Designation: ~~F88/F88M – 21~~ F88/F88M – 23

Standard Test Method for Seal Strength of Flexible Barrier Materials[1]

This standard is issued under the fixed designation F88/F88M; 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 strength of seals in flexible barrier materials.

1.2 The test may be conducted on seals between a flexible material and another flexible material, a rigid material, or a semi-rigid material.

1.3 Seals tested in accordance with this test method may be from any source, laboratory or commercial.

1.4 This test method measures the force required to separate a test strip of material containing the seal. It also identifies the mode of specimen failure.

1.5 This test method differs from Test Method F2824. Test Method F2824 measures mechanical seal strength while separating an entire lid (cover/membrane) from a rigid or semi-rigid round container.

~~1.6 This test method differs from Test Method F904. Test Method F904 measures the bond strength or ply adhesion of laminates made from flexible materials such as cellulose, paper, plastic film, and foil.~~

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

1.7 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

[1] This test method is under the jurisdiction of ASTM Committee F02 on Primary Barrier Packaging and is the direct responsibility of Subcommittee F02.20 on Physical Properties.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

D882 Test Method for Tensile Properties of Thin Plastic Sheeting
D883 Terminology Relating to Plastics
E171 Practice for Conditioning and Testing Flexible Barrier Packaging
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
F17 Terminology Relating to Primary Barrier Packaging
~~F904 Practice for Separation of Plies for Bond Strength of Laminated Flexible Materials~~
F2824 Test Method for Mechanical Seal Strength Testing for Round Cups and Bowl Containers with Flexible Peelable Lids
F3263 Guide for Packaging Test Method Validation

3. Terminology

3.1 *Definitions:*

3.1.1 *average seal strength, n*—average force per unit width of seal required to fully separate a flexible material from a rigid ~~material~~ material, semi-rigid material, or another flexible material, under the conditions of the test.

3.1.1.1 *Discussion*—
The average force normally is calculated by the testing machine from the digitized plot of force versus grip travel. The plot starts from zero force after slack has been removed from the test strip. The initial ramp-up from zero to the force level required to peel the seal is not indicative of seal strength, and data from that part of the curve should not be included in the calculation of average strength, nor should the return to zero following complete failure of the specimen. The amount of data actually discarded on each end of the measured seal-profile curve must be the same for all tests within any set of comparisons of average seal strength (see 6.1.1 and ~~9.8.1~~9.9.1).

3.1.2 *maximum seal strength, n*—maximum force per unit width of seal required to ~~completely~~fully separate a flexible material from a rigid ~~material~~ or semi-rigid material, or another flexible material, under the conditions of the test.

3.1.3 *flange, n*—any geometric feature of a rigid or semi-rigid component, which provides a counterpart surface to which a flexible component can form a seal.

3.1.4 *interferences, n*—conditions that may lead to increased variation or challenges in obtaining consistent measurement of test samples.

4. Significance and Use

4.1 Seal strength is a quantitative measure for use in process validation, ~~process control, and capability.~~capability, and control. Seal strength is not only relevant to opening force and package integrity, but to measuring the packaging processes' ability to produce consistent seals. Seal strength at some minimum level is a necessary package requirement, and at times it is also desirable to ~~limit~~ have an upper limit to the strength of the seal to facilitate opening.

NOTE 1—Seal strength values are a measurement of the output of the seal separation and may also involve mechanical properties of the materials that form the seal, given the potential for deformation or elongation over the course of the test. This separation is indicative of the area of the package being sampled and does not take into account simulation of a user interfacing with an entire package during the opening process.

NOTE 2—Lower seal strength specifications are typically utilized to provide assurance of package closure, which can contribute to seal integrity.

NOTE 3—Upper seal strength specifications are typically utilized to limit the amount of force required to open a package, ensuring that a user is able to open the design. Upper seal strength specifications are typically limited to seals that are intended to be peeled by the end user.

4.1.1 The maximum seal force is important information, but for some applications, average force to ~~open~~separate the seal may be useful, and in those cases also should be reported.

4.2 A portion of the force measured when testing materials may be a bending component and not seal strength alone. A number of fixtures and techniques have been devised to hold samples at various angles to the pull direction to control this bending force. Because the effect of each of these on test results is varied, consistent use of one technique (Technique A, Technique B, or Technique C) throughout a test series is recommended. Examples of ~~fixtures and~~ techniques are illustrated in Fig. 1.

4.2.1 *Technique A: Unsupported*—Each tail of the specimen is secured in opposing grips and the seal remains unsupported while the test is being conducted.

