kN, n. - the force required to start or continue a tear in material.

Puncture strength of geotextiles [IST 180.4-84]

Scope

This method is used to measure the puncture strength of geotextile fabrics.

Applicable documents

ASTM Standards:

D-123: Definitions of Terms Relating to Textiles

D-461: Section 13 Bursting Strength of Felts

D-751: Standard Test Methods of Testing Coated Fabrics

D-3786: Test for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method

D-1776: Conditioning Textiles for Testing

Other Standards:

TAPPI T 403 os-74: "Bursting Strength of Paper"

Definitions

Strength, bursting - n. - the force or pressure required to rupture a textile by distending it with a hydraulic force, applied perpendicular to the plane of the constrained fabric.

Apparent maximum opening size of geotextiles [IST 180.6-84]

Scope

This test method is used to determine the Apparent Maximum Opening or Pore Size (AOS) of a geotextile by sieving glass beads through it. Geotextiles should be compatible with the adjacent soil to prevent soil movement. This procedure is used to indicate the maximum pore size, determines the ability of the fabric to restrain native soil particles, thus preventing piping. This test method should not be used as a criteria for clogging resistance.

Applicable documents

ASTM Standards:

- E-11: Standard Size Sieves
- D-123: Standard Definitions of Terms Relating to Textiles
- D-1898: Recommended Practice for Sampling of Plastic
- D-422: Particle Size Analysis of Soils
- D-1776: Conditioning Textiles for Testing

Definition

Apparent Opening Size (AOS) — The sieve size in mm, of the smallest glass beads where only 5% or less of the beads pass through the fabric. This value will be designated as O95.

Permittivity of geotextiles [IST 180.7-94]

Scope

This method covers a procedure for determining the hydraulic conductivity (water permeability) of geotextiles in terms of permittivity under a standard set of testing conditions.

Applicable documents

ASTM Standards

- D-123: Definitions of Terms Relating to Textiles
- D-653: Definitions of Terms and Symbols referring to Soil and Rock Mechanics
- D-1776: Conditioning Textiles for Testing

Definitions

Permittivity, (Ψ), (T^{-1}) s^{-1}, - n. — the volumetric flow rate of water per unit cross-sectional area per unit head, in the normal direction through a geotextile.

Hydraulic Conductivity (k), (LT^{-1}), - n. — the rate of discharge of water at standard temperature conditions (20°C–68°F) through a unit cross-sectional area of a porous medium under a unit hydraulic gradient.

Asphalt retention and area change of paving engineering fabrics [IST 180.8-84]

Scope

This method covers a procedure for determining the asphalt retention and area change for paving grade engineering fabrics.

This procedure is applicable to engineering fabrics that are utilized in an asphalt saturated interlayer in asphalt bituminous pavement.

Applicable documents

ASTM Standards:

- D-61-012: Definitions of Terms and Symbols Relating to Geotextiles
- D-123: Definitions of Terms Relating to Textiles
- D-629: Quantitative Analysis of Textiles
- D-1117: Standard Methods of Testing Nonwoven Fabrics
- D-1776: Conditioning Textiles for Testing

Definitions

Asphalt Retention is the weight of asphalt cement retained by a paving engineering fabric per unit area of specimen after submersion in asphalt cement and draining.

The Change in Area is the area change per unit of original material expressed in percent.

Extraction tests [IST 190.0-86]

Scope

This test method covers the general procedure to determine the amount of extractable components in a nonwoven fabric. The solvent selected is dependent upon the proposed end use of the fabric. Recommended solvents are distilled water, and reagent grade ethyl alcohol, and trichloro trifluorethane. Ethers and highly toxic solvents are not recommended. Obviously, solvents that dissolve the fibers or bonding agents should not be used.

Specific property

The level of extractable components in a nonwoven fabric is the amount of material soluble in a selected solvent. This is an important parameter for applications in which the level of soluble components is required to be low.

