Designation: F1921/F1921M – 12ε1

Standard Test Methods for Hot Seal Strength (Hot Tack) of Thermoplastic Polymers and Blends Comprising the Sealing Surfaces of Flexible Webs[1]

This standard is issued under the fixed designation F1921/F1921M; 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.

ε[1] NOTE—Designation was corrected editorially in October 2013.

1. Scope

1.1 These two test methods cover laboratory measurement of the strength of heatseals formed between thermoplastic surfaces of flexible webs, immediately after a seal has been made and before it cools to ambient temperature (hot tack strength).

1.2 These test methods are restricted to instrumented hot tack testing, requiring a testing machine that automatically heatseals a specimen and immediately determines strength of the hot seal at a precisely measured time after conclusion of the sealing cycle. An additional prerequisite is that the operator shall have no influence on the test after the sealing sequence has begun. These test methods do not cover non-instrumented manual procedures employing springs, levers, pulleys and weights, where test results can be influenced by operator technique.

1.3 Two variations of the instrumented hot tack test are described in these test methods, differing primarily in two respects: *(a)* rate of grip separation during testing of the sealed specimen, and *(b)* whether the testing machine generates the cooling curve of the material under test, or instead makes a measurement of the maximum force observed following a set delay time. Both test methods may be used to test all materials within the scope of these test methods and within the range and capacity of the machine employed. They are described in Section 4.

1.4 SI units are preferred and shall be used in referee decisions. Values stated herein in inch-pound units are to be regarded separately and may not be exact equivalents to SI units. Therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *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.* The operator of the equipment is to be aware of pinch points as the seal jaws come together to make a seal, hot surfaces of the jaws, and sharp instruments used to cut specimens. It is recommended that the operator review safety precautions from the equipment supplier.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D882 Test Method for Tensile Properties of Thin Plastic Sheeting

E171 Practice for Conditioning and Testing Flexible Barrier Packaging

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

F88 Test Method for Seal Strength of Flexible Barrier Materials

F2029 Practices for Making Heatseals for Determination of Heatsealability of Flexible Webs as Measured by Seal Strength

3. Terminology

3.1 *Definitions:*

3.1.1 *adhesive failure, n*—a failure mode in which the seal fails at the original interface between the surfaces being sealed.

3.1.2 *breadth, n*—temperature range over which peel force of a seal is (relatively) constant.

3.1.3 *burnthrough, n*—a state or condition of a heatseal characterized by melted holes and thermal distortion.

3.1.3.1 *Discussion*—Burnthrough indicates that the sealing conditions (time or temperature, or both) were too high to produce an acceptable seal.

[1] These test methods are under the jurisdiction of ASTM Committee F02 on Flexible Barrier Packaging and are 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.

3.1.4 *cohesive failure, n*—a failure mode where either or both of the sealed webs fails by splitting approximately parallel to the seal, and the seal itself remains intact.

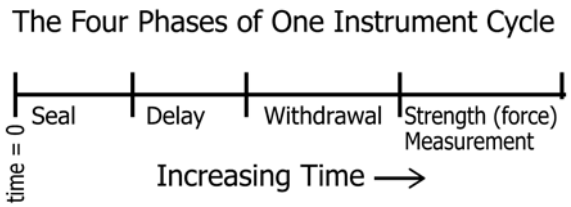
3.1.4.1 *Discussion*—Refer to Fig. 1. The term may be defined somewhat differently when applied to sealing systems involving an adhesive material as a separate component.

3.1.5 *cooling curve, n*—the graphical depiction of the increase in strength of the seal with time, as it cools during the period immediately following conclusion of the sealing cycle (for example, see Fig. 2).

3.1.5.1 *Discussion*—The cooling curve is a plot of hot seal strength versus cooling time. The portion of the cooling curve of greatest practical significance is the first 1000 ms following opening of the heatseal jaws.

3.1.6 *cooling time, n*—time in the instrument cycle between the opening of the seal jaws and the termination of the peel force measurement.

3.1.7 *cycle, n*—the combination of instrument mechanical and electrical operations automatically performed from initiation of sealing through peeling apart a seal and measuring the hot tack strength. The cycle can be broken down into four phases: sealing, delay, withdrawal, and peel.



3.1.8 *delay time, n*—the time interval from when the heatseal jaws open after sealing two film surfaces, to the point at which withdrawal of the sample from between the jaws is initiated.

