Designation: D 5734 – 95 (Reapproved 2001)

Standard Test Method for Tearing Strength of Nonwoven Fabrics by Falling-Pendulum (Elmendorf) Apparatus[1]

This standard is issued under the fixed designation D 5734; 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 measurement of the average force required to propagate a single-rip tear starting from a cut in a nonwoven fabric using a falling-pendulum (Elmendorf) apparatus.

1.2 This standard Elmendorf tear tester with interchangeable pendulums has become the preferred test apparatus for determining tearing strength up to 6400 grams-force. It is recognized that some older test instruments with augmenting weights continue to be used. As a consequence, these older test instruments may be used when agreed upon between the purchaser and the supplier. The conditions for the older units as used with this test method are included in the appendix. For tearing strength above 6400 grams-force, a high-capacity test instrument is available equipped with augmenting weights to increase the capacity.

1.3 This test method is applicable to most nonwoven fabrics that are treated or untreated, including heavily sized, coated, or resin-treated, provided the fabric does not tear in the direction crosswise to the direction of the force applied during the test. If the tear does not occur in the direction of the test, the fabric is considered untearable in that direction by this test method.

1.4 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses may be approximate.

1.5 *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[2]

D 689 Test Method for Internal Tearing Resistance of Paper[3]

D 1776 Practice for Conditioning Textiles for Testing[2]

D 4848 Terminology of Force and Deformation Properties of Textiles[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *length of tear*, *n*—in tensile testing, the length of fabric torn, as measured on the fabric before tearing.

3.1.2 *lengthwise direction*, *n—in textiles*, the direction in a machine-made fabric parallel to the direction of movement the fabric followed in the manufacturing machine.

3.1.2.1 *Discussion*—For nonwovens, an easily distinguishable pattern for orientation may not be apparent, especially if removed from the roll. Care should be taken to maintain the directionality by clearly marking the direction.

3.1.3 *nonwoven fabric*, *n*—a textile structure produced by bonding or interlocking of fibers, or both, accomplished by mechanical, chemical, thermal, or solvent means, or combination thereof.

3.1.4 *tearing energy*, *n*—in tensile testing of fabrics, the work done in tearing the specimen.

3.1.5 *tearing force*, *n*—the average force required to continue a tear previously started in a fabric.

3.1.5.1 *Discussion*—For nonwovens, the tearing force is recorded as the maximum force required to continue a tear previously started in a fabric.

3.1.6 *tearing strength*, *n*—the force required either to start or to continue or propagate a tear in a fabric under specified conditions.

3.1.7 *widthwise direction*, *n—in textiles*, the direction in a machine-made fabric perpendicular to the direction of movement the fabric followed in the manufacturing machine.

3.1.8 For definitions of other textile terms used in this test method, refer to Terminologies D 123 and D 4848.

4. Summary of Test Method

4.1 The force required to continue a slit previously cut in a nonwoven fabric is determined by measuring the work done in tearing it through a fixed distance. The tester consists of a sector-shaped pendulum carrying a clamp which is in alignment with a fixed clamp when the pendulum is in the raised, starting position with maximum potential energy. The specimen is fastened in the clamps and the tear is started by cutting

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

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

[3] *Annual Book of ASTM Standards*, Vol 15.09.

[4] *Annual Book of ASTM Standards*, Vol 07.02.

a slit in the specimen between the clamps. The pendulum is then released and the specimen is torn as the moving jaw moves away from the fixed one. The scale attached to the pendulum is graduated to read the tearing force of the specimen.

5. Significance and Use

5.1 This test method for the determination of tearing strength by the pendulum method is used in the trade for the acceptance testing of commercial shipments of nonwoven fabrics, but caution is advised since technicians may fail to get good agreement between results on certain fabrics. Comparative tests as directed in 5.1.1 may be needed.

5.1.1 In case of a dispute arising from differences in reported test results when using this test method for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative test to determine if there is a statistical bias between their laboratories. Statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens that are as homogeneous as possible and that are from a lot of material of the type in question. The test specimens should then be randomly assigned in equal numbers to each laboratory for testing. The average results from the two laboratories should be compared using Students *t*-test and an acceptable probability level chosen by the two parties before the testing began. If a bias is found, either its cause must be found and corrected or the purchaser and the supplier must agree to interpret future test results in the view of the known bias.

5.2 Compared to other methods for testing tearing strength this test method has the advantage of simplicity and speed since specimens are cut with a die and results are read directly from the scale on the pendulum. The specimens are relatively small in area and thus, require less fabric. The reading obtained is directly proportional to the length of the material torn, therefore, it is essential that the specimen be prepared to the exact size specified. For best results, the recommended capacity of the tester selected is the one where the specimens tear between 20 and 80 % of the full-scale value.

5.3 Instrument models are available with pneumatically operated clamps and removable pendulums and are recommended for this test. In addition, microprocessor systems for automatic collection of data can provide economical and reliable results when properly calibrated. In any event, the older units without the deep cut-out in the pendulum that allow specimen contact with the sector are not recommended.