Reference method

ASTM Method D2257-80 - Extractable Matter in Yarns

ASTM — standard methods of testing nonwoven fabrics

According to ASTM publication, *Annual Book of ASTM Standard,* Volumes 07.01 and 07.02, 1991, the standards applicable to nonwoven fabrics are given in Table 10.3* in an alphabetical order showing the year of the original adoption as standard, or, in the case of revision, the year of the last revision.

Table 10.3. Summary of ASTM-Standard Tests for nonwovens*

Title - (Property to be Tested)	Standard Test Method Number
Abrasion Resistance of Textile Fabrics by uniform abrasion.	D 4158-1982
Abrasion Resistance of Textile Fabrics: Rotary platform, double head tester.	D 3884-1980
Air Permeability of Textile Fabrics.	D 737-1975 (Reapproved 1980)
Breaking Force/Elongation of Textile Fabrics, by Grab Test. (See Table 10.2.)	D 5034-1990
Breaking Force/Elongation of Textile Fabrics, by Raveled Strip/Cut Strip Procedures (See Table 10.2.)	D 5035-1990
Breaking Load and Elongation of Textile Fabrics (See Table 10.2)	D 1682-1964 (Reapproved 1975)
Electrostatic Propensity of Textiles	D 4238-1990
Felt Testing Methods	D 461-1987
Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabric: Diaphragm Bursting Strength Tester	D 3786-1987
Nonwoven Fabric Testing	D 1117-1980
Snagging Resistance of Fabrics by Mace Test Method	D 3939-1980
Stiffness of Fabric by the Circular Bend Method	D 4032-1982
Woven/Thermal/Flocked/ Nonwoven/Knitted/Household Blanket Fabrics, Perf. Spec.	D 3393-1981 (Reapproved 1990)

***NOTE:** Several of the methods given in Table 10.3, have been mentioned as recommended tests by INDA as previously indicated. In most of the cases, the scope of the test does not vary significantly from the scope of the test standards provided by INDA. For the details of the performance of the tests and application of these standards, reference should be made to the ASTM annual Book of ASTM Standards (volumes 07.01 and 7.02, 1991).

AATCC — Standard test methods of testing nonwoven fabrics

An important feature of all AATCC test methods is that test results are numerically quantified as opposed to being reported as pass-fail. Test results are the basis for describing material or process characteristics.

As shown in Table 10.4, each test method is designated by a number followed by a date which indicates the year in which the method was issued, last revised or reaffirmed. The designation should be quoted in full in referring to a particular method.

Table 10.4. Summary of AATCC test methods*

Title (Property to be Tested)	Standard Test Method Number
Abrasion Resistance of Fabrics: Accelerator Method	93-1989
Absorbency of Bleached Textiles	79-1986
Bond Strength of Bonded and Laminated Fabrics	136-1989
Water Repellency: Spray Test	22-1980 (Reaffirmed 1989)
Water Repellency: Tumble Jar Dynamic Absorption Test	70-1989
Water Resistance: Hydrostatic Pressure Test	127-1989
Water Resistance: Impact Penetration Test	42-1989
Water Resistance: Rain Test	35-1989

***NOTE:** Several of the methods given in Table 10.4 have been mentioned as recommended tests by INDA as previously indicated. In most cases, the scope of the test does not vary significantly from the scope of the test standards provided by INDA. For the details of the performance of the tests and applications of these standards, reference should be made to 1991, Technical Manual, of the American Association of Textile Chemists and Colorists (AATCC).

Part B

Absorbency characteristics of nonwoven fabrics

Background

The subject of absorbency characteristics of textile materials and structure has been a substantial section of high and excellent quality published work. The publications dealt with both the theoretical aspects of the interactions of liquids with the textile material. It has been observed that the writings dealing with the experimental studies of such characteristic do not come up to the same level of excellence. There have been for many years a general uncertainty and unclear views and understanding regarding the properties to be measured and the methods and procedure for the measurement.

The above phenomena could be related to the rapidly expanding market of disposable absorbent products throughout the world. The competition for new, improved, unique products is becoming tougher. Manufacturers of such products and their product development staff and/or technologists or scientists are faced with the ever increasing challenge of innovative new technologies.

