INTERNATIONAL

Designation: 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 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]

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
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, 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 9.9.1).

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

[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.

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, 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 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 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 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.

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°*—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 A1.

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 in. to 12 in. [200 mm to 300 mm]/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].

NOTE 9—Alternate specimen cutting methods and tools may be utilized if deemed appropriate for the application.

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.

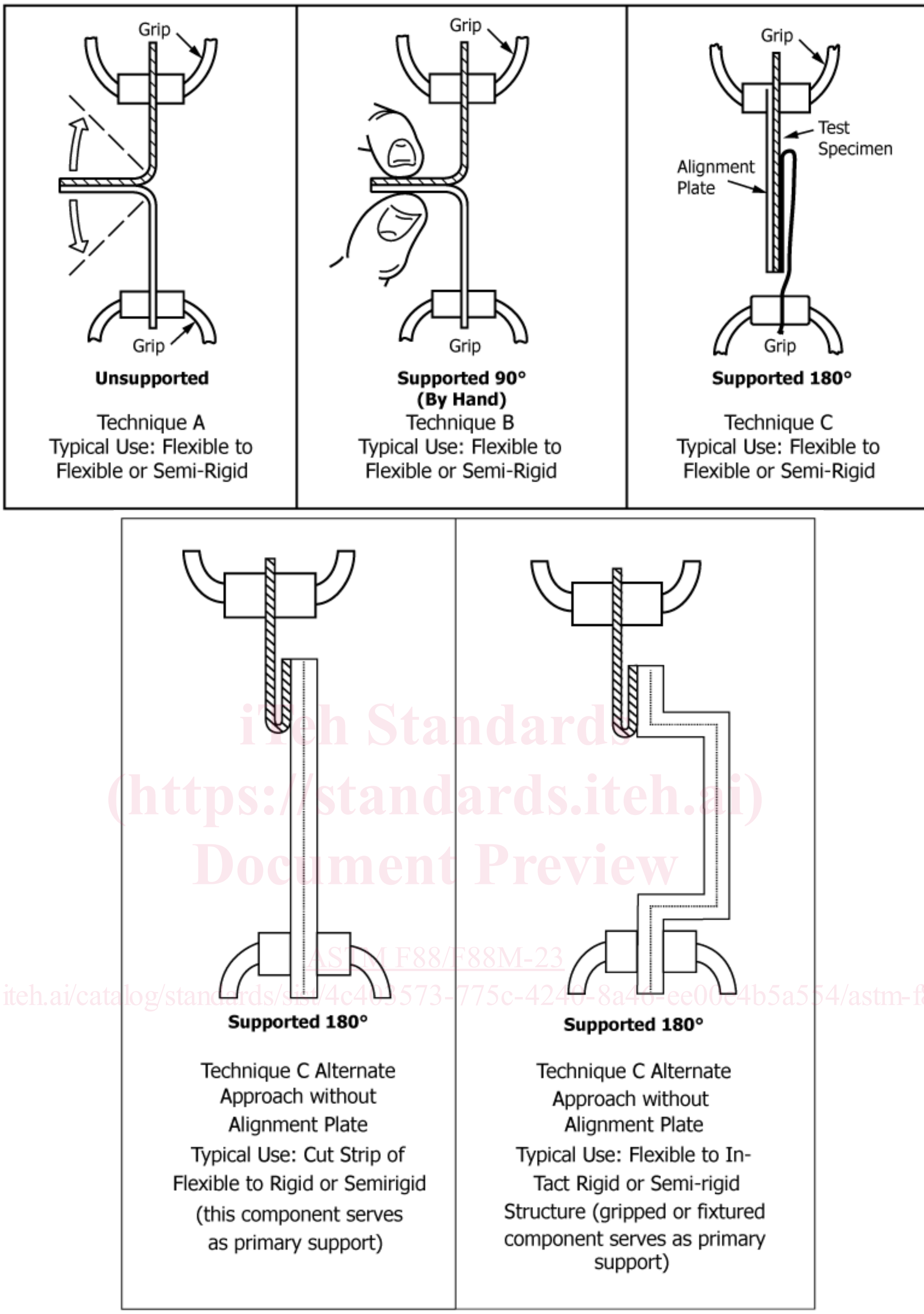


Diagram Key

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

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.