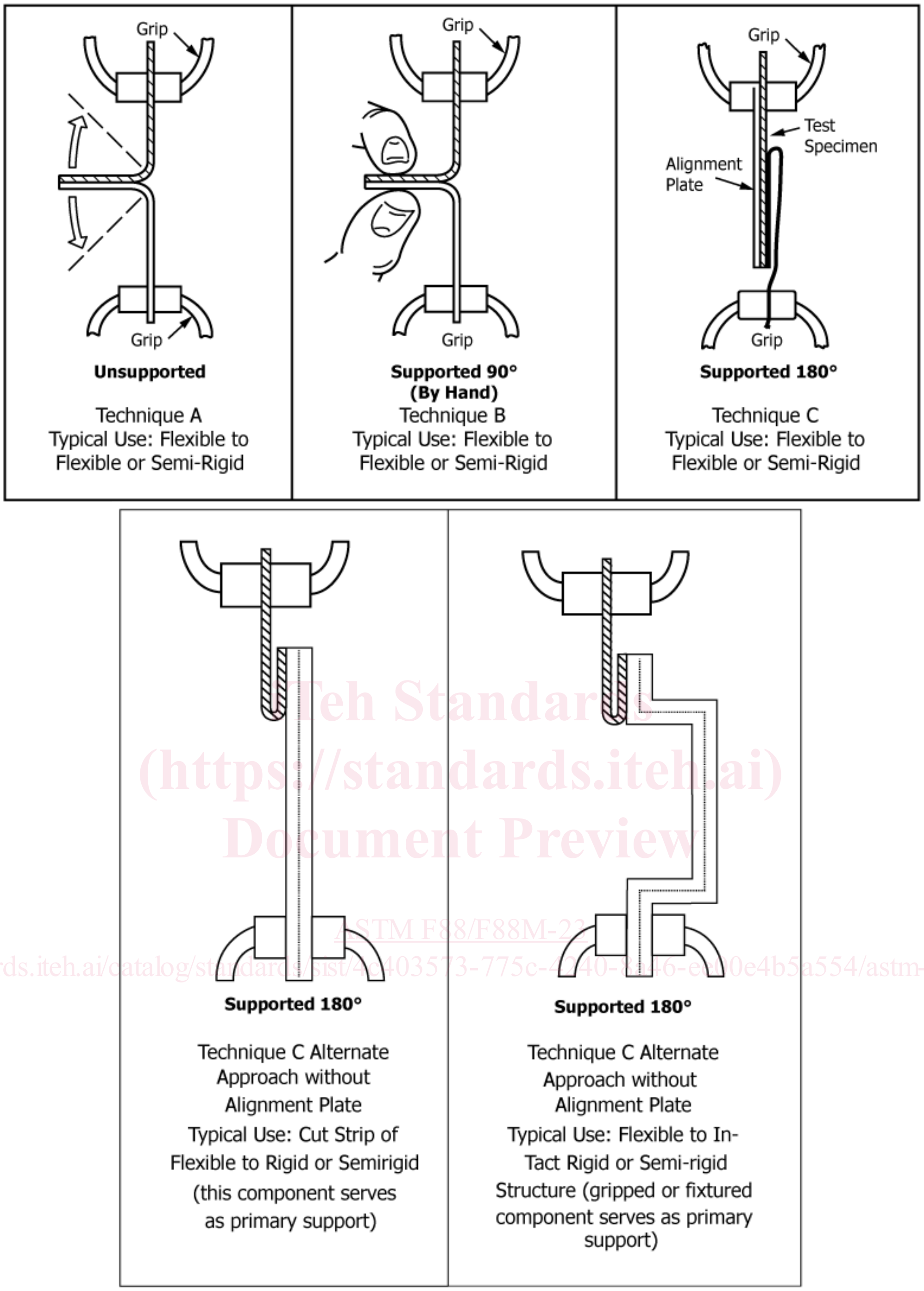


Diagram Key

APPLICATION	LINE	DESCRIPTION
Flexible to Flexible, Rigid, or Semi-Rigid Seal	\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	Flexible Film or Substrate #1
Flexible to Flexible Seal		Flexible Film or Substrate #2
Flexible to Rigid or Semi-Rigid Seal	- - - - - - - - - - - - - - - - - - -	Rigid or Semi-Rigid Film or Substrate

FIG. 1 Tail Holding Methods

4.2.2 *Technique B: Supported 90° (By Hand)*—Each tail of the specimen is secured in opposing grips and the seal remains hand-supported at a 90° perpendicular angle to the tails while the test is being conducted.

NOTE 4—Excessive lateral forces applied via hand may impact results. Actual gripping of samples is not intended and will influence results; contact is intended to be loose, only preventing tail movement up or down.

4.2.3 *Technique C: Supported 180°*—The For flexible to flexible applications, the least flexible tail is typically supported flat against a rigid alignment plate held in one grip. The more flexible tail is typically folded 180° over the seal and is held in the opposing grip while the test is being conducted. Alternatively, in rigid and semi-rigid applications, the package structure may be maintained for the least flexible side; with this structure gripped or fixtured.

NOTE 5—Properties of some flexible materials may cause movement or flipping of the tail throughout the course of the test; this has potential to impact the measured strength and should be reported with results.

NOTE 6—Test method validation should account for use of fixtures or alignment plates, as well as determination of which material is placed into which grip as these factors are known to impact results, and feasibility of each approach may vary depending on design features. Examples of optional fixtures and equipment with built in fixturing are included in Appendix X4 for reference. Refer to Guide F3263 for guidance on test method validation.

5. Interferences

5.1 The value obtained for seal strength can be affected by properties of the specimen other than seal strength. Some flexible barrier materials have properties, such as shape and dimension, that may vary or change and need to be taken into consideration when testing for seal strength. Examples include materials that may stretch (elongation), flexing around the perimeter of a seal flange, or the shape/design of the rigid or semi-rigid material flanges (for example, in a tray), or variation in material properties such as caliper. These interferences are discussed in Annex A1the annex..

6. Apparatus

6.1 *Tensile Testing Machine*—A testing machine of the constant rate-of-jaw-separation type. The machine shall be equipped with a device for recording the tensile load and the amount of separation of the grips; both of these measuring systems shall be accurate to ±2 %. The rate of separation of the jaws shall be uniform and capable of adjustment from approximately 8 to 12 in. [200 to 3008 in. to 12 in. [200 mm to 300 mm] mm]/min. /min. The gripping system shall be capable of minimizing specimen slippage and applying an even stress distribution to the specimen.