In this section of the chapter, an attempt will be made to introduce the most popular absorbency characteristics and the method by which they could be measured.

Technological importance of moisture absorption

The property of absorption of moisture is a valuable feature of clothing materials. Apart from its direct utility in keeping the skin dry, the absorption of moisture causes the fabric to act as a heat reservoir, protecting the body from sudden changes of external conditions. This is due to the heat evolved when the moisture is absorbed which is the result of the exothermic reaction.

The absorption changes the various properties of the material, such as:

(a) It causes swelling to occur, which alters the dimensions of the material resulting in changes in the size, shape, and permeability of the nonwovens.

(b) The mechanical properties and friction properties are altered.

(c) Absorbency affects the material processing prior to final stages of manufacturing.

(d) Wetting and drying may cause permanent set or creasing.

(e) Absorbency plays an important role in determining the electrical properties of the material.

(f) Absorbency has a significant direct commercial interest, especially if the material is dealt with on a basis of weight and not number of pieces.

Definition

Absorbency: This is the criteria which is generally characterized by the mode and the extent of the transport of liquid into an absorbing material.

The definition of the specific aspects of absorbency will be given with the test method explained for its measurement.

Factors affecting absorbency

The following factors play different roles in the different absorbency characteristics:

(a) Intrinsic liquid attraction capacity of the materials which determines the affinity between the liquid and the absorbent.

(b) The structure of nonwoven substances with regard to the pressure of capillary tubes and pore size distribution.

(c) The swelling property of the material itself which affects the liquid retention property of the nonwoven.

The techniques of measuring absorbency are designed to measure the amount of liquid absorbed. These techniques can be divided into two broad types:

(1) Spontaneous (demand) liquid absorption, and

(2) Liquid retention.

The various test methods for measuring the absorbency characteristics are:

A. Moisture absorption

B. Demand absorbency test

C. Liquid retention test

D. Measurement of rate of absorbency.

Techniques of absorbency measurement

The phenomenon of absorption of moisture by textile materials has been recognized for a long time (Leonardo da Vinci, 1452-1519, and earlier Nicholas of Cusa, 1401-1463). The technique of measuring the increase in weight due to the absorption of moisture varied over these years, depending on the property to be tested.

The basic or conventional relationship between the amount of moisture absorbed by the material and the relative humidity of the atmosphere (RH%) with which it is in equilibrium is shown in Fig. 10.3. There is hysteresis between the absorption and desorption approach of the material to the surrounding atmosphere. Various materials also show different absorption capacity as shown in Fig. 10.4. Reference should be made to ASTM D — 1909 Commercial Moisture Regain.

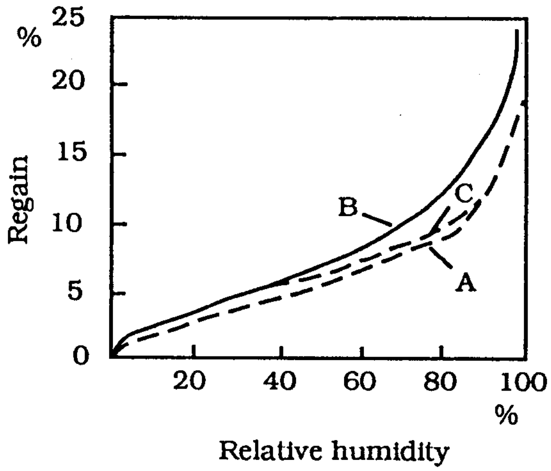


Fig. 10.3. Typical curves of regain against relative humidity. (A): absorption, (B): desorption, (C): intermediate (soda-boiled cotton).