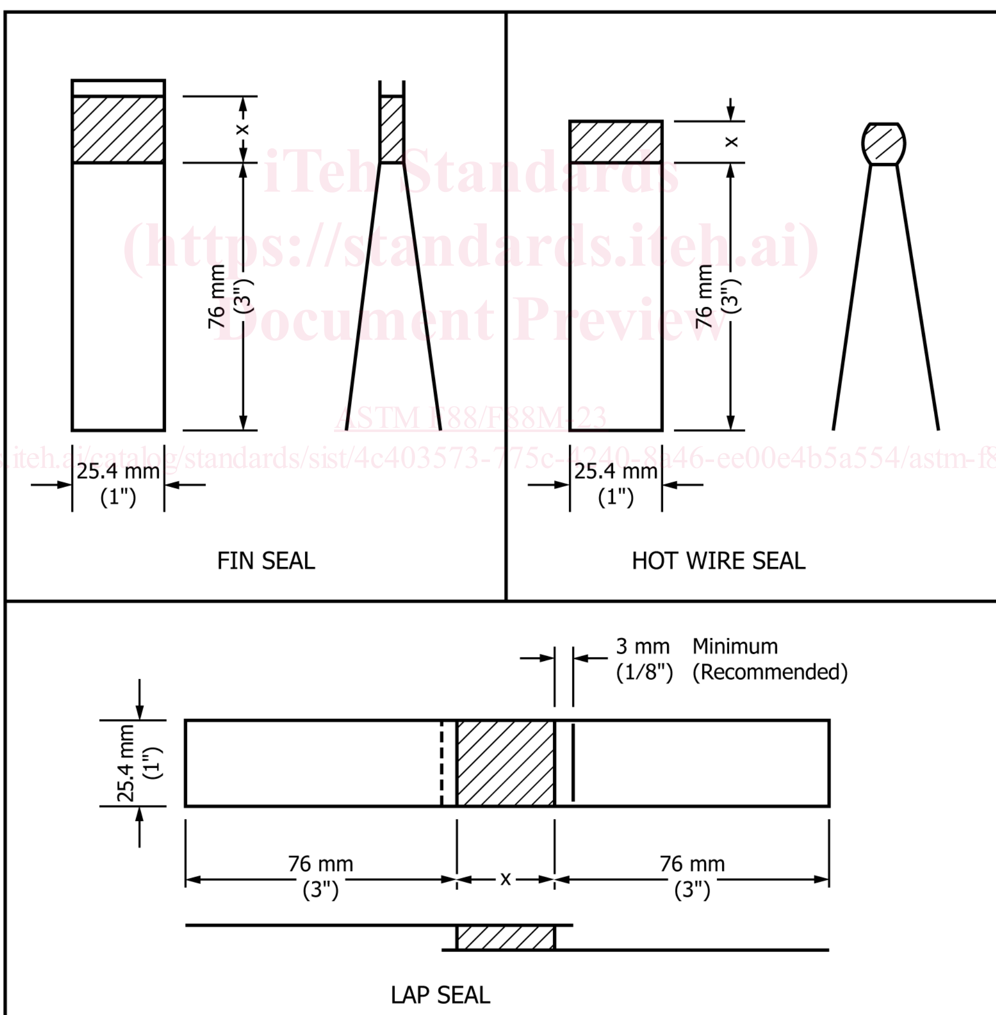
9. Procedure

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 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



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

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 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 8 in./min to 12 in./min [200 mm/min to 300 mm/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.

