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 F 1921; 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 These 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.

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.

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]

D 882 Test Methods for Tensile Properties of Thin Plastic Sheeting

E 171 Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials

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

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

3.1.3 *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.

3.1.3.1 *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.

3.1.4 *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 (see Fig. 2).

3.1.4.1 *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.

3.1.5 *cooling time*, *n*—the time interval from when the heatseal jaws open at conclusion of the sealing cycle, to the point at which the hot-tack force is determined.

3.1.6 *delay time*, *n*—the time interval from when the heatseal jaws open at conclusion of the sealing cycle, to the point at which withdrawal of the sample from between the jaws is initiated.

[1] These test methods are under the jurisdiction of ASTM Committee F02 on Flexible Barrier Materials and are the direct responsibility of subcommittee F02.30 on Test Methods.

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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.

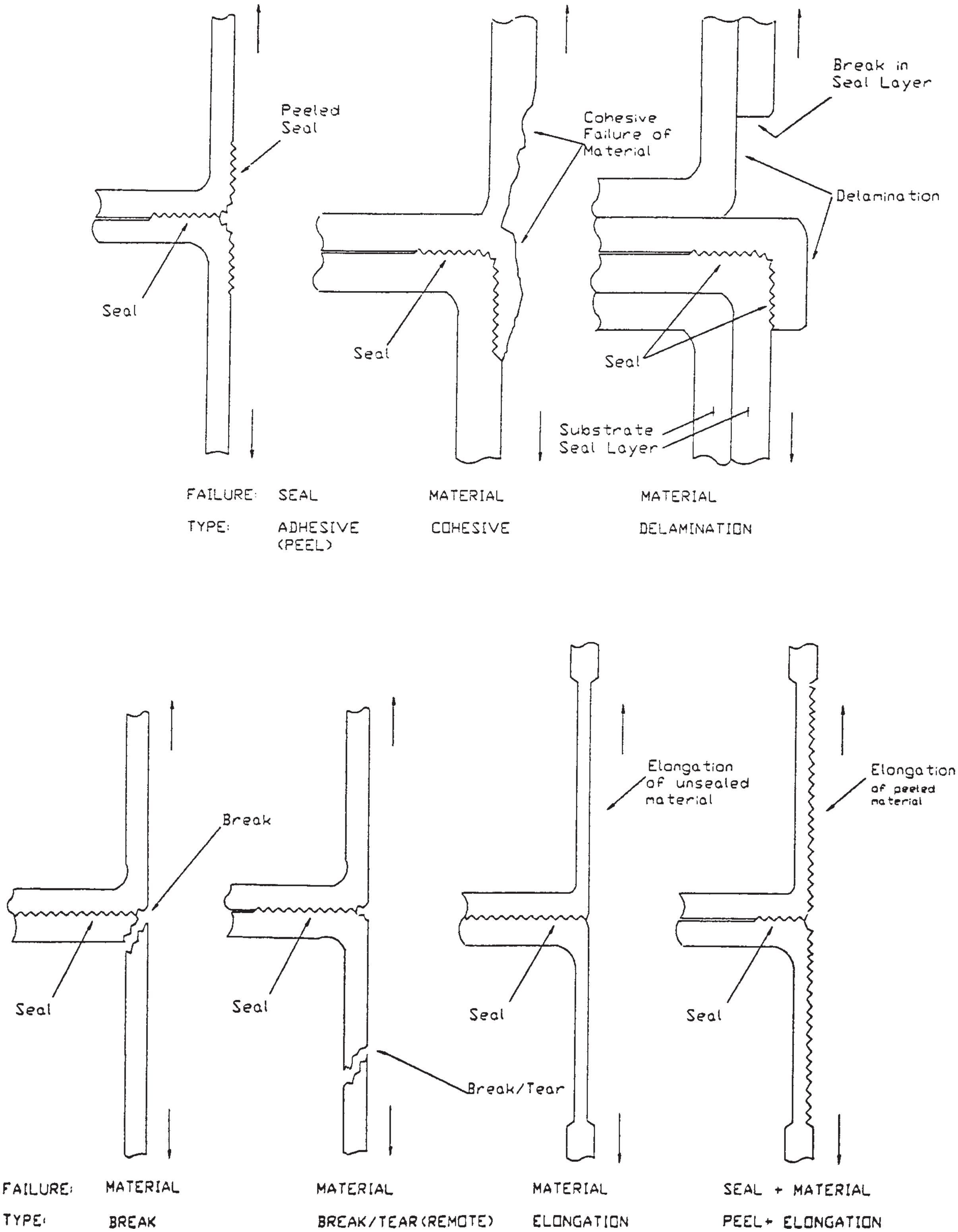

FIG. 1 Test Strip Failure Modes

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

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

3.1.9 *hot tack*, *n*—strength of a hot seal measured at a specified time interval after completion of the sealing cycle but prior to the temperature of the seal reaching ambient.