6. Apparatus

6.1 *Falling-Pendulum- (Elmendorf) Type Tester*[5], as described in Annex A1 and shown in Fig. A1.1. The tester includes: a stationary clamp, a movable clamp carried on a pendulum formed by a sector of a circle that is free to swing on a bearing, means for leveling, knife mounted on a stationary post for starting a tear, means for holding the pendulum in a raised position, means for instantly releasing the pendulum, and means for registering the maximum arc through which the pendulum swings when released, and a graduated scale mounted on the pendulum.

6.1.1 The tester may have a pointer mounted on the same axis as the pendulum that is used to register the tearing force, or it may be substituted by means of calculating and displaying the required results without the use of a pointer, such as digital display and computer-driven systems. The clamps may preferably be air actuated, but manual clamping is permitted. The pendulum must have a cutout above the clamp that prevents the specimen from coming in contact with the sector during the test.

6.1.2 The standard test instrument should be equipped with an interchangeable pendulum of the required capacity. Interchangeable pendulum models are available in capacities of 1960, 3920, 7840, 15680, 31360, and 62720 mN (200, 400, 800, 1600, 3200, and 6400 gf). The pendulum is equipped with a scale reading directly in percentage of its capacity.

6.1.3 The high-capacity instruments have a 62720-mN (6400-gf) capacity pendulum with available augmenting weights to increase the capacity to 125540, and 250880 mN (12 800 and 25 600 gf). The tester is equipped with scales reading directly in hectograms (100-gf units) for each capacity. See Annex A1.

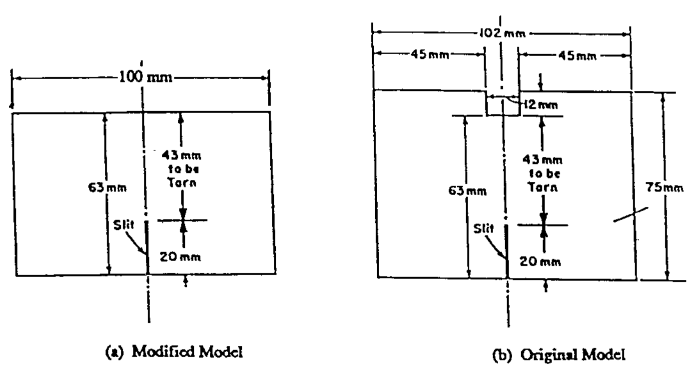
6.2 *Calibration Weight*, for graduation of 50 % of scale, one required for each capacity pendulum, or,

6.2.1 *Optional, Three-Check-Weight Set*, for 20, 50, and 80 % of scale. Each capacity requires its own set of weights. When required, calibration weights are available from the manufacturer for high-capacity instruments.

NOTE 1—While calibration weights are made with scale values of 20, 50, and 80 % of scale, it is not absolutely necessary to utilize a complete set. It is acceptable to use one calibration weight which is in the range of the expected test results, generally 50 % of the scale in use.

6.3 *Cutting Die*, having essentially the shape and dimensions shown in Fig. 1(*a*) or 1(*b*). Either die provides the basic rectangular test specimen 100 ± 2 mm (4 ± 0.05 in.) long by 63 ± 0.15 mm (2.5 ± 0.005 in.) wide. The critical dimension of the test specimen is the distance 43.0 ± 0.15 mm (1.69 ± 0.005 in.) that is to be torn during the test.

NOTE 2—The modified die model shown in Fig. 1(*a*) is typically used for nonwoven fabric testing. The original die model shown in Fig. 1(*b*)



NOTE 1—All tolerances ± 0.5 %.

FIG. 1 Example of Die For Cutting Notched Specimens

[5] Elmendorf Tear Testers suitable for use and meet the requirements of this test method are available from Thwing-Albert Instrument Co., Philadelphia, PA and Testing Machines, Inc., Amityville, NY.

was that used in woven fabric testing. Either die may be used. These dies can be made to order by most die manufacturers.

6.4 *Air Pressure Regulator*, capable of controlling air pressure between 410 and 620 kPag (60 and 90 psig), when applicable, for air clamps.

6.5 *Setting Gage*, for cutting blade that will provide a cut slit that leaves a 43 ± 0.15-mm (1.69 ± 0.005-in.) specimen tearing distance for a 63 ± 0.15-mm (2.5 ± 0.005-in.) wide specimen, or equivalent.

6.6 *Jaw Spacing Gage*, 2.8 ± 0.3-mm (0.125 ± 0.012-in.) width, or equivalent.

6.7 *Oil*, lightweight, non-gumming clock type.

6.8 *Silicone Grease*, when applicable, for air clamp lubrication.

6.9 *Vacuum Cleaner*, when applicable, for cleaning dust and fiber from pendulum scale sensor, or equivalent.