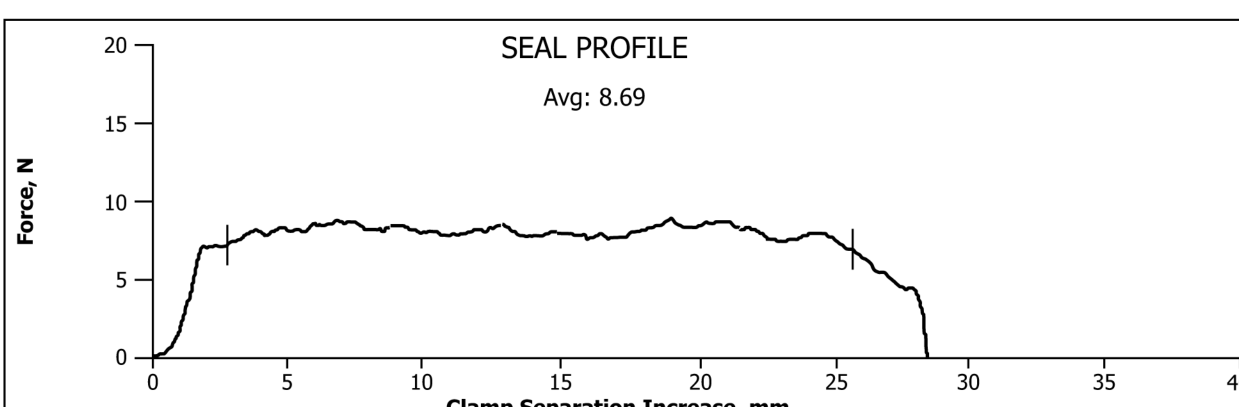
9.9.1 Follow the machine manufacturer's instructions to select the desired algorithm for calculating average seal strength. Fig. 3 illustrates the effect of an algorithm that uses data only from the central 80 % of the curve to calculate the average.

9.9.2 If the test strip does not peel significantly in the seal area and separation 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 separate 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.

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



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

FIG. 3 Calculation of Average Seal Strength

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.

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 (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.

TABLE 1 Materials and Techniques

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 "2" (Both MAXIMUM Values and AVERAGE Peel Values were reported)
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 "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	Load Cell 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

10.1.15 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 9.9)—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.

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: Flexible to Flexible Applications

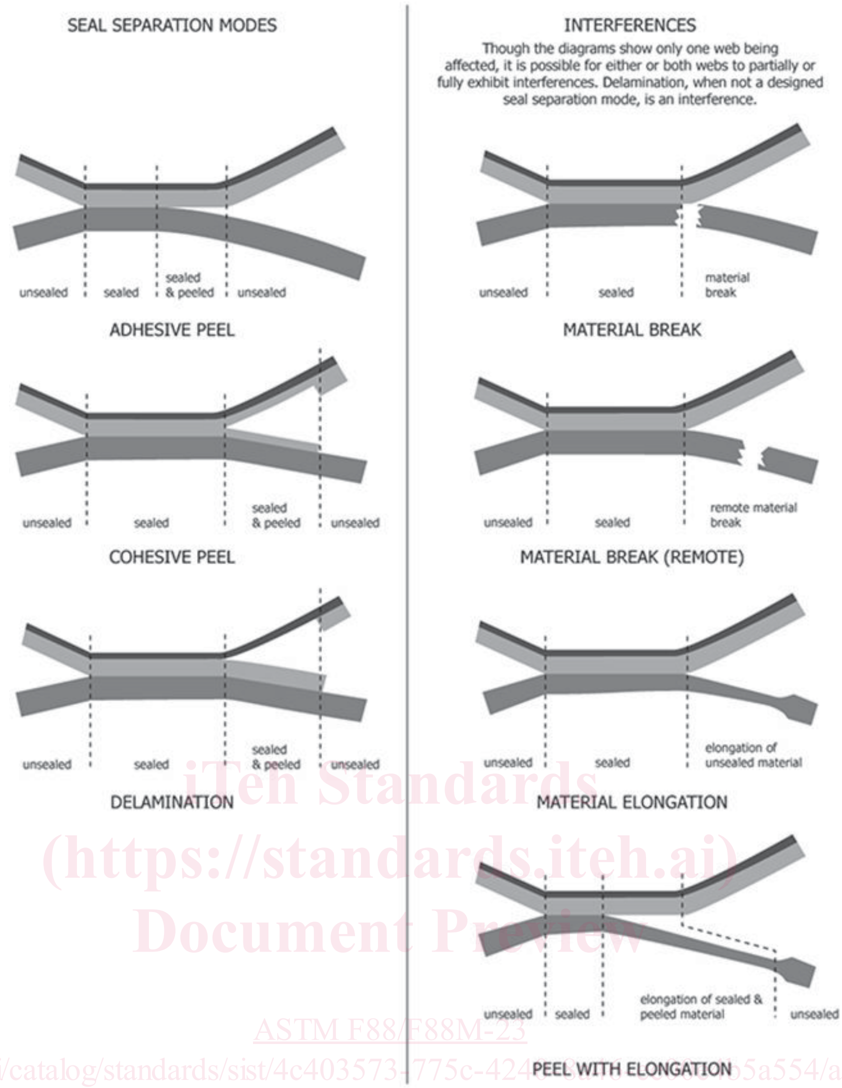
11.1 *Precision*—A round robin was conducted using Practice E691 as a guide, involving 18 laboratories measuring a total of 1980 samples distributed over three different test groups of six laboratories each.[3] In order to maintain a focus on testing the method itself, laboratory samples were used to 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 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