NOTE 7—If the tensile testing machine utilizes a spring and hook-based apparatus to extend the sample, it is expected to impart more variation in results as it travels, as compared to modern equipment. When utilizing spring and hook-based apparatus, it is recommended to take this factor into consideration and limit the variation imparted by the weighing system movement to a maximum distance of 2 % of the specimen extension within the range being measured.

NOTE 8—Impact of jaw-separation rate is discussed in Appendix X3.

6.1.1 If calculation of average seal strength is required, the testing machine system shall have the capability to calculate its value over a specified range of grip travel programmable by the operator. Preferably, the machine shall have the capability also to plot the curve of force versus grip travel.

6.2 *Specimen Cutter,* conforming to the requirements of 6.5 of Test Method D882, sized to cut specimens to a width of 0.984 in. [25 mm], 0.591 in. [15 mm], or 1.00 in. [25.4 mm]. Tolerance shall be ±0.5 %.

NOTE 9—Alternate specimen cutting methods and tools may be utilized if deemed appropriate for the application if still in compliance with application.F88/F88M.

NOTE 10—Any deviation from sample tolerance or width shall be supported through documented rationale and/or supportive data. Recommended tolerance for sample cutting tool is ±0.5 %. Sample cutting method and associated variation that may support to establish alternate tolerances may be assessed in validation of the test method; refer to Guide F3263 for test method validation guidance.

NOTE 11—Seal strength is proportional to sample width under the same test conditions. Impact of variation in sample width is discussed in Appendix X3.

7. Sampling

7.1 The number of test specimens shall be chosen to permit an adequate determination of representative performance.

7.2 Testing of samples with visual defects or other deviations from normality may or may not be appropriate depending on the purpose of the investigation. Indiscriminate elimination of defects can bias results.

8. Aging and Conditioning

8.1 If conditioning before testing is desired and appropriate, then see Practice E171.

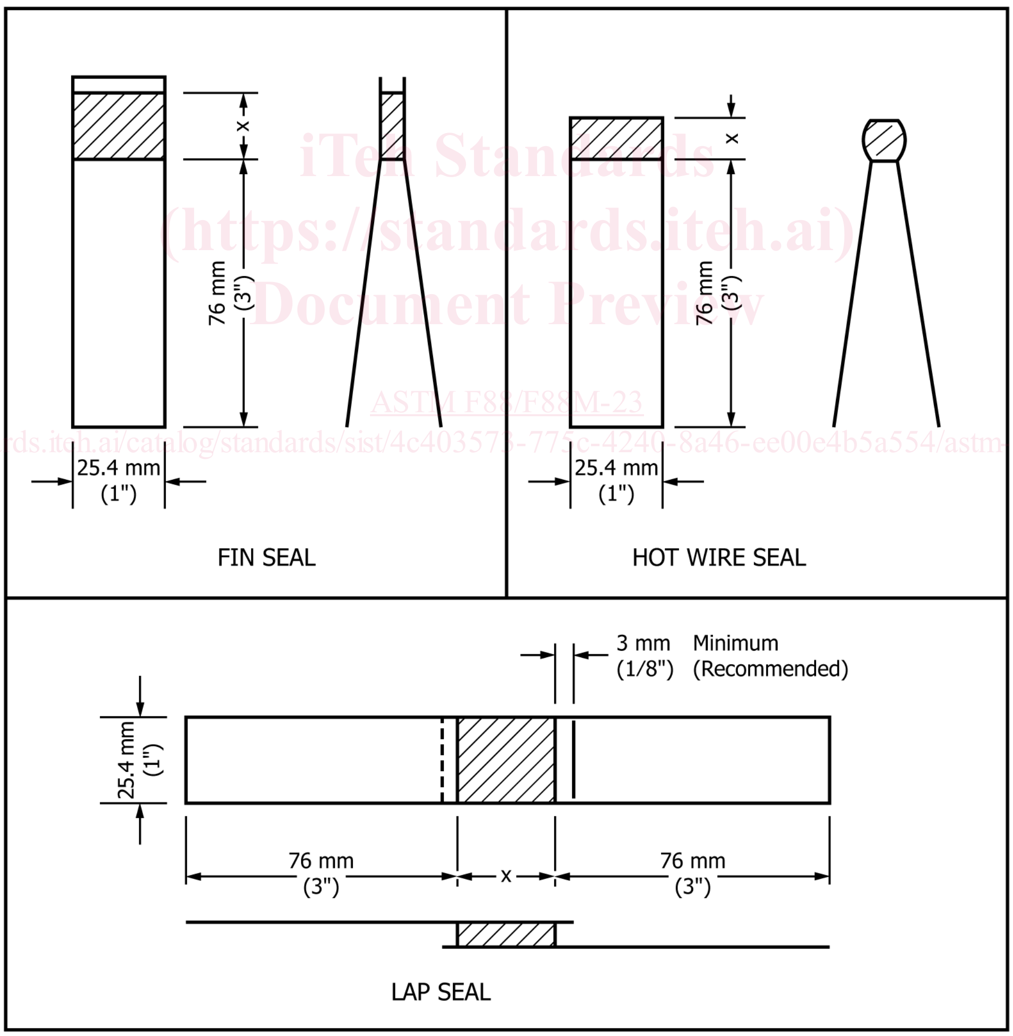
8.2 Heat seal conditioning periods may be determined by experimentation as sufficient to achieve seal strength stability.