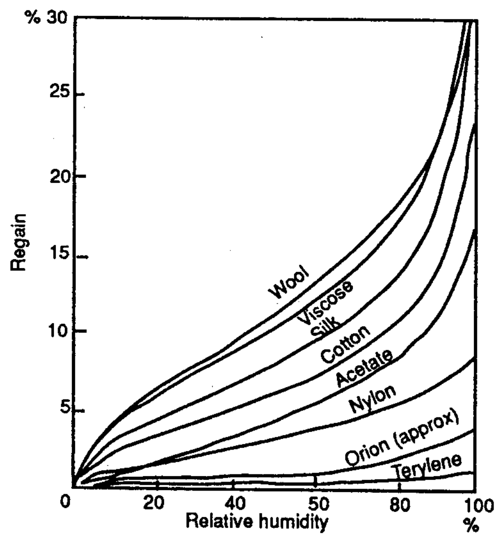


Fig. 10.4. Regain-r.h. relations for cotton, viscose rayon, acetate, silk, wool, nylon, orlon acrylic fiber and Terylene polyester fiber.

The measurement of the moisture absorption of fibrous materials has been conducted by several techniques described as, gravimetric method (oven drying method), indirect methods (using electrical properties — capacitance method), and several other approaches. Reference should be made to ASTM D-2654, moisture (content/pickup/ regain) in textile fibers (natural/man-made/ filament/finished fabrics) ASTM D-4920, terminology of moisture in textiles.

The other phenomenon which describe the absorbency characteristics of textile materials and of significant interest to describe the performance of nonwoven structures are:

(a) Demand Absorbency and Wicking

(b) Liquid Retention

(c) Rate of Fluid Uptake.

Demand Absorbency and Wicking Test

The demand wettability phenomena is of particular interest in the performance of different types of sponges. In this phenomena, the liquid will enter the absorbent sample only when, and as long as, the sample demands it. In the test procedure, the dry sample is kept in contact with the liquid in such a way that absorption occurs under at least a slight negative hydrostatic head.

AATCC — Test Method 39-1980, TAPPI Routine Control Methods, RC-8 (1950) and ASTM D-1117-79 have been used to measure wettability of fabrics. Most of these techniques rely on visual observation of an advancing liquid front. Lichstein *(37)* described the use of a demand wettability apparatus that overcomes most of the objections of other techniques and is quite suitable for determining wettability rates using nonsurfactant fluids (Fig. 10.5).

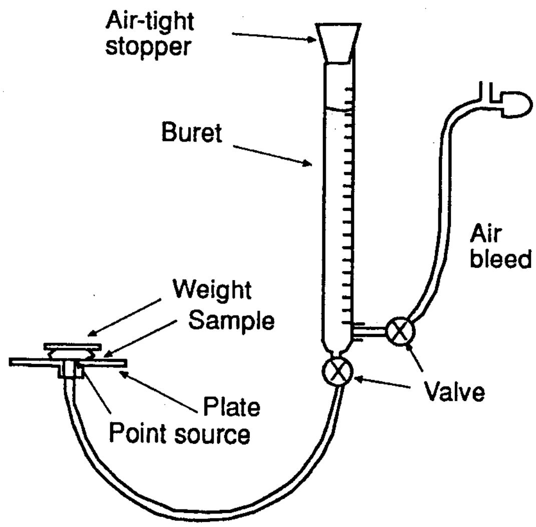


Fig. 10.5. Demand wettability tester with constant head bubbler and point source liquid contact.

The method allows measurement of the wetting rate in terms of volume which gives partial capacity as a function of time and finally the total capacity. A special feature is the ability to measure the wettability at zero hydrostatic head. Liquid flow to the absorbent material stops at saturations.

The following principles apply to operation of the device. Fluid exiting from the fluid delivery opening, just below the sample, is continuous with that contained in the buret. Fluid leaving the buret is replaced by air, at atmospheric pressure, from the air bleed at the base of the buret. Fluid flows only when the pressure on the column of liquid is more than the atmospheric pressure at the exit. This happens only when there is a finite hydrostatic head. The hydrostatic head is calculated as the difference in height between the air bleed and the fluid exit. When the device is operated at more than zero hydrostatic head, fluid is delivered at a constant rate. The rate is determined by the rate at which air is allowed to enter the air bleed and not dependent on the height of the liquid column in the buret.