7. Sampling and Test Specimens

7.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of rolls, or pieces, of nonwoven fabric directed in an applicable material specification or other agreement between the purchaser and the supplier. Consider the rolls, or pieces, of nonwoven fabric to be the primary sampling units. In the absence of such an agreement, take the number of nonwoven fabric rolls specified in Table 1.

NOTE 3—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between rolls or pieces of fabric and between specimens from a swatch from a roll or pieces of fabric to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

7.2 *Laboratory Sample*—For the laboratory sample, take a swatch extending the width of the fabric and approximately 1 m (1 yd) along the lengthwise direction from each roll, or piece, in the lot sample. For rolls of fabric, take a sample that will exclude fabric from the outer wrap of the roll or the inner wrap around the core.

7.3 *Test Specimens*—From each laboratory sampling unit, take five specimens from the lengthwise direction and five specimens from the widthwise direction, for each test condition described in 8.1-8.3 as applicable to a material specification or contract order. Use the cutting die described in 6.3 and shown in Fig. 1(*a*) and 1(*b*).

7.3.1 *Direction of Test*—Consider the short direction as the direction of the test.

7.3.2 *Cutting Test Specimens*—Cut the specimens for the measurement of the lengthwise direction from different positions across the fabric width with the shorter dimension parallel to the lengthwise direction. Cut the specimens for the measurement of the widthwise direction from different positions along the length of the fabric with the shorter dimension parallel to the widthwise direction. When specimens are to be tested wet, cut from areas adjacent to the dry test specimens. Label to maintain specimen identity.

7.3.2.1 Cut specimens representing a broad distribution across the width of the laboratory sample and no nearer the edge than one tenth its width. Ensure specimens are free of folds, creases, or wrinkles. Avoid getting oil, water, grease, and so forth, on the specimens when handling.

TABLE 1 Number of Rolls or Pieces, of Nonwoven Fabric in the Lot Sample

Number of Rolls, Pieces in Lot, Inclusive	Number of Rolls or Pieces in Lot, Sample
1 to 3	all
4 to 24	4
25 to 50	5
over 50	10 % to a maximum of ten rolls or pieces

8. Preparation of Apparatus and Calibration

8.1 For the standard test instrument, select the pendulum such that the tear occurs between 20 and 80 % of the full-scale range. Secure the pendulum to the instrument, spacing the clamps as directed in A2.4.

8.1.1 For the high-capacity test instrument, when required, select the augmenting weight such that the tear occurs between 20 and 80 % of the full-scale range. Secure the augmenting weight to the pendulum.

8.2 When equipped with a registering sensor, examine the scale and the complementary black sensor strip along the bottom edge of the pendulum. Using care and without touching the sensor, vacuum away any loose fibers and dust.

8.3 Examine the knife edge for sharpness, wear, and central alignment as directed in A2.5-A2.7.

8.4 For air clamps, set the air pressure to the clamps to about 550 kPag (80 psig).

8.4.1 Maximum pressure should be no more than 620 kPag (90 psig) and minimum pressure no less than 410 kPag (60 psig).

8.5 When using microprocessor automatic data gathering systems, set the appropriate parameters as defined in the manufacturer's instructions.

8.6 Verify the calibration of the selected capacity pendulum scale using the one check weight method described in A3.2, unless otherwise specified.

8.6.1 The scale may be verified either by the relatively simple procedure which uses one Elmendorf check weight, or alternatively by the three-check-weight procedure, or the potential energy procedure. The same accuracy and effectiveness are claimed for each procedure. The one- and three-check-weight sets are available from the manufacturer. The single-weight procedure described in this section has been recommended for use to 80 % of scale. See Annex A3.

9. Conditioning

9.1 *Condition 1, Unspecified Testing Conditioning*—No conditioning is required unless otherwise specified in a material specification or contract order.

9.2 *Condition 2, Standard Testing Conditioning*:

9.2.1 When specified, precondition the specimens by bringing them to approximate moisture equilibrium in the standard atmosphere for preconditioning textiles as directed in Practice D 1776.

9.2.2 After preconditioning, bring the test specimens to moisture equilibrium for testing in the standard atmosphere for testing textiles as directed in Practice D 1776 or, if applicable, in the specified atmosphere in which the testing is to be performed.

9.3 *Condition 3, Wet Specimen Testing Conditioning*:

9.3.1 Place the specimens in a container and submerge in distilled or deionized water at ambient temperature until thoroughly soaked. (See 9.3.1.1.)

9.3.1.1 The time of immersion must be sufficient to wet out the specimens, as indicated by no significant change in tearing force followed by longer periods of immersion. For most fabrics this time period will be about one hour. For fabrics not readily wet out with water, such as those treated with water-repellent or water resistant materials, add a 0.01 % solution of a nonionic wetting agent to the water bath.

10. Procedure

10.1 Test the specimens in the atmosphere as directed in an applicable material specification or contract order.

10.2 Raise the pendulum to the starting position and set the pointer against its stop.

10.3 *For Tester-Slit Specimens*:

10.3.1 Place the long sides of the specimen centrally in the clamps with the bottom edge carefully set against the stops and the upper edge parallel to the top of the clamps. Close the clamps, securing the specimen with approximately the same tension on both clamps. The specimen should lie free with its upper area directed toward the pendulum to ensure a shearing action.