8.3 Modification of conditioning practices may be necessary to meet specific test objectives, such as the measurement of seal strength at specified storage or handling temperature.

9. Procedure

9.1 Calibrate the tensile machine in accordance with the manufacturer's recommendations.

9.2 Prepare sealed test specimens for testing by cutting to the dimensions shown in Fig. 2. Edges shall be clean-cut and perpendicular to the direction of seal. Specimen legs may be shorter than shown, depending on the grip dimensions of the testing machine, recommended distance between grips, or the size of the package under test. Multiple locations around the perimeter of the package may be tested.



NOTE 1—*X* is the seal dimension to be tested and this dimension varies with sealer configuration.

NOTE 2—Images above represent typical designs and preparation approaches; other designs compliant with this standard may warrant alternate approaches.

NOTE 3—Sample width dimensions are referenced as examples only; reference 6.2 for options.

FIG. 2 Recommended Specimen Dimensions

NOTE 12—In some applications, sample webs may be indistinguishable from each other, but have differences relevant to test results. In these situations, it is recommended to properly label the tail of each web to enable consistency in gripping and material direction and support reporting considerations in 10.1.8 and 10.1.11.

9.3 When preparing test specimens of flexible material (such as a lid) sealed to a rigid material (such as a tray), and where the flange thickness and seal geometry allow, cutting through the flexible material (such as a lid), while leaving the rigid material intact is acceptable. Alternatively, cutting completely through the flange is another acceptable approach, as long as all subsequent seal strength data for comparison is prepared and tested in the same manner. Additionally, caution is needed to avoid damage to the seal or injury to the operator. See A2.2 for further discussion.

9.4 Clamp each leg of the test specimen in the tensile testing machine. The sealed area of the specimen shall be approximately equidistant between the grips. Recommended distance between grips for specimens comprised of a flexible material sealed to a rigid material (such as a tray) is dependent on the size and the design of the rigid material (tray); see Annex A1 and Annex A2 for further discussion. Initial grip distance may be limited by equipment capability and structure. Consistency in initial grip distance is subject to reporting per 10.1.6. Recommended distance between grips (initial unconstrained specimen length) for seals between flexible material is:

Fin and Hot-Wire Seals		
Highly[A] extensible materials	0.39 in.	[10 mm]
Less[A] extensible materials	1.0 in.	[25 mm]
Lap Seals	X + 10 mm[B]	

[A] Grip separation distance is recommended to be limited for highly extensible materials (100 + % elongation at seal failure) to minimize interferences (see annex).
[B] Refer to Fig. 2, Note 1Note 1, , for definition of *X*.

Warning—Caution should be exercised to avoid injury to the operator of the machine, or damage to the machine itself based on grip travel and potential for contact with the operator, or collision of machinery apparatus, or related fixtures.

9.5 Center the specimen laterally in the grips. Align the specimen in the grips so the seal line is perpendicular to the direction of pull, allowing sufficient slack so the seal is not stressed prior to initiation of the test.

9.6 The orientation of the fin-seal tail during the test can have a significant impact on the measured seal strength. The test report should indicate the details of any technique used to control tail orientation.

9.7 The seal shall be tested at a rate of grip separation of 88 in./min to 1212 in. in./min/min [200 mm [200 to 300 /min to 300 mm mm/min]/min].

NOTE 13—Impact of variation in grip separation rate is discussed in Appendix X3.

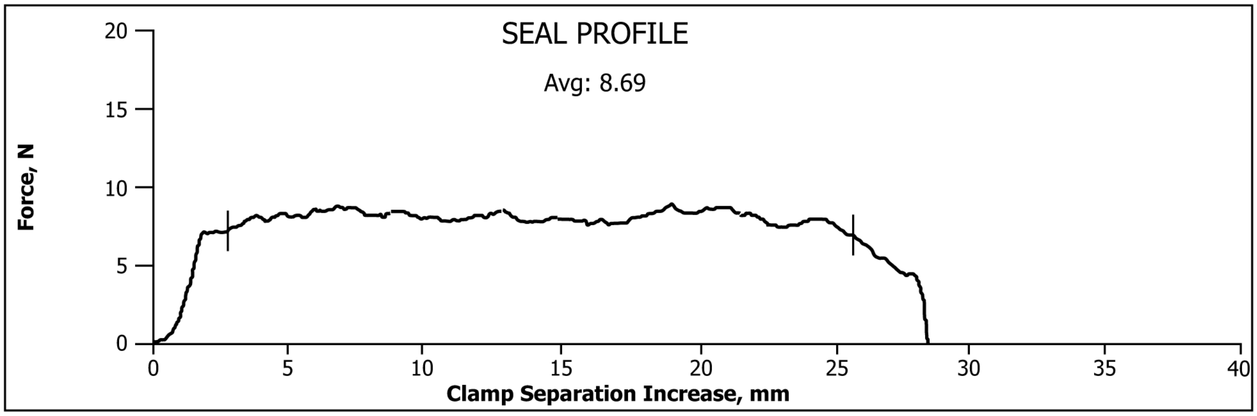
9.8 For each cycle, report the maximum force encountered as the specimen is stressed to failure and identify the mode of specimen failure.