3.1.9 *dwell time, n*—the time interval during the seal phase when the sealing jaws are in contact with, and exerting pressure on, the material being sealed.

3.1.10 *failure mode, n*—a visual determination of the manner in which the test strip fails during grip separation.

3.1.11 *hot tack strength, n*—force per unit width of a seal needed to peel apart a hot seal measured at a specified time interval after sealing but prior to the seal cooling to ambient temperature.

3.1.11.1 *Discussion*—The desired outcome of the test is to peel apart the seal formed by the test instrument. Other types of film failure in the tensile phase of the instrument test cycle may not represent hot tack strength.

3.1.12 *hot-tack curve, n*—a plot of measured hot-tack strength versus sealing temperature at fixed dwell time and sealing pressure (for example, see Fig. 3).

3.1.12.1 *Discussion*—This is the basic curve used for comparing materials for their hot tack performance. It shows not only the maximum hot seal strength achievable by each material and the sealing temperature required, but also the breadth of the sealing temperature range at any specified level of hot tack. The portion of the curve at higher sealing temperatures may be affected by failure of the substrate rather than the seal and may not be an accurate representation of hot tack strength.

3.1.13 *seal initiation temperature, n*—sealing temperature at which a heatseal of minimum measureable strength is produced.

3.1.14 *sealing pressure, n*—force required, with transfer of heat, to fuse two surfaces together to form a seal. Pressure settings may be different than the actual applied pressure and should be verified as part of instrument calibration.

3.1.15 *sealing temperature, n*—maximum temperature reached at the interface between the two web surfaces being sealed during the dwell time of the sealing cycle.

3.1.15.1 *Discussion*—Sealing temperature will equal jaw temperature (both jaws at same temperature) if the dwell time is long enough for the interface to reach equilibrium with the jaws. At this point, seal strength will no longer rise with increasing dwell time.

3.1.16 *withdrawal time, n*—the time interval from the end of the delay phase to the beginning of the peel of the hot seal.

4. Summary of Test Method

4.1 Two sample strips are sealed by applying pressure from seal jaws under defined conditions of temperature, contact time and pressure. The strips may be either the same film or dissimilar films. Some instrument designs allow the use of a single strip of film which is cut during the sealing phase to form two strips. Either one or both of the seal jaws may be heated. The jaw faces may either be smooth or textured and may be covered with a material to promote release from the hot film.

4.2 When the jaws of the sealing unit open, the sealed strip is automatically withdrawn from between the jaws by retraction of the grips holding the unsealed ends of the strips.