[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.



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

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.

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

12. Precision and Bias: Flexible to Rigid Applications

12.1 The precision of this test method for Flexible to Rigid applications is based on an interlaboratory study of Test Method F88/F88M, Test Method for Seal Strength of Flexible Barrier Materials, conducted in 2021. Six volunteer laboratories were asked to test four different material configurations. Every "test result" represents an individual determination, and

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
1	Supported 90°	0.0396	0.0473	0.1109	0.1324	0.957
1	Unsupported at 12 in./min	0.0929	0.1286	0.2601	0.3602	1.424
1	Unsupported at 8 in./min	0.1063	0.1488	0.2977	0.4166	1.417
2	PEAK 90°	0.2629	0.2539	0.7361	0.7361[A]	0.923
2	AVG 90°	0.1600	0.1599	0.4480	0.4480	0.684
2	PEAK Unsupported	0.2683	0.2630	0.7513	0.7513[A]	1.709
2	AVG Unsupported	0.2510	0.2492	0.7029	0.7029[A]	1.453
2	PEAK 180°	0.2977	0.3292	0.8335	0.9218	3.239
2	AVG 180°	0.3070	0.3567	0.8596	0.9988	2.990
2	PEAK 180° Reverse	0.5536	0.5971	1.5501	1.6720	1.464
2	AVG 180° Reverse	0.2560	0.2451	0.7167	0.7167[A]	0.936
3	3 mil Film Unsupported	0.0605	0.1059	0.1695	0.2966	1.695
3	3 mil Film 180°	0.1786	0.3003	0.5001	0.8408	3.463
3	5 mil Foil Unsupported	0.0382	0.0272	0.1069	0.2051	1.209
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."

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

all participants were instructed to report 30 replicate test results for each material. Practice E691 was followed for the design of study and analysis of the data; the details are given in Research Report RR:F02-2001.[4]

12.1.1 *Repeatability Limit (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the determined values only in one case in 20.

12.1.1.1 Repeatability limit can be interpreted as the maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

12.1.1.2 Repeatability limits are listed in Table 5 and Table 6 below.

12.1.2 *Reproducibility Limit (R)*—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20, as 95 % repeatability is expected, exceeding the values in 5 % of the cases.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F02-2001. Contact ASTM Customer Service at service@astm.org.