10.3.2 Push down on the handle of the built-in knife blade cutting a 20 ± 0.15-mm (0.787 ± 0.006-in.) slit in the specimen using the pendulum knife extending from the bottom edge and leaving a balance of fabric 43.0 ± 0.15 mm (1.69 ± 0.005 in.) remaining to be torn.

10.4 *For Die-Cut or Manually Slit Specimens*:

10.4.1 If a die without a slit is used, manually cut a 20 ± 0.15-mm (0.787 ± 0.006-in.) long slit in the center of one edge of the long direction of the specimen. Ensure that the balance of the fabric remaining to be torn is 43 ± 0.15 mm (1.69 ± 0.005 in.). The length of the cut is important when tearing energy is determined.

10.4.2 Place the parallel, unslit sides of the specimen in the clamps with the bottom edge carefully set against the stops, the upper edge parallel to the top of the clamp and the slit centrally located between the clamps. Close the clamps, securing the specimen with approximately the same tension on both clamps. The specimen should lie free with its upper area directed toward the pendulum to ensure a shearing action.

10.5 For wet specimens, remove the specimens from the water and immediately mount it on the testing machine in the normal set up. Perform the test within two minutes after removal of the specimen from the water.

10.6 Depress the pendulum stop downward to its limit and hold it until the tear is completed and the pendulum has completed its forward swing. Catch the pendulum by hand just after the threshold of its backward swing and return to its locked starting position for additional test. When equipped, be careful not to disturb the position of the pointer.

10.6.1 The decision to discard the results of a tear shall be based on observation of the specimen during a test and upon the inherent variability of the material. In the absence of other criteria, such as in a material specification, if an unusual cause is detected, the value may be discarded and another specimen tested.

10.6.2 Reject readings obtained where the specimen slips in the jaw or where the tear deviates more than 6 mm (0.25 in.) away from the projection of the original slit. Note when puckering occurs during test.

10.6.3 For microprocessor systems, follow the manufacturer's directions for removing values from memory when the decision to discard a tear value has been made, otherwise for some test instruments, manual calculation of the average is required.

10.6.4 If, during application of the tearing force to the specimen, the force does not reach 20 % or reaches over 80 % of full-scale range, change to the next lower or higher full-scale range, as applicable. See 8.6.

10.6.5 Record if the tear was crosswise to the normal (parallel) direction of tear and describe that specimen, or that sample, as applicable, as untearable.

10.7 Remove the torn specimen and continue until five tears have been recorded for each principal direction, as required, from each laboratory sampling unit.

10.8 When all samples have been tested and calculations completed, place the pendulum in the rest position (free hanging).

11. Calculation

11.1 *Tearing Force, Individual Specimens*:

11.1.1 *Standard Test Instrument*—Determine the Elmendorf tearing force for individual specimens to the nearest millinewton (gram-force) using Eq 1:

$$F = R \times C/100 \tag{1}$$

where:

F = tearing force, mN (gf),
R = scale reading, and
C = full-scale capacity, mN (gf).

11.1.2 *High-Capacity Test Instrument*—Determine the Elmendorf tearing force for individual specimens to the nearest mN (gf) using Eq 2:

$$F = R \times 1000 \tag{2}$$

where:

F = tearing force, mN (gf), and
R = scale reading, mN (gf).

NOTE 4—mN = gf/9.81.

11.2 *Tearing Strength*—Calculate Elmendorf tearing strength as the average tearing force for each principal direction of the laboratory sampling unit and for the lot.

11.3 *Standard Deviation and Coefficient of Variation*—Calculate when required.

11.4 *Computer Processed Data*—When data is automatically computer processed, calculations are generally contained in the associated software. Record values as read from the direct reading scale to the nearest millinewton (gram-force). In any event, it is recommended that computer processed data be verified against known values and its software described in the report.

12. Report

12.1 Report that the Elmendorf tearing strength was determined as directed in this test method. Describe the material or product sampled and the method of sampling used.

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

12.2.1 Elmendorf tearing strength for each principal direction, as requested,

12.2.2 Condition of test, ambient air, or wet,

12.2.3 Puckering, if it occurs during the test,

12.2.4 Number of tests rejected because of crosswise tearing,

12.2.5 Any specimens or samples that were untearable (crosswise tears),

12.2.6 When calculated, the standard deviation or the coefficient of variation,

12.2.7 For computer-processed data, identify the program (software) used,

12.2.8 Make, model, and capacity of testing machine,

12.2.9 Type of clamps used,

12.2.10 Test room conditioning, and

12.2.11 Any modification of the test method.

13. Precision and Bias

13.1 *Summary*—Preliminary interlaboratory test data have shown that the variance in tear strength testing by this test method is dependent upon the manufacturing method of the material under evaluation; therefore, no general statement can be made concerning least critical differences. The following data were generated during the interlaboratory test and are presented for reference. In comparing two averages of five observations, the difference between averages should not exceed the following values in 95 out of 100 cases when all the observations are taken by the same well-trained operator using the same piece of equipment and specimens are randomly drawn from the same sample:

Manufacturing Method	Tearing Force (gf) Difference
Machine Direction	
Dry Laid	45
Resin Bonded	35
Thermal	54
Wet Laid	37
Transverse Direction	
Dry Laid	54
Resin Bonded	46
Thermal	33
Wet Laid	35

Larger differences are likely to occur under all other circumstances. This procedure for determining tearing force has no other known bias and is considered a referee method.