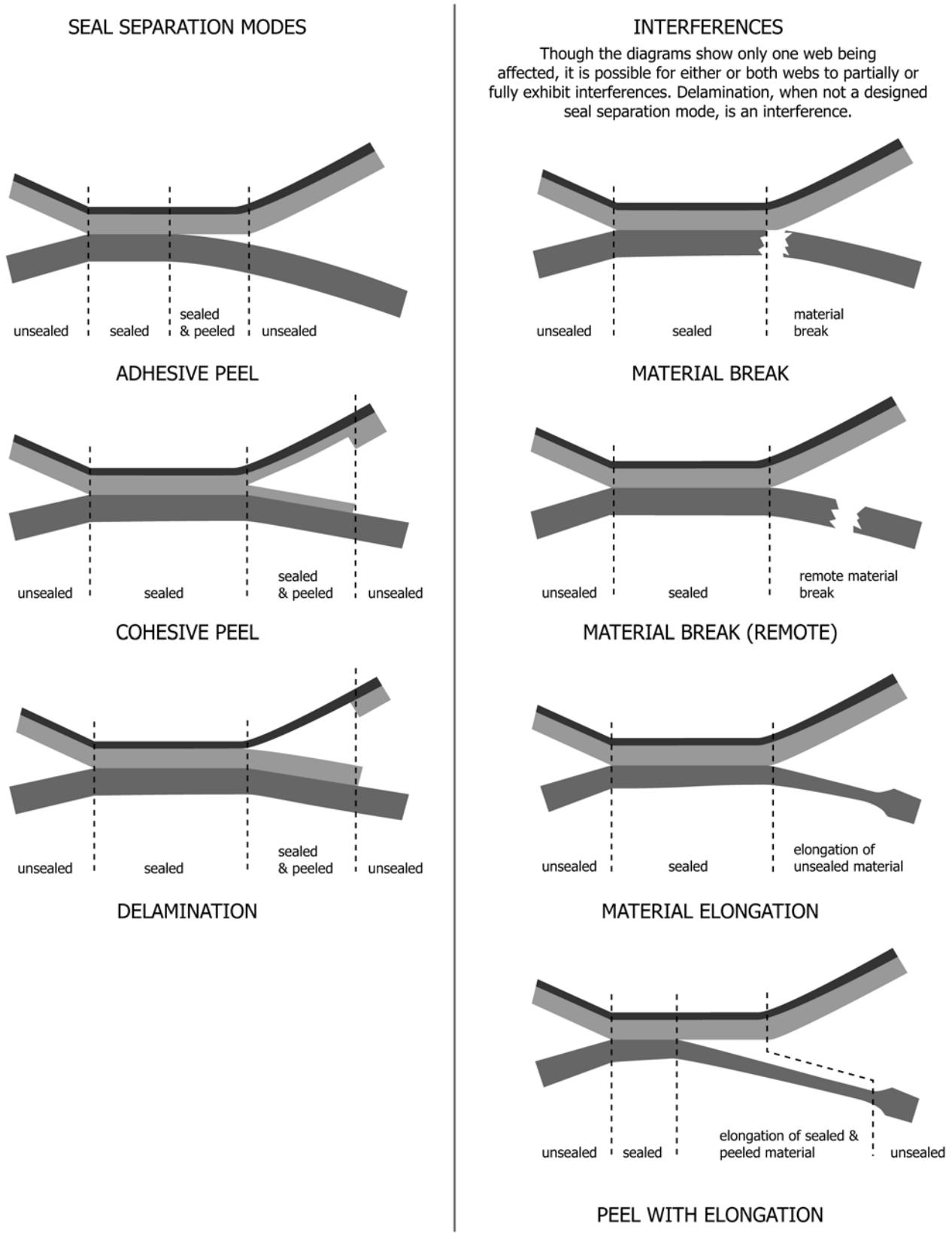
4.3 As the grips move apart at a set speed and the sealed sample is peeled to eventual failure, the force required to peel open the seal is measured by the testing machine.

4.4 In Method A (machines of the Fixed Delay type) the machine measures and plots hot tack strength versus time after jaw opening, starting after a manufacturer-set delay and withdrawal period, which is part of the cooling curve for the material. The computer then measures the force at various user-selectable times (minimum of two), and reports the force as hot-tack strength at those cooling times.

4.5 In Method B (machines of the Variable Delay type) the computer plots maximum hot tack strength versus time after completion of a user-selected delay time. The maximum force encountered during grip travel is determined from that plot and reported as hot-tack strength for the delay time employed in that test.

4.6 In both methods the operator cannot influence the test once the sealing cycle is initiated.

4.7 Hot-tack strength at various sealing temperatures is plotted as the hot-tack curve of the material tested (see Fig. 3).



NOTE 1—Schematic representation of seal failure modes for seals between two webs. No diagram is included for systems including an adhesive as a third component.