3.1.10 *hot-tack curve*, *n*—a plot of hot-tack strength versus sealing temperature (see Fig. 3).

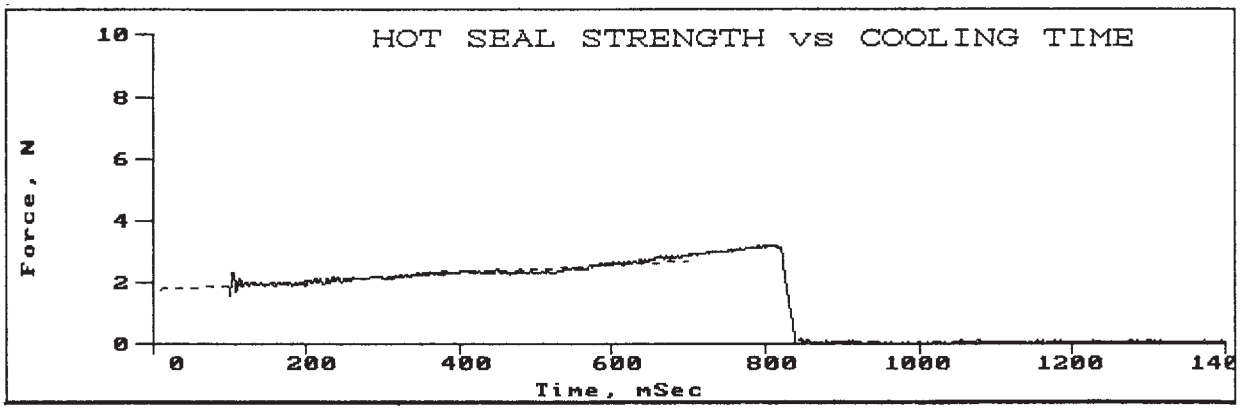

FIG. 2 Cooling Curve

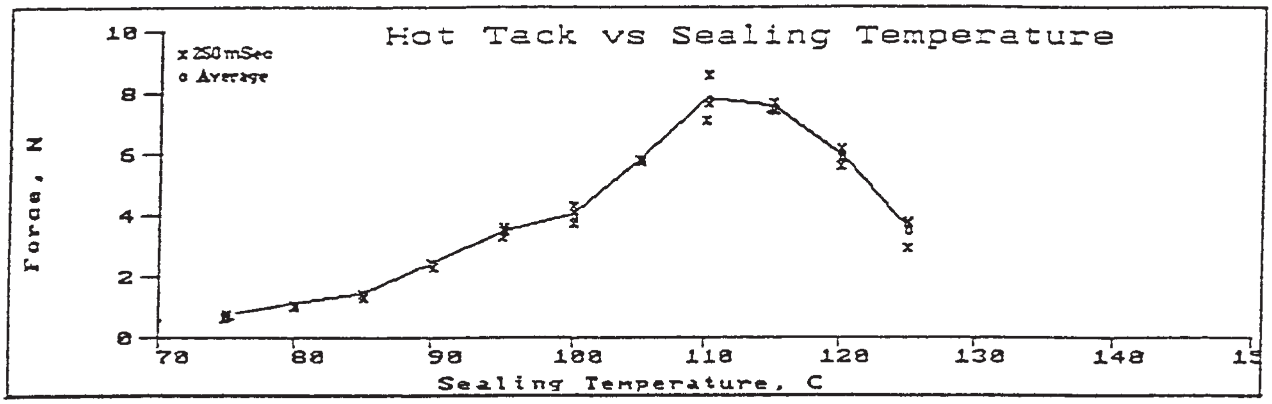

FIG. 3 Hot Tack Curve

3.1.10.1 *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.

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

3.1.11.1 *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.

3.1.12 *withdrawal time*, *n*—the time interval from when withdrawal is initiated, to the point in time when all slack has been removed from the test strip between the seal and the grips, so that measurement of the strength of the seal can commence.

4. Summary of Test Method

4.1 A sample strip is sealed by applying pressure from two flat heated jaws under defined conditions of temperature, contact time and pressure.

4.2 When the jaws of the sealing unit open, the sealed strip is automatically withdrawn from between the jaws at conclusion of a set delay time (which may be zero), by retraction of the grips.

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

4.4 In Method A (machines of the Theller type) the machine measures and plots strength versus time after jaw opening, starting after a withdrawal period of 100 to 150 ms, which is the cooling curve for the material. The computer then determines the force coordinates of the curve at various times, and reports the values as hot-tack strength at those cooling times. The machine is factory-set to start withdrawal within 10 ms after jaw opening.

4.5 In Method B (machines of the DTC and J & B type) the computer plots strength versus time after completion of a set 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).