13.2 *Interlaboratory Test Data*—A preliminary interlaboratory test was run in 1992 in which randomly drawn samples of four materials were tested in each of three laboratories. Two operators in each laboratory tested five specimens of each material. The four materials used in this evaluation were all manufactured by different processes as shown in 13.1. Analysis of the data using the adjunct to Practice D 2904 suggested reporting the components of variance and least critical differences based upon the method of manufacturing. The components of variance, expressed as standard deviations, for each method of manufacturing are listed in Table 2 (see Note 5). Further testing is in progress to elucidate the dependence on manufacturing process and possible test method revision.

13.3 *Precision*—For the components of variance listed in Table 2, the averages of two observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Table 3 (see Note 6). Due to the dependence of the components of variance on the manufacturing process no meaningful statement can be made at this time relative to between material comparisons.

13.4 *Bias*—The procedure in this test method for determining the tearing strength of nonwoven fabrics by this test method has not been checked against accepted reference materials but contains no known bias other than the effect of the manufacturing process, as noted. This test method is accepted as a referee method.

NOTE 5—The square roots of the components of variance are listed in Table 2 so that the variability is expressed in the appropriate units of measure rather than as the square of those units of measure.

NOTE 6—The values of the tabulated differences should be considered to be a general statement, particularly with respect to between-laboratory 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 homogeneous as possible, and then randomly assigned in equal numbers to each of the laboratories.

14. Keywords

14.1 Elmendorf; falling pendulum; nonwoven fabric; tearing strength; tear tester

TABLE 2 Components of Variance as Standard Deviations

NOTE 1—Tearing force expressed in grams-force.

Manufacturing Process	Single-Operator Component	Within-Laboratory Component	Between-Laboratory Component
Machine Direction			
Dry Laid	36	36	44
Resin Bonded	28	38	17
Thermal	44	56	0
Wet Laid	30	0	41
Transverse Direction			
Dry Laid	44	0	47
Resin Bonded	37	52	53
Thermal	27	0	16
Wet Laid	28	14	27

TABLE 3 Critical Differences for Conditions Noted
95 % Probability Level

NOTE 1—Tearing strength expressed in grams-force.

Manufacturing Process	Observations in Each Average	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
Machine Direction				
Dry Laid	5	45	45	130
	10	32	32	126
Resin Bonded	5	35	111	121
	10	25	108	118
Thermal	5	54	165	165
	10	38	161	161
Wet Laid	5	37	37	119
	10	26	26	116
Transverse Direction				
Dry Laid	5	54	54	141
	10	38	38	135
Resin Bonded	5	46	153	212
	10	33	149	209
Thermal	5	33	33	54
	10	23	23	49
Wet Laid	5	35	53	92
	10	25	46	88

ANNEXES

(Mandatory Information)

A1. DESCRIPTION OF APPARATUS

A1.1 The Elmendorf tear tester providing means for holding the specimen with two clamps, one stationary and one movable, and for tearing it by the fall of the pendulum due to the force of gravity. The textile model, is basically the standard Elmendorf tester and is used with interchangeable pendulums to provide the required capacity. The instrument includes the following parts (Fig. 1(*b*)).

A1.1.1 The high-capacity Elmendorf tester is a basic 62720-mN (6400-gf) capacity instrument. This capacity can be increased to 125 540 and 250 880-mN (12 800 and 25 600- gf) capacities with the use of augmenting weights available from the manufacturer. It is not equipped with interchangeable pendulums.

A1.1.2 Optionally, test instruments are equipped with a means of calculating and displaying the required results without the use of an autographic recorder, such as computer-driven systems. Also, they may be equipped with air-actuated clamps.

A1.1.3 *Sector-Shaped Pendulum*, carrying a circumferential scale graduated to read the tearing force directly in percent of full-scale capacity for standard test instruments, and in 1000-g units for the high-capacity instruments. The pendulum section has a cutout in the region adjacent to the clamp so that the specimen does not rub against the sector during the test.

A1.1.4 Means for holding the pendulum in a raised position, and means for releasing it instantaneously.

A1.1.5 *Pointer and Pointer-Stop*, for registering the maximum arc through which the pendulum swings when released. The pointer is mounted on the same axis as the pendulum with constant friction just sufficient to stop the pointer at the highest point reached by the swing of the section. The adjustable pointer stop provides means for setting the zero of the instrument.