FIG. 1 Test Strip Failure Modes

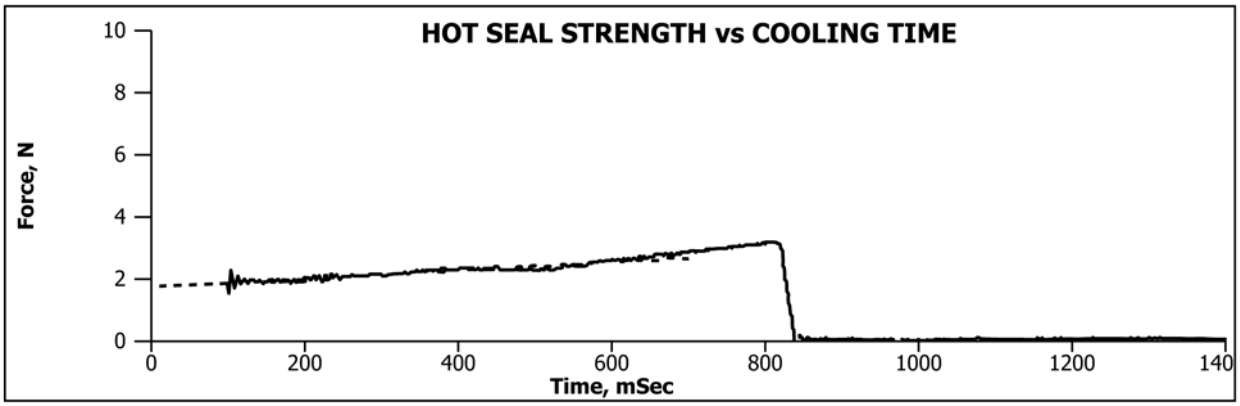


FIG. 2 Cooling Curve

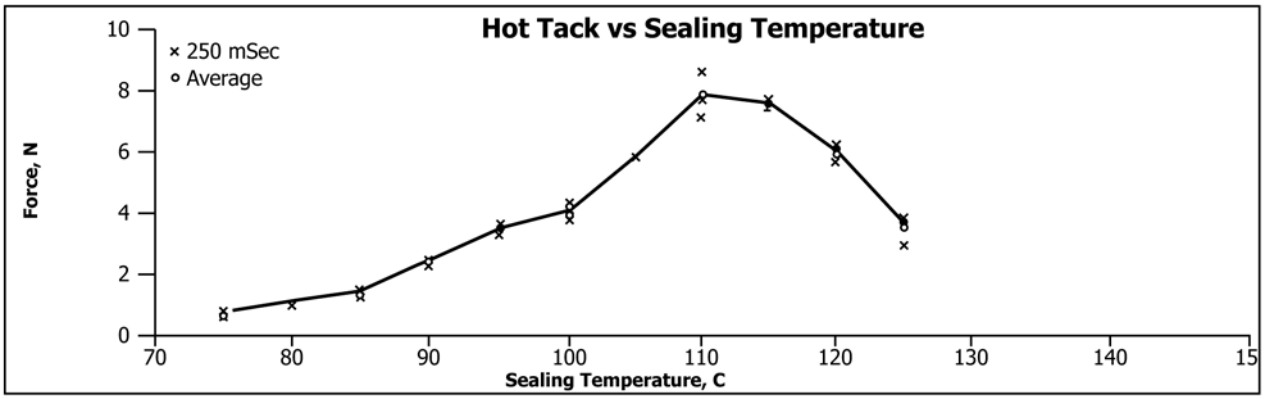


FIG. 3 Hot Tack Curve

4.8 The type of seal failure is noted for each determination.

5. Significance and Use

5.1 In form-fill operations, sealed areas of packages are frequently subject to disruptive forces while still hot. If the hot seals have inadequate resistance to these forces, breakage can occur during the packaging process. These test methods measure hot seal strength and can be used to characterize and rank materials in their ability to perform in commercial applications where this quality is critical.

6. Apparatus

6.1 *Specimen Cutter*—Sized to cut specimens to a width of either 25 mm (0.984 in.), 15 mm (0.591 in.), or 1.00 in. (25.4 mm). Tolerance shall be ±0.5 %. Cutter shall conform to requirements specified in Test Method D882.

6.2 *Testing Machine*[3]—An automated sealing and tensile testing instrument having the following minimum capabilities:

6.2.1 Equipped with two heated jaws for making seals,

6.2.2 User-selectable and precise control of jaw temperatures, dwell time and pressure,

6.2.3 User-selectable constant rate of grip separation,

6.2.4 Automatic activation of the withdrawal and pull cycles when seal jaws open,

6.2.5 Measures the force required to cause failure in the sealed specimen, and

6.2.6 Displays measurements in SI, inch-pound, or mixed units.

7. Instrument Calibration

7.1 Calibration of the hot tack tester should be in accordance with manufacturer's instructions and should include, as a minimum, seal bar temperature, seal bar pressure, phase times, transducer, and withdrawal rate.

7.2 The interval between calibrations may be determined locally based on frequency of use and stability of calibration.

8. Test Specimen

8.1 Conditioning of samples or specimens prior to hot-tack testing is commonly omitted. The atmospheric conditions of Specification E171 are recommended when it is desired to precondition materials to be tested.

8.2 The number of test specimens shall be chosen to permit an adequate determination of representative performance. When hot tack strength is being measured at a series of sealing temperatures, a minimum of three replicates shall be used to determine the mean value at each temperature. When the measurements are not part of a series where an identifiable trend is expected, a minimum of five replicates shall be employed.

[3] For further information on machines, users of these test methods are referred to internet web sites of the various manufacturers.

8.3 Specimens may be prepared by cutting test material in either the machine direction (MD) or the transverse direction (TD). If the direction of seal stress is of concern, the direction in which the samples are cut should be noted in the final report.