Figure 10.6 is a detailed view of the sample area where the sample is held in a horizontal position and the source of fluid is below the sample. Figure 10.7 is a view of the sample being held horizontally while the source of liquid is above the sample. Figure 10.8 pictures the air bleed to the buret. The activating mechanism for initiating wicking is seen in Fig. 10.9.

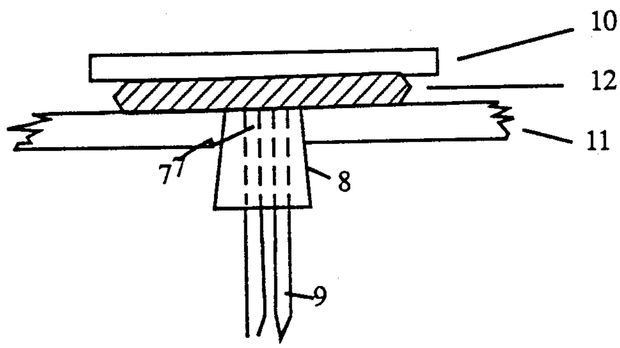


Fig. 10.6. Liquid source below sample

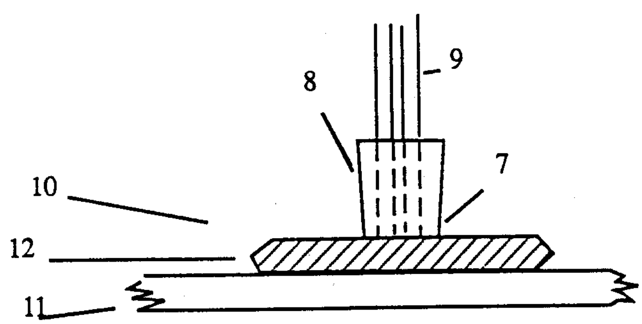


Fig. 10.7. Liquid source above sample

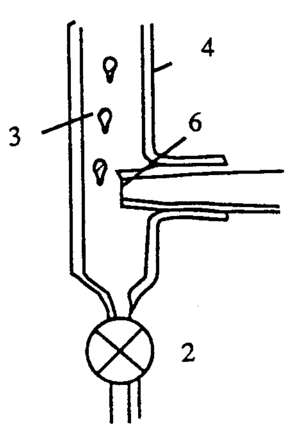


Fig. 10.8. Air bleed to buret

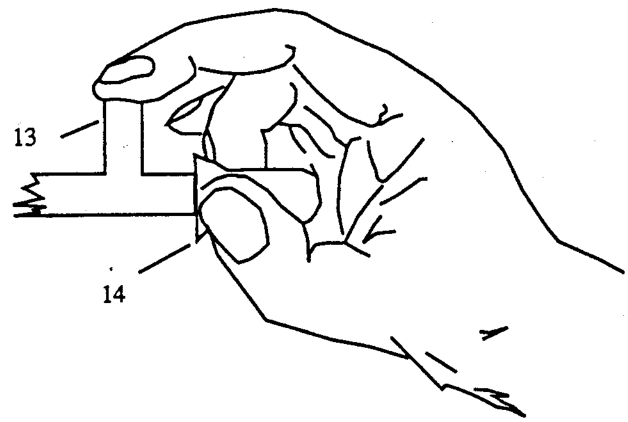


Fig. 10.9. Wicking initiation mechanism

Choksi, Spaith, and Shiff *(14)* developed equipment and testing to measure the absorption characteristics of woven and nonwoven laparotomy sponges. Lichstein's wettability device was found to be inappropriate for using surfactant biological fluids, such as blood, due to foaming. The developed apparatus is shown in Fig. 10.10. Several differences in wettability between water and biological fluids indicated the importance of using biological fluids for testing surgical sponges.