9.9 If the test strip peels apart in the seal area, either by adhesive failure, cohesive failure, or delamination, the average peel force may be an important index of performance and should be measured by the testing machine as a part of the test cycle.

9.9.1 Follow the machine manufacturer's instructions to select the desired algorithm for calculating average seal strength. Fig. 3 illustrates the effect of an algorithm that uses data only from the central 80 % of the curve to calculate the average.

9.9.2 If the test strip does not peel significantly in the seal area and failureseparation is largely by breaking, tearing, or elongation of the substrate material, as opposed to actual separation of the seal between two materials, average force to failureseparate may have little significance in describing seal performance and should not be reported in such cases (see Annex A1.1).

NOTE 14—If average force reporting is conducted for a given dataset, but not reported for specific samples within that dataset due to interferences as described above, the rationale shall also be noted with the corresponding interferences per 10.1.13.



MARKERS ON SEAL PROFILE PLOT AT 10% AND 90%
ESTABLISH DATA WINDOW OF 80% FOR CALCULATION

FIG. 3 Calculation of Average Seal Strength

9.10 A plot of force versus grip travel may be useful as an aid in interpretation of results. In those cases, the testing machine should be programmed to generate the plot.

9.11 Other properties, such as energy to cause seal separation, may be appropriate in cases where grip travel results only in peel. When other failure modes (elongation, break, tear, delamination (when not a designed peel seal separation mode) or other) are present in addition to peel of the seal, energy, and other functions must be interpreted with caution.

10. Report

10.1 Report the following:

10.1.1 Complete identification of material being tested.

TABLE 1 Materials and Techniques

~~Test Series "A"~~ ~~(MAXIMUM Values)~~
Test Series "1" (MAXIMUM Values)
Heat Seal Coated 50# Basis Weight Paper sealed to Film (48 ga. PET/2 mil LDPE) Supported 90° @ 12 in./min Unsupported @ 12 in./min Unsupported @ 8 in./min
~~Test Series "B"~~ ~~(Both MAXIMUM Values and AVERAGE Peel Values were reported)~~
Test Series "2" (Both MAXIMUM Values and AVERAGE Peel Values were reported)
~~Uncoated 1073B Tyvek sealed to Film (48 ga. PET/2 mil LDPE)~~ Uncoated 1073B Tyvek® sealed to Film (48 ga. PET/2 mil LDPE) Supported 90° @ 12 in./min Unsupported @ 12 in./min Supported 180° @ 12 in./min Reverse direction of materials in grips @ 12 in./min
~~Test Series "C"~~ ~~(MAXIMUM Values)~~
Test Series "3" (MAXIMUM Values)
Coex HDPE 3 mil film with peelable sealant layer sealed face-to-face Foil Composite 5 mil with same peelable sealant surface sealed face-to-face Unsupported @ 12 in./min Supported 180° @ 12 in./min

TABLE 2 Test Equipment

Manufacturer	Models	Load Cell	
		lb	N
Dillon	AFG-50N	11.2	50
Instron	4464, 5500R, 5564, 5565, S5R1123, 4442, MN-44	1124, 112.4, 22.5, 11.2, 2	5 kN, 500, 100, 50, 9
Lloyd Instruments	1300-36	22.4	100
MTS Sintech Renew	4204	25	111.2
Test Resources	2000ZR	25	111.2
Thwing Albert	EJA	11.2	50
Vinatoru Enterprises	CCT, HST	11.2	50

10.1.2 Equipment and test method or practice used to form seals, if known.

10.1.3 Equipment used to test seals.

10.1.4 Ambient conditions during tests; temperature and humidity.

10.1.5 Grip separation rate.

10.1.6 Initial grip separation distance.

10.1.7 Seal width.

10.1.8 Machine direction of material in relation to direction of pull may be noted, if known and relevant to the test outcome.

10.1.9 Force (strength) values to three significant figures.

10.1.10 Technique of holding the tail (Technique A, B, or C) and any special fixtures used to hold specimens.

NOTE 15—Variations on Technique shall also be ~~noted.~~noted (including support mechanisms for technique C).

NOTE 16—Locations for clamping or fixturing of samples shall also be noted, if known and relevant to the test outcome.