8.4 Specimen width may be either 25 mm, 15 mm, or 1.00 in. Test results shall identify the width used. Specimen length must be adequate for the testing machine (range of 25 to 35 cm; 10 to 14 in.).

8.5 A typical hot tack curve may require 25 to 50 specimens of each material.

8.6 Specimens that fail at some obvious film flaw such as a nick or a gel shall be discarded and a resample measurement made.

9. Procedure

9.1 *Sealing Conditions*—Enter values of sealing parameters into machine controller. Sealing conditions for hot tack testing shall be the same for all makes and types of testing machines.

9.1.1 *Temperature*—Set both sealing jaws to the same temperature, which will vary depending on the properties of the material under test. In running a hot tack curve, temperature is set initially to a low temperature and typically increased in 5°C to 10°C intervals, although to locate maxima or other features of the curve smaller steps may be desirable locally. The first temperature point of the curve is typically at about the seal initiation temperature.

9.1.2 *Dwell Time*—Must be long enough for the sealing interface to come to the known temperature of the jaws, which depends on the thickness and construction of the material. Typical minimum dwell times:

Films—25 μ (1 mil) and thinner: dwell time, 500 ms (0.5 s).
Films—25 μ to 64 μ (1 to 2.5 mil): dwell time, 1000 ms (1 s).

9.1.3 *Sealing Pressure*—Set pressure in the range of 15 to 30 N/cm2 (22 to 44 psi).[4]

9.2 Clamp the strip to be tested in the machine grips, observing alignment precautions and proper orientation of the heatseal side in accordance with the manufacturer's instructions.

9.3 *Measurement of Hot Tack Strength*—Enter the desired instrument cycle parameters into the machine controller. The following parameters are commonly used for routine hot-tack testing, but may be varied over the ranges provided by each machine manufacturer, depending on the intended application of the data. Values of all instrument cycle parameters must be included in the report.

9.3.1 *Method A (Fixed Delay)*—Typical test parameters:

Cooling times for hot tack measurements:	Minimum of two settings, in ms
Clamp separation rate:	200 cm/min

9.3.2 *Method B (Variable Delay)*—Typical test parameters:

Delay time (user-selectable):	100 ms
Clamp separation rate:	1200 cm/min

9.4 Start the machine. It will progress through the seal, delay, withdrawal, and hot tack strength-testing phases of the test cycle, and automatically record numerical test data.

9.5 Remove strip from grips. Observe and record mode of specimen failure. For meaningful evaluation and comparison of materials, in all test methods and with all types of testing machines, this step is essential. The mode of failure shall be determined visually for each specimen tested, in accordance with the following or a similar classification, and the results included in the test report:

Failure Mode, see Fig. 1 (equivalent to Test Method F88, Fig. 4)
Adhesive failure of the seal; peel
Cohesive failure of the material
Delamination of surface layer (s) from substrate
Break of material at seal edge
Break or tear of material remote from seal
Elongation of material
Peel with Elongation of material

Frequently, more than one mode will occur in the course of failure of an individual strip. Record all modes observed.

9.6 After three or more replicates have been run, the computer calculates, displays and records the average and standard deviation values when so programmed.

9.7 After all specimens have been tested at the current temperature level, set the machine to the next temperature and proceed with testing to develop data for the hot tack curve. Leave all other variables constant.

9.8 The end point of the hot tack curve is when increasing temperature levels cause a progressive decrease in the force to failure. In this region of the curve, the specimen can fail by a variety of non-peel methods, such as excessive stretch, breaking, tearing, distortion, shrinkage, or burnthrough, to name a few.

10. Calculation

10.1 Computer-controlled versions of the testing machines previously listed do all required calculations automatically. Other versions may require statistical calculations by the operator.

10.2 For each series of tests, the arithmetic mean of all test values shall be calculated to three significant figures when the force value is, respectively, 1.00 lb, 1.00 N, or 100 g or above, and to two significant figures when the force value is below those levels.

10.3 The standard deviation (estimated) shall be calculated as described in Test Method D882 and reported to two significant figures.

11. Report

11.1 Report the following information, with values in SI units:

11.1.1 *General Information:*

11.1.1.1 Date of testing,

11.1.1.2 Operator,

11.1.1.3 Machine—type and model, and

11.1.1.4 Laboratory ambient temperature and humidity.

11.1.2 *Materials Tested*—Complete ID as appropriate. Include test strip parameters, such as direction of cut.