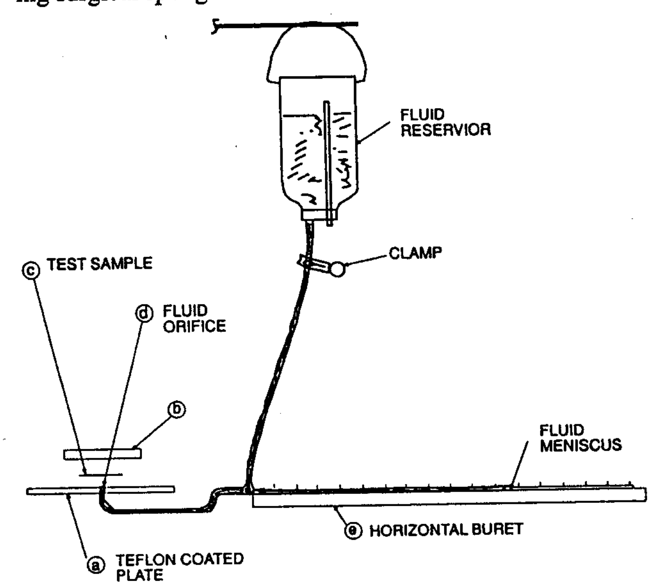


Fig. 10.10. Schematic diagram of the test setup

This apparatus has some special features for measuring the wicking rate and absorbent capacity of fabrics and thin sheets of foams. The test sample is held between two flat plates coated with Teflon to minimize capillary flow between the plates and sample. Fluid is kept in a bottle or collapsible bag above the assembly and drains into a buret. The absorption test begins by raising the open end of the buret so the liquid rises out of the orifice and comes in contact with the sample. When the buret returns to the starting position, wicking continues, and the flow rate is determined from the time passed and the volume absorbed. Total volume of absorbed fluid is found after the flow has stopped.

Modified demand wettability test *(79)*

A modified technique for measuring the demand wettability characteristics has been developed by the Textile Research Institute (TRI) and the testing instrumentation and set-up are shown in Fig. 10.11. The uptake of liquid is monitored by following the weight loss indicated by the top loading recording balance. This has been made possible by the recent advance in the design of such devices, allowing one to record small weight changes (e.g,. 1.0 mg) while maintaining large loads on the weighing pan. These balances have adequate response and damping characteristics to make it possible to obtain a real time record of the movement of liquid into the nonwoven fabric. The linkage between the wetting chamber and the reservoir is achieved by two sections of flexible tubing joined by a clamped rigid tube.

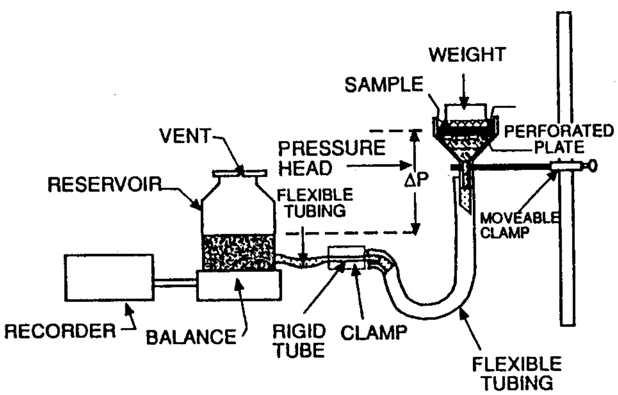


Fig. 10.11. Instrumentation for studying demand wettability under negative pressure gradients

In practice, the filter paper alone is wetted, and the negative pressure gradient established by first lowering and then raising the wetting chamber. The nonwoven sample is attached to a weighted compression plate by means of double-sided tape and placed on the wet filter paper. The progress of liquid uptake is then recorded. The performance of the absorbing material can be established in any of the ways which have been used in the past: maximum rate of uptake, total uptake, time to reach 50% of total uptake, time for 100% add-on (when the weight of added liquid equals the weight of dry fabric), etc. Data obtained at different negative pressure gradients can be extrapolated to zero gradient, usually using semilog plots that produces straight lines.

This technique has been further developed by adding a computer interfaced with the recorder and the above results could be obtained in a fully automated fashion. The technique was also used by Miller *(431)* to measure the pore size and pore size distribution of nonwoven surgical sponges.