A1.1.5.1 When equipped with electronic data gathering systems, the pointer and pointer-stop are not required.

A1.1.6 *Knife*, mounted on a stationary post for initial slitting of the specimen. It is centered between the clamps and adjusted in height to give a tearing distance of 43.0 ± 0.15 mm (1.69 ± 0.005 in.); that is, the distance between the end of the slit made by the knife and the upper edge of the specimen is 43.0 ± 0.15 mm (1.69 ± 0.005 in.) when the lower edge of the 63.0-mm (2.5 ± 0.005-in.) wide specimen rests against the bottom of the clamp.

A1.1.7 *Leveling Screw*.

A1.1.8 *Stationary Clamp*.

A1.1.9 *Movable Clamp*, carried on a pendulum formed by a sector of a circle free to swing on a ball-bearing.

A1.1.10 With the pendulum in its initial position ready for a test, the two clamps are separated by a distance of 2.8 ± 0.3 mm (0.10 ± 0.01 in.), and are aligned such that the clamped specimen lies in a plane parallel to the axis of the pendulum, the plane making an angle of 0.480 ± 0.009 rad (27.5 ± 0.5°) with the perpendicular line joining the axis and the horizontal line formed by the top edges of the clamping jaws. The distance between the axis and the top edges of the clamping jaws is 103 ± 0.1 mm (4.055 ± 0.004 in.).

A1.1.11 The clamping surface in each jaw is at least 25 mm (1.0 in.) wide and 15.9 ± 0.1 mm (0.625 ± 0.004 in.) deep.

A2. ADJUSTMENT OF APPARATUS

A2.1 *Instrument Mounting*—Place the tester on a sturdy, level bench (or table). Ensure that there is no perceptible movement of the tester base or bench during the swing of the pendulum. Movement of the instrument during the swinging of the pendulum is a significant source of error.

A2.1.1 Threaded bolt holes are usually provided in the base of the instrument and may be used to secure the instrument to the table. An alternative procedure is to place the instrument on a guide that ensures that the instrument always has the same position on the table. A floor-strip is available from some manufacturers for this purpose.

A2.2 *Instrument Balance*—Level the instrument such, that with the sector free, the line on the sector indicating that vertical from the point of suspension is bisected by the edge of the pendulum stop mechanism. Verify this by holding down the pendulum stop and allowing the pendulum to swing free. When the pendulum comes to rest, the positioning line at the center of the pendulum should be directly above the edge of the pendulum stop. Align, if necessary, by turning the leveling thumb screw at the left end of the tester base.

A2.3 *Clamp Alignment*—Raise the pendulum and position the lower edge against its stop. Visually check the alignment of the clamps. If the clamps are not in alignment, replace the pendulum stop or the pendulum bearing and shaft assembly, or both, following the manufacturer's instructions.

A2.4 *Clamp Space Setting, Interchangeable Pendulums*—Set the jaw spacing to 2.8 ± 0.3 mm (0.125 ± 0.012 in.). Loosen the shoulder head screw on top of the pendulum support. With both clamps in the open position, gently pull the pendulum out until the jaw spacer gage will fit into the grips. Gently push the pendulum in until the jaw spacer gage has just enough clearance to slide out the top of the clamps. With the jaw spacer in place, tighten the shoulder head screw on the pendulum support. Remove the jaw spacer gage.

A2.5 *Knife Sharpness*—Check the sharpness of the knife by inserting a spare specimen in the clamps and cutting a slit with the knife blade in the normal manner. If the knife is dull it will produce a V-notch near the top of the cut and push the material outward. When the knife is determined to be dull, sharpen it with a rough stone, alternately, continuing specimen knife cuts, until no V-notch is observed. Replace the knife blade as necessary.

A2.6 *Knife Alignment*—Check that the knife position is centrally located between the clamps. If the knife cannot be positioned centrally, replace one or any combination thereof: the pendulum bearing and shaft assembly, the cutter handle bearing pin, knife blade.

A2.7 *Specimen Tearing Distance*—Check the specimen tearing distance with the knife setting gage. Place the gage in the stationary specimen clamp in the usual manner for testing material. Ensure the gage is positioned with the wide dimension upwards and the projection extending over the edge of the stationary clamp far enough such that the knife can be adjusted to the bottom edge of the gage. Adjust the knife position such that the highest point of the blade just touches the bottom edge of the gage and then secure it in place. Replace the knife when it no longer can be adjusted to the gage. Or optionally:

A2.7.1 Check the tearing distance by using the die to cut a specimen from coordinate paper graduated in millimetres. Apply a small amount of graphite (from an ordinary lead pencil) to the cutting knife or the edge of the die used for cutting the slit so that when the cut is made some of the graphite transfers to the paper; this serves to contrast the cut from the uncut portion of the paper and facilitates the measurement. Make sure this measurement either with a precision steel rule graduated in 0.2 mm (0.01 in.) or better and under magnification, or alternatively, by use of a go-no-go gage available from the manufacturer of the instrument. If necessary, adjust the height of the knife.