11.1.3 *Instrument Cycle Parameters* for the method used:

11.1.3.1 Method A (Fixed Delay)

(1) Cooling Times for the reported hot tack strength

[4] Force per unit area of seal.

TABLE 1 Force, Method A PE (*N*)

Temp (°C)	Average[A] $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
100	-2.67	23.31	24.04	65.28	67.31
105	5.00	13.33	18.37	37.32	51.44
110	8.75	7.62	17.42	21.32	48.79
115	39.87	12.84	39.69	35.94	111.12
120	167.33	31.78	76.68	88.98	214.70
125	215.39	15.86	132.06	44.41	369.76
130	257.56	34.44	212.17	96.42	594.09
135	332.60	23.11	175.04	64.72	490.10
140	415.33	86.41	191.59	241.96	536.46
145	285.44	114.82	118.99	321.48	333.17
150	124.67	183.90	183.90	514.93	514.93

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

TABLE 2 Force, Method A Ionomer (*N*)

Temp (°C)	Average[A] $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
75	44.67	4.16	4.16	11.66	11.66
80	82.67	19.47	78.61	54.52	220.12
85	219.61	55.71	89.24	155.98	249.88
90	233.94	52.96	125.32	148.28	350.89
95	282.67	34.47	152.18	96.51	426.10
100	293.33	38.45	167.35	107.66	468.59
105	311.72	39.75	156.99	111.29	439.57
110	349.56	35.06	138.17	98.16	386.88
115	305.44	25.69	185.64	71.92	519.79
120	290.06	44.10	179.18	123.48	501.70
125	295.78	38.64	165.34	108.20	462.96
130	260.78	39.73	183.36	111.24	513.41
135	243.25	52.72	206.40	147.61	577.93
140	319.17	37.97	166.18	106.31	465.29

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

TABLE 3 Force, Method B PE (*N*)

Temp (°C)	Average[A] $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
80	33.00	9.54	9.54	26.71	26.71
90	78.64	44.94	82.46	125.82	230.90
95	112.56	41.31	77.11	115.66	215.90
100	137.86	48.03	92.14	134.49	257.99
105	254.75	81.40	195.23	227.92	546.64
110	433.15	32.89	225.68	92.08	631.91
115	643.54	39.08	270.12	109.43	756.32
120	776.25	89.34	380.38	250.16	1065.08
125	695.57	59.34	301.54	166.15	844.32
130	756.61	45.86	217.07	128.42	607.79
135	718.22	52.00	200.37	145.61	561.04
140	684.61	53.97	248.03	151.11	694.48
145	843.61	32.25	226.47	90.29	634.12
150	599.48	69.75	69.75	195.29	195.29

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

(2) Grip Separation Rate

11.1.3.2 Method B (Variable Delay)

(1) Delay Time

(2) Grip Separation Rate

11.1.4 *Hot Tack Strength Results:*

TABLE 4 Force, Method B Ionomer (*N*)

Temp (°C)	Average[A] $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
60	83.75	43.87	79.77	122.85	223.34
65	103.26	12.59	100.21	35.25	280.58
70	127.09	38.32	72.63	107.30	203.37
75	220.17	39.55	46.99	110.74	131.57
80	302.94	38.74	143.33	108.48	401.32
85	454.15	37.28	170.11	104.38	476.32
90	590.92	56.91	216.51	159.34	606.23
95	616.92	31.68	195.26	88.71	546.73
100	668.53	57.24	211.19	160.28	591.33
105	728.44	40.04	213.22	112.11	597.01
110	732.92	28.81	207.68	80.68	581.51
115	745.33	57.55	171.29	161.15	479.60
120	650.89	65.29	141.19	182.81	395.32
125	713.19	49.41	137.48	138.36	384.96
130	604.43	92.57	156.69	259.19	438.73
135	540.55	53.87	145.51	150.84	407.42
140	459.33	54.37	174.82	152.23	489.50

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

11.1.4.1 Average force and standard deviation, and

11.1.4.2 Hot tack curve.

11.1.5 *Failure Modes.*

11.1.6 *Observations and Comments.*

12. Precision and Bias

12.1 The precision of this test method is based on an interlaboratory study of F1921, Test Methods for Hot Seal Strength (Hot Tack) of Thermoplastic Polymers and Blends Comprising the Sealing Surfaces of Flexible Webs in 2011. A total of eight laboratories tested two different polymer plastic packaging films, by Methods A and B, at up to nineteen different temperatures. Each temperature was considered to be an independent study; precision and bias were determined using the test results for each temperature. Every test result represents the average of three individual determinations. Except for the limited amount of data reported at several of the material / temperature combinations, Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:F02-1031.[5]