Liquid retention tests

Several tests have been developed and adopted for measuring the retention capacity of textile materials especially nonwovens. These tests involve measuring the amount of liquid retained by the sample after a drainage process. The retained fluid is essentially a result of desorption rather than absorption.

In the holding capacity test by ASTM D 1117: "Testing Nonwoven Fabrics," the absorbent sample is over saturated with liquid, then the excess liquid is allowed to drain off by gravity. The amount of liquid retained per dry weight of the sample is a measure of the capacity of the sample.

The removal of excess liquid can also be done by applying an external pressure or a high gravitational field by centrifugal force. The measurement of "Water retention value," (WRV) is now used as a standard test for absorbency of different textile structures, as pointed out by Thode *et al.* *(80)*, Silvy *et al.* *(82)* and Jayme *(81)*. In this test, the over flooded sample is subjected to a high gravitational field, in general above 1000 g in a centrifuge. The WRV, expressed in percent, is the weight of water retained per weight of dry material.

Desorption of the excess fluid can also be carried out by hydrostatic force. A technique was described by Burgni and Kapur *(83)*, using a porous plate absorbency tester. The detailed analysis of this type of phenomena was discussed by Buras *et al.* *(84)* and several other workers *(85-88)*. For most fiber assemblies a hydrostatic head of 30 cmHg is applied which is approximately the same as those obtained by centrifuging at 1000 g for 5 minutes. This is illustrated in Fig. 10.12. There is a good agreement between the two sets of retention values for all fiber webs except in the case of a wool fiber web.

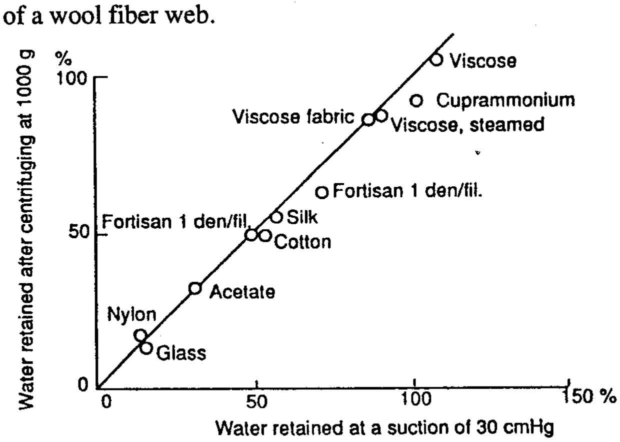


Fig. 10.12. Comparison of water retention by suction and by centrifuge

Measurement of rate of fluid uptake

A new technique has been developed by Miller *et al.* (89) for monitoring spontaneous uptake of a liquid by a porous absorbent. The measurement principle is illustrated in Figs. 10.13 and 10.14. The test specimen, in the form of a disk having a diameter of 3.4 cm, is mounted horizontally in the cylindrical holding chamber. The specimen sits on a 2-mm wide ledge located about one centimeter up to inner core. The combination of O-ring and beveled compression ring keeps the specimen in place and supplies enough lateral tension to prevent significant sagging. The threaded sealing ring serves to apply pressure on the O-ring. The chamber with mounted specimen is suspended in a container (a Petri dish, i.d. = 9.65 cm) that sits on a top-loading recording balance. Care should be taken to level the chamber so that the specimen is precisely horizontal.

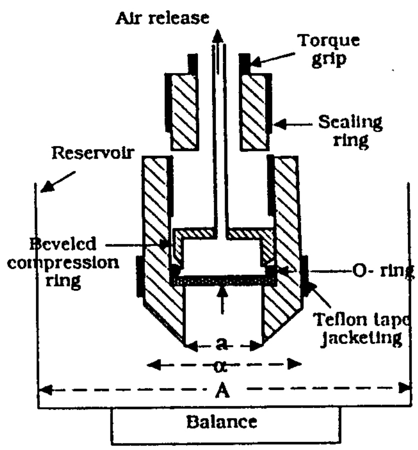
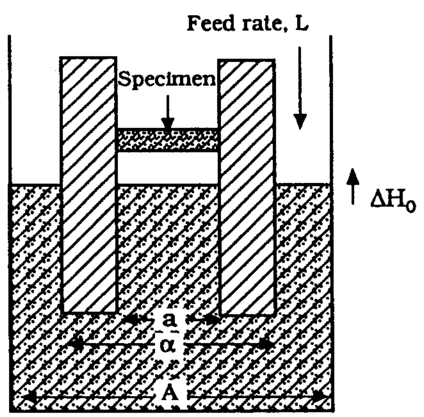