A2.7.2 Do not change the specimen dimensions to adjust the tear distance.

A2.8 *Main Bearing Friction*—Clean, oil, and adjust the bearing. Raise the pendulum to its cocked position. When equipped, set the pointer against its stop. Press and hold down the pendulum stop and let the pendulum swing freely. Ensure the pendulum is free swinging and the calibration can be verified as directed in Annex A3.

A2.9 *Scale Inspection*—When soiled, or calibration cannot be attained, clean the white area at the bottom of the pendulum with mild soap and water. Ensure the mirrored divisions of the scale are clean and free of any foreign matter. Ensure the black sensing strip on the pendulum is clean of fibers and not scratched. Blow off fibers and dust from the black strip using a low-pressure air nozzle. When scratches are evident, touch up with flat black paint enamel.

A2.10 *Pendulum Stop Release*—When a jerky release is observed, check the pendulum or the pendulum stop release for any wear. Adjust the height of the pendulum stop until a smooth release is obtained. If a smooth release cannot be obtained by this adjustment, the pendulum or the pendulum stop may require repair or replacement. If the pendulum stop height is changed, verify clamp alignment and zero position.

A2.11 *Zero Pointer Stop*—Operate the leveled instrument several times with nothing in the clamps, the movable clamp being closed. If zero is not registered, adjust the pointer stop until the zero reading is obtained. Do not change the level to adjust the zero.

A2.12 *Pointer Friction*—Set the pointer at the zero reading on the scale before releasing the sector, and after the release, ensure that the pointer is not pushed more than 3 scale divisions (4 mm or 0.08 in.) or less than two scale divisions (2.5 mm or 1 in.) beyond the zero. If the pointer friction does not lie between two and three divisions, remove the pointer, wipe the bearing clean, and apply a trace of clock oil to the groove of the bearing. Reassemble and check pointer friction. Recheck zero and readjust the pointer stop if necessary.

A2.13 *Oil and Grease*—Apply a very small amount of clock oil in the groove of the bearing and sleeve assembly. DO NOT oil the flat surfaces of the bearing and sleeve assembly. Apply a small amount of silicone grease to the air clamp plunger rods.

A3. VERIFICATION OF SCALE

NOTE A3.1—Historically, four different check weight systems have been offered by manufacturers and used to verify calibration depending upon the date of manufacture. Early machines consisted of five check weights for scale values of 20, 35, 55, 75, and 90 %. (No longer available from the manufacturer.) Following this, machines were manufactured that utilized three check weights for scale values of 20, 50, and 80 %. Current machines utilize one check weight for a scale value of 50 %. In addition the potential energy method has been used. Use of the 50 % check weight and a working range from 20 to 80 % of full scale is recommended.

A3.1 Verify the scale reading of the test instrument in accordance with A3.2.

A3.1.1 For other methods of verification of the scale reading refer to one of the procedures described in the appendix.

A3.2 *One-Check-Weight Procedure*—Use a one check weight calibrated for a value of 50 % of the Elmendorf tester scale. Each capacity scale requires its own check weight. For example, at 800 g of the 1600-g scale. The check weight shall be constructed such that each weight can be inserted in the clamps by the procedure used for a fabric specimen and having the bulk of the check weight mass facing downward. The useable portion of the scale is 20 to 80 %.

A3.2.1 Position the pendulum in its cocked position against the stop and set the digital readout, or pointer, to zero.

A3.2.2 Depress the pendulum stop downward to its limit and hold it until the pendulum has completed its forward swing. Catch the pendulum by hand just after the threshold of its backward swing and return it to its locked starting position. The pointer, or when equipped, the digital readout should read 0.00. In any event, do not change the level of the instrument to adjust the zero. (See A3.2.6-A3.2.8 as applicable, if adjustment is required.)

A3.2.2.1 For the pointer system, the pointer should not be pushed less than 2.5 mm nor more than 4.0 mm beyond zero. If zero is not registered, the pointer stop should be adjusted until the zero reading is obtained, otherwise service in accordance with Annex A2.

A3.2.3 With the pendulum in the raised position, open the clamp of the pendulum, slide the 50 % check weight, with the bulk of the mass downward, into position, and fasten it securely in the clamp.

A3.2.4 Depress the pendulum stop downward to its limit and hold it until the pendulum has completed its forward swing. Catch the pendulum by hand just after the threshold of its backward swing and return to its locked starting position. The pointer or, when equipped, the digital readout should read 50 ± 0.5 %. (See A3.2.7 or A3.2.8 as applicable, if adjustment is required.)

A3.2.5 Remove the 50 % calibration weight and close the clamp, and when equipped, set the pointer to zero.

A3.2.6 For the pointer system, if zero (0.00) and 50 % readings are not obtained, clean and oil the bearing and sleeve assembly in accordance with A2.12 and A2.13.