12.1.1 *Repeatability limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

12.1.1.1 Repeatability limits are listed in Tables 1-4 below.

12.1.2 *Reproducibility limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

[5] For a copy of the draft Research Report, please contact Caitlin Farrell at cfarrell@astm.org

12.1.2.1 Reproducibility limits are listed in Tables 1-4 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 statements 9.1.1 and 9.1.2 would have an approximate 95 % probability of being correct.

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 857 results, from a total of eight laboratories, on two materials, by alternative methods, at nineteen different temperatures.

12.4 *Hot Tack Curves*—The output of either Method A or Method B is a hot tack curve. Figs. 4 and 5 compares the average results of Method A and Method B for each of the test films.

12.4.1 The interpretation of hot tack curves has always rested on the relationship between seal bar temperature and seal strength. Acceptance or rejection of materials has rested on what combination of sealing variables gave the broadest region of maximum seal strength. It is shown in Figs. 4 and 5 that this is a relative measure. Method A results are less than Method B results in an absolute sense, but both methods give the same basic curve and would provide practical guidance for film performance in vertical form-fill-seal applications.

13. Keywords

13.1 heatseal; heatsealability; hot tack; seal strength

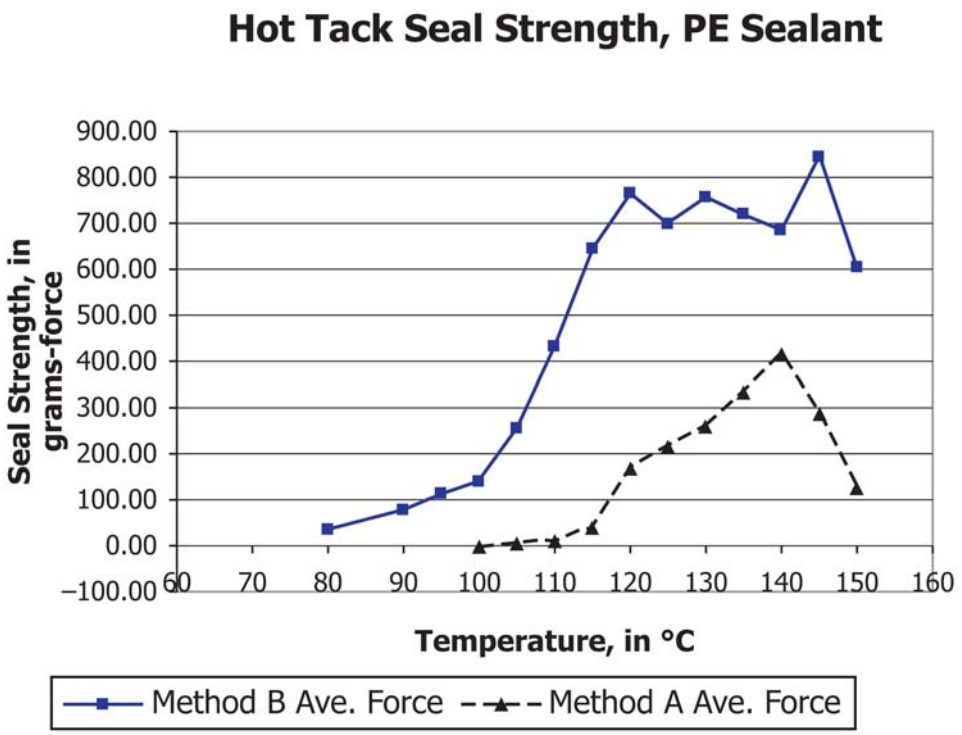


FIG. 4 Hot Tack Seal Strength, PE Sealant

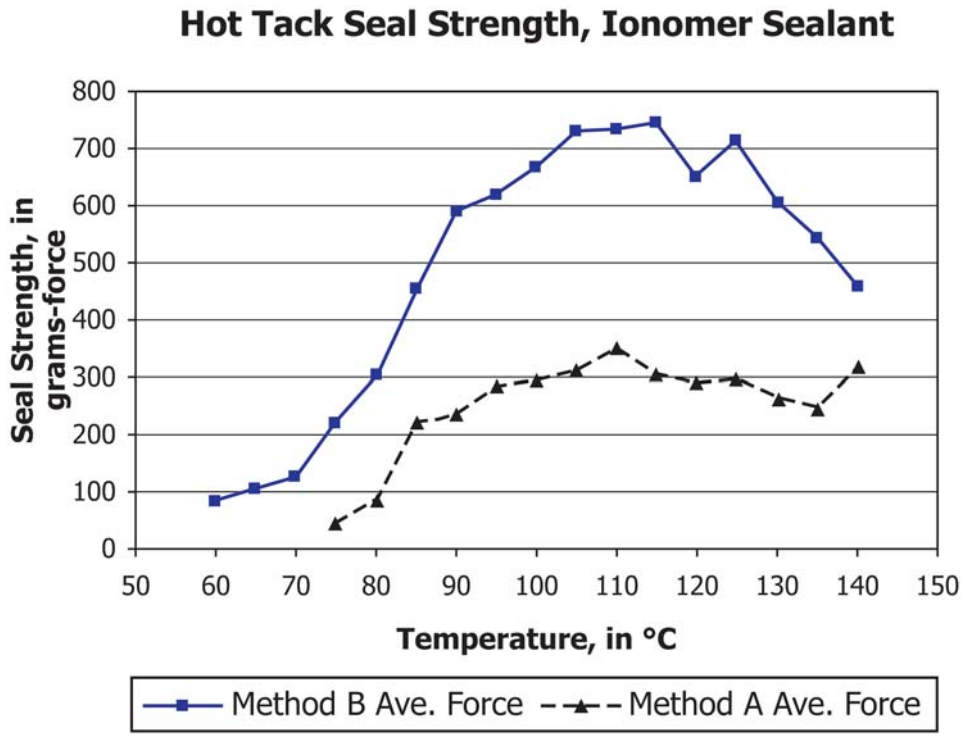


FIG. 5 Hot Tack Seal Strength, Ionomer Sealant

APPENDIX

(Nonmandatory Information)

X1. COMPARISION OF METHODS A (Fixed Delay) and B (Variable Delay)

X1.1 *Timing of Data Acquisition*—A basic principle of hot tack testing is to measure the strength of the hot seal as soon as possible after the sealing jaws open, since the seal starts to cool immediately and, as it cools, it gains strength. But before the strength can be measured, the seal must be withdrawn from the jaws and