Fig. 10.13. Specimen holder for measuring spontaneous uptake of liquid by fabrics



$$W_0 = L + \Delta H_0 (\alpha - a)$$

Fig. 10.14. Condition before contact with fabric

Liquid is added to the container so that it rises and makes contact with the material. To save time, the liquid is delivered at a fast rate until it is a few millimeters below the specimen. The feed rate is then reduced to a value that will be lower than the anticipated absorption rate: if the feed rate is indeed slower than the absorption rate, the balance reading after contact will decrease. As Fig. 10.13 shows, the bottom surface of the specimen holder is beveled to a sharp edge for two reasons: to prevent air bubbles from being trapped by the rising liquid, and also to identify the moment when the liquid enters the lower section of the chamber via an abrupt drop in the balance reading. Since the distance to the specimen from this bottom edge is known, it is a simple matter to establish how much additional liquid must be added to bring the level up close to the specimen. At that level, the feed rate is switched from fast to slow, and data collection begins.

The level of liquid surrounding the specimen holder will drop when absorption starts, changing the wetting of the outer surface of the brass holder from advancing to receding. Since this change could produce a reduction in the balance reading which would result in an overestimation of the absorption rate, the outer surface of the holder is covered with Teflon™ tape in the region of the liquid level during the absorption process.

For many applications, a strip chart recording, such as the typical one in Fig. 10.15, of the balance reading as liquid is added — before, during, and after absorption — will be adequate. Once the absorption process is completed, the balance reading starts to increase at practically the same rate as before absorption, so that it is a simple matter to identify the end of the absorption period. The two slopes, Wo and W, can be evaluated manually and inserted into Eqs. 1 and 2 to obtain the absorption rate. A more accurate procedure would be to feed the digital readout from the balance to a computer that would calculate the rate. Since most top-loading balances do not provide readouts at a constant time interval, one would have to use the computer clock to establish the true intervals between readings. Also, the first one or two balance readings should be ignored in calculating W, because, for several reasons, absorbency measurements generally show an initial sluggish response before the maximum uptake rate is reached.

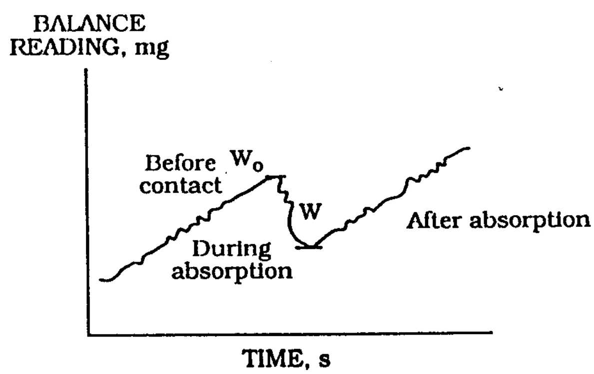


Fig. 10.15. Typical recorder trace during a spontaneous uptake experiment

The uptake rate can be determined from the balance responses before and after contact along with known specimen holder and liquid container dimensions from Eq. 1.

$$Qa = \{1 - [(\alpha - a)/A]\}\, W_0 - [1 - (\alpha/A)]\, W \qquad (1)$$

where:

Qa = uptake rate
a = cross-sectional area of the outside of the cell
α = cross-sectional area of the inside of the chamber (and of the effective specimen)
A = cross-sectional area of the liquid container
W_0, W = balanced reading (mg) before contact and during absorption as obtained from the recorded trace (Fig. 10.15).

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