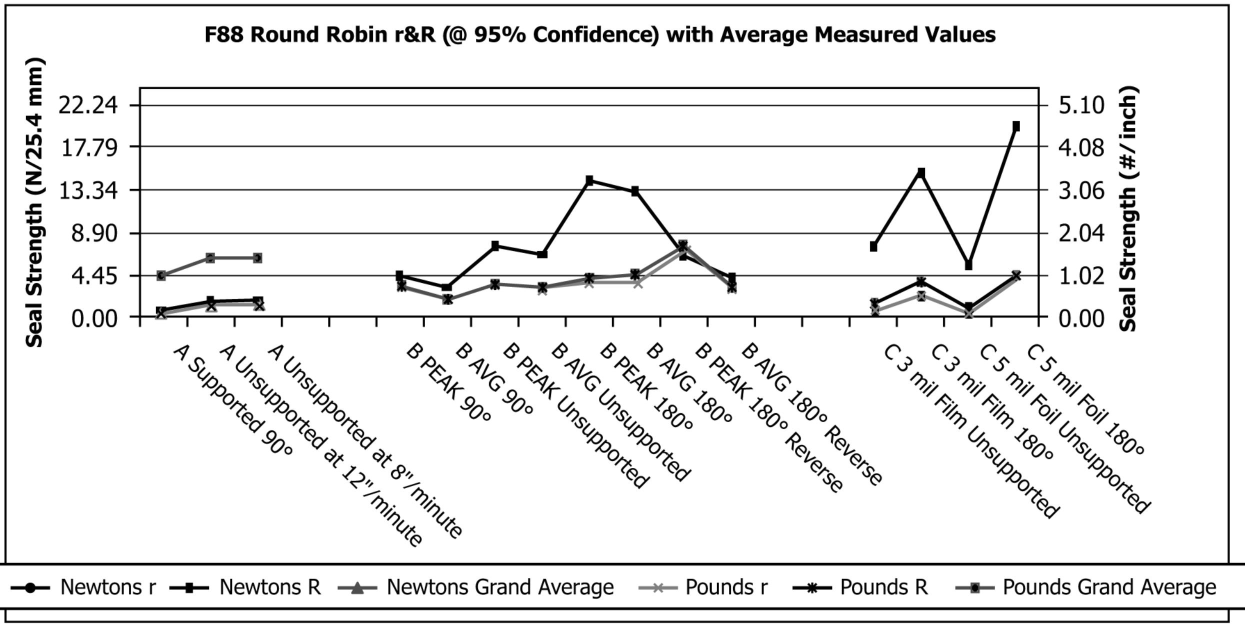


FIG. 5 F88/F88M Round Robin r and R (at 95 % confidence) with Average Measured Values

TABLE 5 Peak Strength (lbf per in.)

Material	Number of Laboratories	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit	Reproducibility CoV
	n	x̄	S_r	SR	r	R	%
Vertical Separated Strip	3	1.53092	0.17032	0.20365	0.47689	0.57021	13.3
Vertical Full Tray	3	1.50954	0.19078	0.48934	0.53418	1.37014	32.4
Horizontal Separated Strip	3	1.54850	0.18103	0.22233	0.50687	0.62253	14.4
Horizontal Full Tray	3	1.67291	0.13249	0.18631	0.37096	0.52166	11.1

[A] The average of the laboratories' calculated averages.

TABLE 6 Average Strength (lbf per in.)

Material	Number of Laboratories	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit	Reproducibility CoV
	n	x̄	S_r	SR	r	R	%
Vertical Separated Strip	3	1.28679	0.15346	0.18074	0.42969	0.50608	14.0
Vertical Full Tray	3	1.17903	0.16141	0.36840	0.45195	1.03153	31.2
Horizontal Separated Strip	3	1.41866	0.16315	0.21139	0.45683	0.59189	14.9
Horizontal Full Tray	3	1.53236	0.12731	0.17941	0.35648	0.50235	11.7

[A] The average of the laboratories' calculated averages.

12.1.2.1 Reproducibility limit can be interpreted as the maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

12.1.2.2 Reproducibility limits are listed in Table 5 and Table 6 below.

12.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

12.1.4 Any judgment in accordance with statement 12.1.1 would normally have an approximate 95 % probability of being correct. Test method validation is essential for users of the standard to understand reproducibility. Refer to Guide F3263 for guidance on test method validation.