the slack must be removed from the test strip. A second principle—that is a fundamental difference between the instrumented methods of these test methods and non-instrumented methods—is to control or measure the time span between jaw opening and the point in time when hot tack readings are taken. Since Methods A and B approach these points differently, the differences that affect timing are compared as follows:

X1.1.1 *Method A*—Machine type: Fixed Delay.

X1.1.1.1 *Delay Time*—The machine is set by the manufacturer to start withdrawal of the seal 5 to 10 ms after the jaws open.

X1.1.1.2 *Withdrawal Time*—Depends on grip speed (about 75–150 ms), also set by the manufacturer.

X1.1.1.3 *Time When Seal Strength Measurement Starts*—After the completion of the combined delay-withdrawal period.

X1.1.1.4 *Time When Hot Tack Readings are Taken*—250 ms and later (minimum of two times), but may be shorter.

X1.1.2 *Method B*—Machine type: Variable Delay.

X1.1.2.1 *Delay Time*—User-Selectable.

X1.1.2.2 *Withdrawal Time*—Depends on grip speed.

X1.1.2.3 *Time When Seal Strength Measurement Starts*—After the completion of the combined delay-withdrawal period.

X1.1.2.4 *Time When Hot Tack Reading is Taken*—The maximum force reading encountered during the measurement cycle is recorded. The time after jaw opening that this occurs varies with delay time, grip speed, and sample being tested.

X1.2 *Speed of Testing*—The force required to peel heatseals increases with peel rate. Method B is typically run at higher clamp separation rates than Method A, and normally gives higher values for hot tack strength.

X1.3 In peel testing, when movement of the grips holding the test strip is translated completely into peeling the seal apart, the peel rate is 50 % of the grip separation rate.

X1.4 As the grips of the testing machine separate, any stretch, delamination, or other elongation of the test strip except for peel of the heatseal, results in a decrease in peel rate. Peel rate is then no longer determined directly by the set rate of grip separation. This reduction in peel rate affects peel force.