10.1.11 If the seal is made between two different materials, record which material is clamped in each grip.

10.1.12 Number of specimens tested and method of sampling.

10.1.13 Any other pertinent information that may affect test results such as interferences as described in Annex A1.

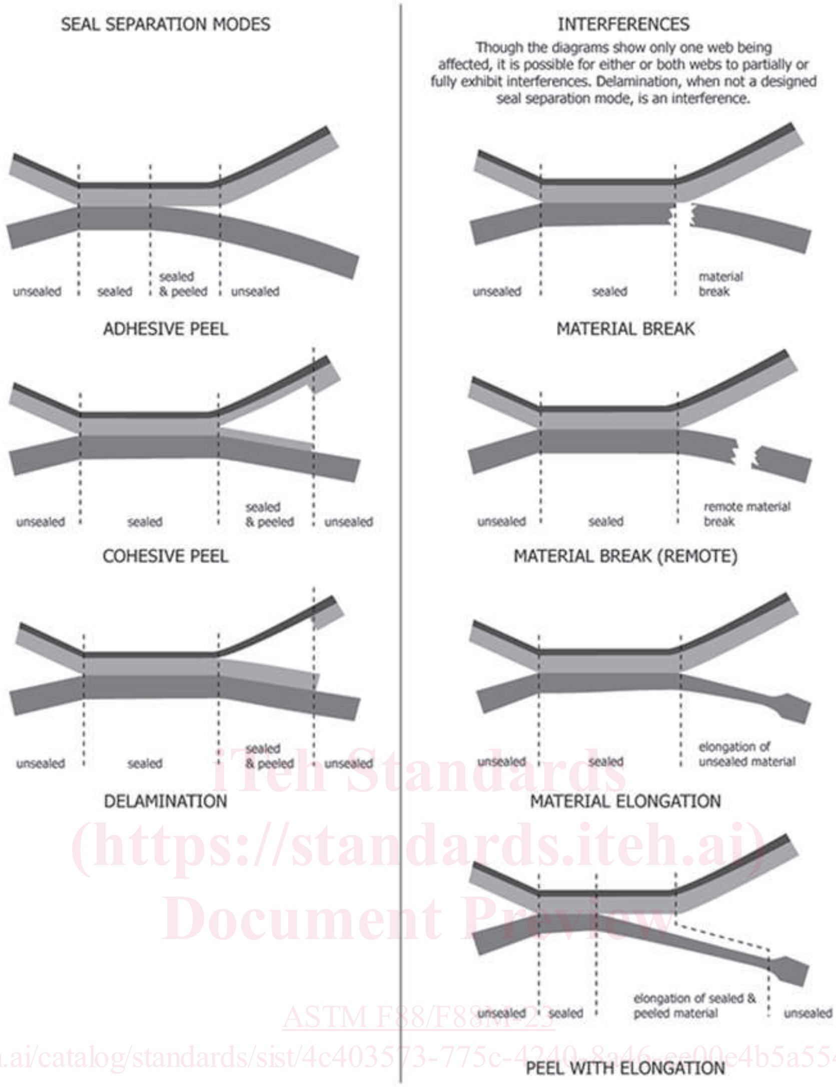
10.1.14 Visual determination of mode of specimen failure. Frequently more than one mode will occur in the course of failure of an individual strip. Record all modes observed. A suggested classification of modes is (see Fig. 4):

Adhesive failure of the seal; peel.
Cohesive failure of the material.
Break or tear of material in seal area or at seal edge.
Delamination of surface layer(s) from substrate.
Elongation of material.
Break or tear of material remote from seal.

10.1.15 Maximum force encountered as each specimen is stressed to failure, expressed preferably in Newtons/metre or lbf/in. of original specimen width. Gmf/in. and lbf/in. are commonly used.

10.1.16 *Average Peel Force,* if applicable (see ~~9.8~~9.9)—If this measurement is reported, a statement of the method or algorithm used to calculate the average should be included.

10.1.17 Plot of force versus grip travel, if deemed significant in interpretation of results.



NOTE 1—Multiple failure modes/seal separation modes and interferences can occur on a single sample.

Color Key:

Color	Description
	Film or Substrate #1
	Sealant Coating or Layer
	Film or Substrate #2

NOTE 2—Typical schematic representation of seal failure modes for seals between two webs.

FIG. 4 Test Strip Failure Modes

10.1.18 Other data not compromised by interferences, if such data are relevant to the specific test purpose.

10.1.19 Any statistical calculation deemed appropriate (most commonly used are mean, range, and standard deviation).

11. Precision and ~~Bias~~Bias: Flexible to Flexible Applications

11.1 *Precision*—A round robin was conducted using Practice E691 as a guide, involving 18 laboratories measuring a total of 1980

TABLE 3 r and R Summary (Inch-Pound Units)

NOTE 1—In accordance with Practice E691, enter the larger of the values obtained by the use of (equation for S_r) and (equation for S_R) as the final value of S_R to be used for precision statements.