12.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

12.3 The precision statement was determined through statistical examination of 720 results, from 6 laboratories, on 4 material configurations. Further details are in Appendix X2.

ANNEXES

(Mandatory Information)

A1. INTERFERENCES

A1.1 *Failure Mode*—The objective of this test method is to measure the strength of seals between a flexible material, and another flexible material, a rigid material, or a semi-rigid material. The intent is to determine seal strength by measuring force required to peel a seal apart while pulling on the ends of a strip of material containing the seal. However, the pulling process may or may not result in the desired mode of strip failure. During the test cycle, the grips are moved apart at a set rate while the force required to extend the ends of the strip is continuously monitored. Extension of the specimen ends can cause one or a combination of the following effects within the specimen itself:

Break or tear of material at edge of seal.
Elongation of the material.
Break or tear of material remote from seal.

A1.1.1 These effects are due to failure of the material itself and must be identified as such in the test report. These effects are typical for weld seal applications. However, for peelable applications, these effects are interferences that can prevent the method from measuring the true strength of the seal.

A1.1.2 Seal characteristics such as coating transfer, deformation, shrinkage, and burnthrough can affect the outcome of the test.

A1.2 *Effect of Material Elongation on Rate of Peel*—Another interference is caused by elongation of the material during the test. If the test strip stretches or delaminates during grip travel, the rate of peel will be lower than that calculated from the grip separation rate. In this instance, the ratio of stretch to peel is unknown and may vary during the test. The rate of peel is then no longer controlled by the machine. Rate of peel is known to affect measured seal strength value.

A1.3 *Initial Clamp Separation Distance*—Since the material between the seal and the grips can interfere significantly with measurement of seal strength, in accordance with the preceding paragraphs, the initial clamp separation distance should be set at a relatively low value to minimize that potential.

A1.4 *Peel Rate versus Grip Separation Rate*—In peel testing, whenever separation of the grips holding the test strip is translated completely into peeling of the seal, an increase in grip separation of X cm causes an advance of the failure line into the seal of 0.5X cm. The peel rate in this ideal situation is therefore ½ of the grip separation rate. This arithmetic is commonly overlooked, leading to peel rate being incorrectly equated with grip separation rate.

NOTE A1.1— For example, a 2 cm separation of grips results in a 1 cm peel on each tail of the sample. Similarly, a 2 cm/min grip separation rate results in a 1 cm/min peel rate of the sample.

A1.5 *Uneven Flanges*—Aprons, offsets, or deeper angles of a rigid or semi-rigid material (such as a tray) may prevent flat/straight peel.

A1.6 *Rigid or Semi-Rigid Material and Flange Area Bending*—If peeling a flexible material (such as a lid) results in flexing around the perimeter of a seal flange, results can vary around the circumference of the semi-rigid material (such as a tray, which may demonstrate strength variation with individual sides of varying lengths). Additionally, when gripping or fixturing a rigid or semi-rigid design, presence of lidding material may increase overall sample rigidity; conversely, removal of lidding material (for example, sample strips or areas adjacent to sample strips) may result in less overall sample rigidity, causing the rigid or semi-rigid material to flex throughout the course of the test, resulting in impact to results.

A1.7 *Curved Flanges*—Non-square or rectangular rigid or semi-rigid material (such as a tray) designs may prevent a perpendicular seal peel.

A2. SAMPLE PREPARATION AND CONSIDERATIONS

A2.1 *Seal Location*—Various locations around the perimeter of a package may have different seal strengths. The location of the tested seal should be noted, if known and relevant to the test outcome.

A2.2 *Specimen Preparation*—When preparing the test strip for a rigid or semi-rigid material (such as a tray) with a flexible material (such as a lid), the rigid or semi-rigid flange may be cut along with the flexible material (such as a lid). When the flange is completely cut through, the resulting section may have a loss of rigidity and may cause variation when comparing seal strength to a sample from an intact flange. Longer rigid or semi-rigid designs may necessitate cutting the specimen into multiple samples, if the length exceeds the height of the tensile testing machine.