A3.2.7 For digital readout systems, if zero (0.00) and 50 % readings are not obtained, loosen the thumb screw securing the photo sensor to the base and move the whole assembly "Right" to increase reading, or "Left" to decrease reading, as required. Continue in accordance with A3.2.1-A3.2.5, alternately making small adjustments of the photo sensor until the target values of 00.0 and 50 % are obtained.

A3.2.8 If zero (0.00) and 50 % readings cannot be obtained, conduct complete maintenance in accordance with Annex A2 until designated readings are obtained and calibration is verified.

A4. INSTRUMENT FACTORS FOR CALCULATION AND TESTING RANGE

A4.1 For instruments with scales calibrated in percent, use the factors given in Table A4.1 for calculating the tearing force in grams-force. These factors take into account the capacity of the tester.

A4.1.1 The acceptable testing range of between 20 and 80 % of the scale value is shown for the direct-reading scale in Table A4.1.

APPENDIXES

(Nonmandatory Information)

X1. USE OF OLDER STANDARD ELMENDORF TESTERS

X1.1 The oldest standard model that did not have a deep cutout in the pendulum allowed the specimen to come in contact with the sector during the test. Consequently, significantly higher values may be obtained than those obtained with the newer models having a deep pendulum cutout. Also, these older models had different clamp designs which contributed to variations in results. These models are not recommended.

X1.1.1 A second generation standard test instrument provided a deep cutout in the pendulum. This unit like the older unit consisted of a basic 1600-gf capacity. The capacity could be increased to 3200-gf capacity with a NIST augmenting weight, and further to 6400-gf capacity with a textile augmenting weight. These test units and augmenting weights are no longer available from the manufacturer. These instruments may be used when agreed upon between the purchaser and the supplier.

X1.1.2 Differences between older and newer models coupled with differences in testing practices frequently resulted in differences between operators and laboratories.

X2. OTHER VERIFICATION OF SCALE PROCEDURES

X2.1 Historically, three different calibration practices other than the one-check-weight procedure described in A3.2 have been used. They are as follows:

X2.1.1 *Three-Check-Weight Procedure*—Use a set of three check weights calibrated for three values, 20, 50, and 80 % of the Elmendorf Tester scale. Each capacity scale requires its own set of check weights. For example, at 320, 800, and 1280 of the 1600-gf scale. Each check weight shall be constructed such that each weight can be inserted in the clamps by the procedure used for a fabric specimen having the major portion of the mass of the check weight facing downward. Generally, the usable portion of the scale is 20 to 80 %.

X2.1.1.1 Repeat the procedure described in A3.2 using each of the check weights for the designated percentage of scale.

X2.1.2 *Five-Check-Weight Method*—Use a set of five check weights calibrated for five values, 20, 35, 55, 75, and 90 % of the Elmendorf tester scale. Each capacity scale requires its own set of check weights. For example, at 320, 560, 880, 1200, and 1440 of the 1600-gf scale. Each check weight shall be constructed such that each weight can be inserted in the clamps by the procedure used for a fabric specimen having the major portion of the mass of the check weight facing upward. Generally the usable portion of the scale is 90 %. These check weights are no longer available from the manufacturer.

X2.1.2.1 Repeat the procedure described in A3.2 using each of the check weights for the designated percentage of the scale.

X2.1.3 *Potential Energy Procedure*—Use a weight of known mass (including its attachment) W and with its previously determined center of gravity (including the means of attachment) marked by a punched dot on the side that is to face the front of the tester. Clamp the weight to the radial edge of the sector beneath the jaws with the punched dot showing. Close the jaws of the clamp to the sector.

X2.1.3.1 Raise and set the sector as for tearing a specimen and, by means of a surface gage or cathetometer, measure to the nearest 0.1 mm, the height, H, of the center of gravity of the weight above a fixed horizontal surface. Then release the sector, allow it to swing, and note the pointer reading. Without touching the pointer, raise the sector until the edge of the pointer meets with its stop, in which position again determine the height, H, of the center of gravity of the weight above the fixed surface.

X2.1.3.2 For equipment with microprocessor systems for recording results, the pointer will need to be in place on the bearing assembly to perform the potential energy procedure of scale verification.

X2.1.3.3 The work done is $W (h - H)$ gf/mm. For the standard 1600-gf tester, the pointer reading should be $KW (h - H)$, where K is 1/86 mm (that is one divided by twice the distance torn). For other testers graduated for grams-force of greater or lesser capacity, the reading will be factors of two greater or smaller, respectively.

NOTE X2.1—The value of K for Test Method D 689, (1376 mm) differs from the value of K for this test method (86 mm) since it is based on tearing 16 sheets of paper, and therefore, the distance torn is 16 times greater.

X2.1.3.4 One or more weights may be clamped on the edge of the sector for each calibration point, the work done in raising each weight is calculated and added together.

X2.1.3.5 If the deviations of the indicated readings are greater than one-half division, the instrument should be returned to the manufacturer for repair and adjustment.