Units: lb/in.	s_r	s_R	r	R	Grand Avg
~~A Supported 90°~~	~~0.0396~~	~~0.0473~~	~~0.1109~~	~~0.1324~~	~~0.957~~
1 Supported 90°	0.0396	0.0473	0.1109	0.1324	0.957
~~A Unsupported at 12 in./min~~	~~0.0929~~	~~0.1286~~	~~0.2601~~	~~0.3602~~	~~1.424~~
1 Unsupported at 12 in./min	0.0929	0.1286	0.2601	0.3602	1.424
~~A Unsupported at 8 in./min~~	~~0.1063~~	~~0.1488~~	~~0.2977~~	~~0.4166~~	~~1.417~~
1 Unsupported at 8 in./min	0.1063	0.1488	0.2977	0.4166	1.417
~~B PEAK 90°~~	~~0.2629~~	~~0.2539~~	~~0.7361~~	~~0.7361^{A}~~	~~0.923~~
2 PEAK 90°	0.2629	0.2539	0.7361	0.7361^{A}	0.923
~~B AVG 90°~~	~~0.1600~~	~~0.1599~~	~~0.4480~~	~~0.4480~~	~~0.684~~
2 AVG 90°	0.1600	0.1599	0.4480	0.4480	0.684
~~B PEAK Unsupported~~	~~0.2683~~	~~0.2630~~	~~0.7513~~	~~0.7513^{A}~~	~~1.709~~
2 PEAK Unsupported	0.2683	0.2630	0.7513	0.7513^{A}	1.709
~~B AVG Unsupported~~	~~0.2510~~	~~0.2492~~	~~0.7029~~	~~0.7029^{A}~~	~~1.453~~
2 AVG Unsupported	0.2510	0.2492	0.7029	0.7029^{A}	1.453
~~B PEAK 180°~~	~~0.2977~~	~~0.3292~~	~~0.8335~~	~~0.9218~~	~~3.239~~
2 PEAK 180°	0.2977	0.3292	0.8335	0.9218	3.239
~~B AVG 180°~~	~~0.3070~~	~~0.3567~~	~~0.8596~~	~~0.9988~~	~~2.990~~
2 AVG 180°	0.3070	0.3567	0.8596	0.9988	2.990
~~B PEAK 180° Reverse~~	~~0.5536~~	~~0.5971~~	~~1.5501~~	~~1.6720~~	~~1.464~~
2 PEAK 180° Reverse	0.5536	0.5971	1.5501	1.6720	1.464
~~B AVG 180° Reverse~~	~~0.2560~~	~~0.2451~~	~~0.7167~~	~~0.7167^{A}~~	~~0.936~~
2 AVG 180° Reverse	0.2560	0.2451	0.7167	0.7167^{A}	0.936
~~C 3 mil Film Unsupported~~	~~0.0605~~	~~0.1059~~	~~0.1695~~	~~0.2966~~	~~1.695~~
3 3 mil Film Unsupported	0.0605	0.1059	0.1695	0.2966	1.695
~~C 3 mil Film 180°~~	~~0.1786~~	~~0.3003~~	~~0.5001~~	~~0.8408~~	~~3.463~~
3 3 mil Film 180°	0.1786	0.3003	0.5001	0.8408	3.463
~~C 5 mil Foil Unsupported~~	~~0.0382~~	~~0.0272~~	~~0.1069~~	~~0.2051~~	~~1.209~~
3 5 mil Foil Unsupported	0.0382	0.0272	0.1069	0.2051	1.209
~~C 5 mil Foil 180°~~	~~0.3164~~	~~0.3476~~	~~0.8859~~	~~0.9731~~	~~4.569~~
3 5 mil Foil 180°	0.3164	0.3476	0.8859	0.9731	4.569

^{A} Per Practice E691: "Enter the larger of the values obtained by the use of (equation for s_r) and (equation for s_R) as the final value of s_R to be used for precision statements."

samples distributed over three different test groups of six laboratories each.[3] In order to maintain a focus on testing the method itself, laboratory samples were used to limit the amount of variation in the seals produced. Description of materials measured and methods used are listed in Table 1. Seven different brands of tensile testing equipment were used to collect information. The model identifications and load cell sizes are listed in Table 2. Statistical summaries of repeatability (within a laboratory) and reproducibility (between laboratories) are listed in Table 4 for SI units and Table 3 in units of pounds per inch. Fig. 5 is graphical depictions of data.

11.2 *Concept of "r" and "R" in* Tables 4 and 3—If S_r and S_R have been calculated from a large enough body of data, and for test results that are averages from testing 10 to 30 specimens (see Note ~~6~~17) for each test result, then the following applies:

NOTE 17—Repeatability and reproducibility comparisons for smaller sample size (*n* = 10) can be found in Appendix X1 and Appendix X2 of this test method.

11.2.1 Repeatability "r" is the interval representing the critical difference between test results for the same material and method, obtained by the same operator using the same equipment on the same day in the same laboratory. Test results shall be deemed to be not equivalent if they differ by more than the "r" value for that material or method.

11.2.2 Reproducibility "R" is the interval representing the critical difference between test results for the same material and method, obtained by different operators using the different equipment in different laboratories, not necessarily on the same day. Test results shall be deemed to be not equivalent if they differ by more than the "R" value for that material or method.

11.3 Any judgment in accordance with 11.2.1 or 11.2.2 will have approximately 95 % (0.95) probability of being correct.

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F02-1023. Contact ASTM Customer Service at service@astm.org.

TABLE 4 r and R Summary (SI Units)

NOTE 1—In accordance with Practice E691, enter the larger of the values obtained by the use of (equation for S_r) and (equation for S_R) as the final value of S_R to be used for precision statements.

NOTE 2—The values stated were converted from inch-pound units.