NOTE A2.1—Modifications to samples or addition of fixtures may impact the measured results; however, these factors need to be defined within the testing technique. This includes the use of appliances, jigs, tape, etc. as modifications.

NOTE A2.2—Since forces imparted from bending or cracking of the seal flange may cause damage to the seal, such as splitting, inspection of the samples for damage should be established.

NOTE A2.3—Since injury to the operator preparing and cutting the sample could occur, the instructions for preparing and cutting samples should include practices to avoid injury.

A2.3 *Rigidity*—Definitions for "semi-rigid plastic" and "rigid plastic" are provided in D883, utilizing specific elasticity values, whereas "flexible" is defined in F17 in terms of characteristics regarding ease of flexing or manipulating the material. For the purposes of this standard, the intent of understanding rigidity pertains to sample fixturing and impact on samples throughout the test. From this perspective, the existing definition of "flexible" applies. "Rigid" connotates materials that do not bend under the test conditions, and "semi-rigid" connotates materials with some level of bending under test conditions (for example, easily bent, but typically returns back to original position upon release); a common application for "semi-rigid" is form-fill-seal packaging.

APPENDIXES

(Nonmandatory Information)

X1. FLEXIBLE TO FLEXIBLE ILS BACKGROUND, RATIONALE, AND ANALYSIS

X1.1 The Interlaboratory Study (ILS) performed in 2004 to create the data for the statement found in Section 11 Precision and Bias was collected from 18 labs.[3] The ASTM F02.3 and F02.6 subcommittees in joint participation ran nearly 2000 samples through tensile test devices that fulfilled the requirements of the apparatus section of this test method. Since the method and the techniques discussed in the standard were the focus of the study the joint subcommittee concluded that the samples should be as close to homogeneous as possible, that is, not production machine samples but controlled laboratory made samples. Therefore they were created using materials from one single lot each, then sealed on a single laboratory sealing machine from each of the three companies volunteering for sample preparation and trimmed to the defined cut size prior to shipping out to the test laboratories and their assigned contacts.

X1.1.1 Three protocols were designed, each using a different material combination. The materials used included a heat seal coated paper material sealed to a film (PET/LDPE), an uncoated Tyvek®[5] 1073B material sealed to a film (PET/LDPE) and a set of material composites (3 mil Film/Film and 5 mil foil/foil) with a peelable sealant surface sealed face-to-face. Each series was designed to identify the effects of variations in the use of the method on the final measured result as well as on repeatability (r) and reproducibility (R). These techniques are listed in Table X1.1.

X1.1.2 The ILS were essentially separate and data was not compared from group to group unless changes in technique resulted in common effects to measured values or to r and R. At that point observations could be made as to the effect across material types and uncommon laboratory sources.

X1.1.3 One of the decisions made by the joint committee was on the required sample size needed for assurance of an effective measurement ($n = 30$ versus $n = 10$). It was believed that the greater sample size was necessary to have confidence that data from a destructive test method would result in a statistically accurate statement of variation. This sample size required an extremely high number of samples be made for all laboratories to test all materials and techniques (18 laboratories × 30 samples × 11 techniques). Reducing this number drove the ILS into the three independent series shown in Table X1.1. In order to resolve the question of accuracy or confidence in the outcome of the analysis, the data was also analyzed by splitting the data into $n = 30$ and $n = 10$ using the first ten data points reported by the laboratories. Results in this study are shown in Table X1.2. Overall, the average measured values of the data series differed by less than 0.1 #/in., the "r" actually resulted in improved levels or less than 5 % increases in 73 % of the tests run over the 3 series. Reproducibility suffered most in the test for incorrect loading (Series 2 Reverse) and in the 90° supported tail where a difference in 0.02 in Series 1 accounted for a 17 % increase and in Series 2 a 0.1 and 0.18 accounted for 22 % to 26 %. Looked at another way, Fig. X1.2 plots the average with ±3 standard deviations for each of the sample

[5] Tyvek is a registered trademark of DuPont, Inc.