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 D 882.

6.2 *Testing Machine*[3]—Equivalent to those available from DTC, Theller, and J & B, with the following minimum capabilities:

6.2.1 Equipped with two heated jaws for making seals,

6.2.2 Variable and precise control of jaw temperatures, dwell time and pressure,

6.2.3 Variable 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 units.

7. Test Specimen

7.1 Conditioning of samples or specimens prior to hot-tack testing is commonly omitted. The atmospheric conditions of Specification E 171 are recommended when it is desired to precondition materials to be tested.

7.2 The number of test specimens shall be chosen to permit an adequate determination of representative performance. When hot tack is being measured at a series of sealing temperatures, a minimum of three replicates shall be used to determine the mean value for each material 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.

7.3 Specimens shall be prepared by cutting test material in the machine direction (MD). If the material is anisotropic and the data are expected to apply to situations where the material may be stressed transversely, TD specimens shall also be taken.

7.4 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.)

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

7.6 Specimens that fail at some obvious flaw shall be discarded and a resample measurement made.

8. Procedure

8.1 *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.

8.1.1 *Temperature*—Both jaws must be set at same temperature, which will vary depending on the properties of the material under test. In running a hot tack curve, temperature is typically varied in 5 to 10° 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.

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

8.1.3 *Sealing Pressure*—Set pressure in the range of 15 to 30 N/cm^2(22 to 44 psi).[4]

8.2 Clamp the strip to be tested in the machine grips, observing alignment precautions and proper orientation of the heatseal side.

8.3 *Measurement of Hot Seal Strength*— Enter the desired test 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 test parameters must be included in the report.

8.3.1 *Method A (Testing machine: Theller type)*—Test parameters:

Cooling times for hot tack measurements:	ms[5]
Clamp separation rate:	200 cm/min
Air:	5.0[6]

8.3.2 *Method B (Testing machine: DTC and J & B type)*—Test parameters:

Delay time:	100 ms
Clamp separation rate:	200 mm/s [1200 cm/min]

8.4 Start the machine. It will progress through the seal, withdrawal, and strength-testing cycles, and automatically record numerical test data.

8.5 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)
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

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

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

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

[4] Force per unit area of seal.

[5] The machine automatically measures and displays the seal strength at two operator-selectable cooling times.

[6] See manufacturer's description and recommendation. Air circulation can be varied or turned off entirely.

8.7 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.

8.8 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 fails by excessive stretch, breaking, tearing, distortion, shrinkage, burnthrough, etc.

9. Calculation

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

9.2 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.

9.3 The standard deviation (estimated) shall be calculated as described in Test Method D 882 and reported to two significant figures.

10. Report

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

10.1.1 *General Information*:

10.1.1.1 Date of testing,

10.1.1.2 Operator,

10.1.1.3 Machine—type and model, and

10.1.1.4 Laboratory ambient temperature and humidity.

10.1.2 Materials tested; complete ID as appropriate. Include test strip parameters.

10.1.3 Test Parameters.

10.1.4 *Hot Tack Strength Results:*

10.1.4.1 Average force and standard deviation, and

10.1.4.2 Hot tack curve.

10.1.5 Failure modes.

10.1.6 Observations and comments.

11. Precision and Bias

11.1 *Precision*—Interlaboratory tests are in progress.

11.2 *Bias*—The procedures in these test methods have no bias because the values of hot tack are defined in terms of the methods.

12. Keywords

12.1 heatseal; heatsealability; hot tack; seal strength

APPENDIX

(Nonmandatory Information)

X1. COMPARISION OF METHODS

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: Theller.

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

X1.1.1.2 *Withdrawal Device*—Air cylinders.

X1.1.1.3 *Withdrawal Time*—75 ms.[7]

X1.1.1.4 *Measurement Cycle, Motive Device*—Motor and screw.

X1.1.1.5 *Time When Seal Strength Measurement Starts*—100 to 125 ms.[7,8]

X1.1.1.6 *Time When Hot Tack Readings are Taken*—250 ms ± 1 ms.[8] Time of second reading is set by operator.

X1.1.2 *Method B*—Machine type: DTC and J & B.

X1.1.2.1 *Delay time*—Variable.

X1.1.2.2 *Withdrawal Device*—Motor and screw.[9]

X1.1.2.3 *Withdrawal Time*—Depends on set grip speed. 100 ms is typical.

X1.1.2.4 *Measurement Cycle, Motive Device*—Motor and screw.[9]

X1.1.2.5 *Time When Seal Strength Measurement Starts*—Delay Time + Withdrawal Time.

X1.1.2.6 *Time When Hot Tack Reading is Taken*—The maximum 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,

[7] Theller machines with ¼ in. air tubes; higher for other models.

[8] Time after jaws open.

[9] Early models of DTC employ air cylinders.

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.