Units: N/25.4 mm	s_r	s_R	r	R	Grand Avg
~~A Supported 90°~~	~~0.1761~~	~~0.2103~~	~~0.4932~~	~~0.5889~~	~~4.2569~~
1 Supported 90°	0.1761	0.2103	0.4932	0.5889	4.2569
~~A Unsupported at 12 in./min~~	~~0.4132~~	~~0.5722~~	~~1.1568~~	~~1.6021~~	~~6.3343~~
1 Unsupported at 12 in./min	0.4132	0.5722	1.1568	1.6021	6.3343
~~A Unsupported at 8 in./min~~	~~0.4729~~	~~0.6618~~	~~1.3242~~	~~1.8529~~	~~6.3031~~
1 Unsupported at 8 in./min	0.4729	0.6618	1.3242	1.8529	6.3031
~~B PEAK 90°~~	~~1.1694~~	~~1.1293~~	~~3.2742~~	~~3.2742[A]~~	~~4.1057~~
2 PEAK 90°	1.1694	1.1293	3.2742	3.2742[A]	4.1057
~~B AVG 90°~~	~~0.7117~~	~~0.7112~~	~~1.9927~~	~~1.9927~~	~~3.0426~~
2 AVG 90°	0.7117	0.7112	1.9927	1.9927	3.0426
~~B PEAK Unsupported~~	~~1.1936~~	~~1.1700~~	~~3.3421~~	~~3.3421[A]~~	~~7.6020~~
2 PEAK Unsupported	1.1936	1.1700	3.3421	3.3421[A]	7.6020
~~B AVG Unsupported~~	~~1.1167~~	~~1.1084~~	~~3.1267~~	~~3.1267[A]~~	~~6.4633~~
2 AVG Unsupported	1.1167	1.1084	3.1267	3.1267[A]	6.4633
~~B PEAK 180°~~	~~1.3242~~	~~1.4643~~	~~3.7077~~	~~4.1002~~	~~14.4078~~
2 PEAK 180°	1.3242	1.4643	3.7077	4.1002	14.4078
~~B AVG 180°~~	~~1.3656~~	~~1.5868~~	~~3.8236~~	~~4.4431~~	~~13.3002~~
2 AVG 180°	1.3656	1.5868	3.8236	4.4431	13.3002
~~B PEAK 180° Reverse~~	~~2.4625~~	~~2.6562~~	~~6.8950~~	~~7.4373~~	~~6.5122~~
2 PEAK 180° Reverse	2.4625	2.6562	6.8950	7.4373	6.5122
~~B AVG 180° Reverse~~	~~1.1386~~	~~1.0901~~	~~3.1880~~	~~3.1880[A]~~	~~4.1635~~
2 AVG 180° Reverse	1.1386	1.0901	3.1880	3.1880[A]	4.1635
~~C 3 mil Film Unsupported~~	~~0.2693~~	~~0.4712~~	~~0.7539~~	~~1.3194~~	~~7.5397~~
3 3 mil Film Unsupported	0.2693	0.4712	0.7539	1.3194	7.5397
~~C 3 mil Film 180°~~	~~0.7945~~	~~1.3357~~	~~2.2245~~	~~3.7400~~	~~15.4042~~
3 3 mil Film 180°	0.7945	1.3357	2.2245	3.7400	15.4042
~~C 5 mil Foil Unsupported~~	~~0.1699~~	~~0.3203~~	~~0.4757~~	~~0.8968~~	~~5.3779~~
3 5 mil Foil Unsupported	0.1699	0.3203	0.4757	0.8968	5.3779
~~C 5 mil Foil 180°~~	~~1.4074~~	~~1.5460~~	~~3.9406~~	~~4.3287~~	~~20.3239~~
3 5 mil Foil 180°	1.4074	1.5460	3.9406	4.3287	20.3239

[A] Per Practice E691: "Enter the larger of the values obtained by the use of (equation for s_r) and (equation for s_R) as the final value of s_R to be used for precision statements."

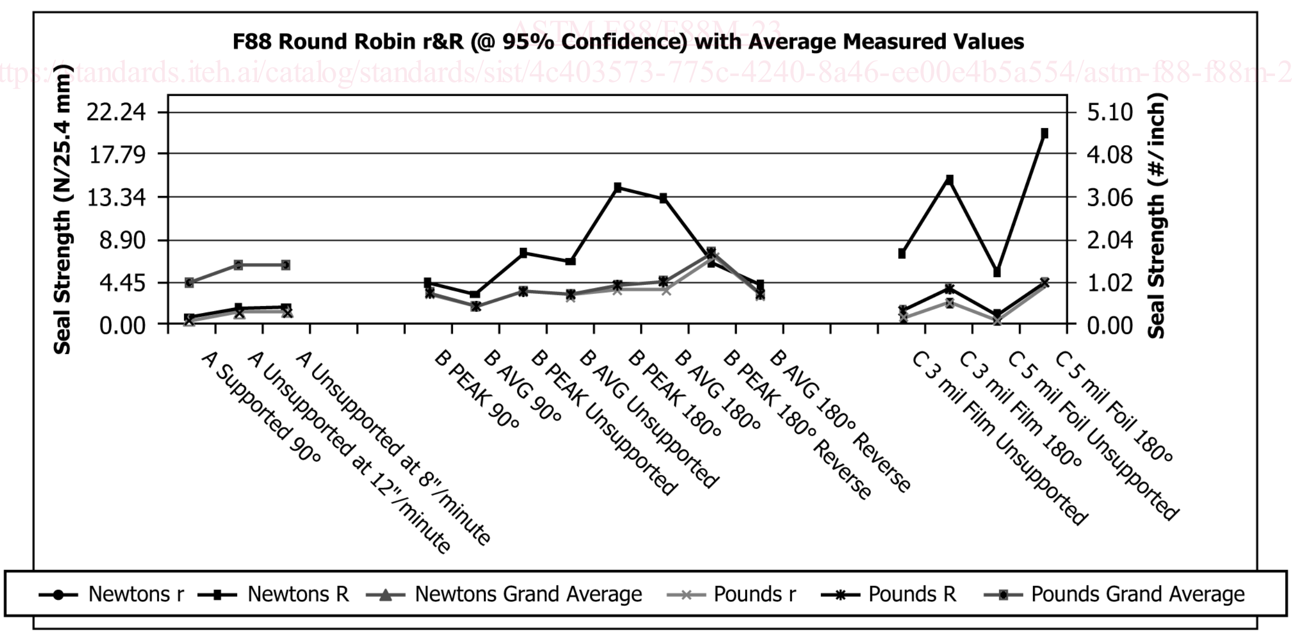


FIG. 5 F88/F88M Round Robin r and R (at 95 % confidence) with Average Measured Values

11.4 *Bias*—There are no recognized standards by which to estimate the bias of this test method.