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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.

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, health, and environmental 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.

1.6 *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

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 Laboratory Heat Seals for Determination of Heat Sealability of Flexible Barrier Materials 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.

[1] These test methods are under the jurisdiction of ASTM Committee F02 on Primary 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.

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

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.

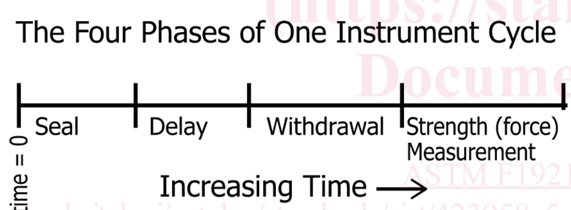
3.1.4.1 *Discussion*—Refer to Fig. 1. The term may be defined somewhat differently when applied to sealing systems involving an adhesive material as a separate component.

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

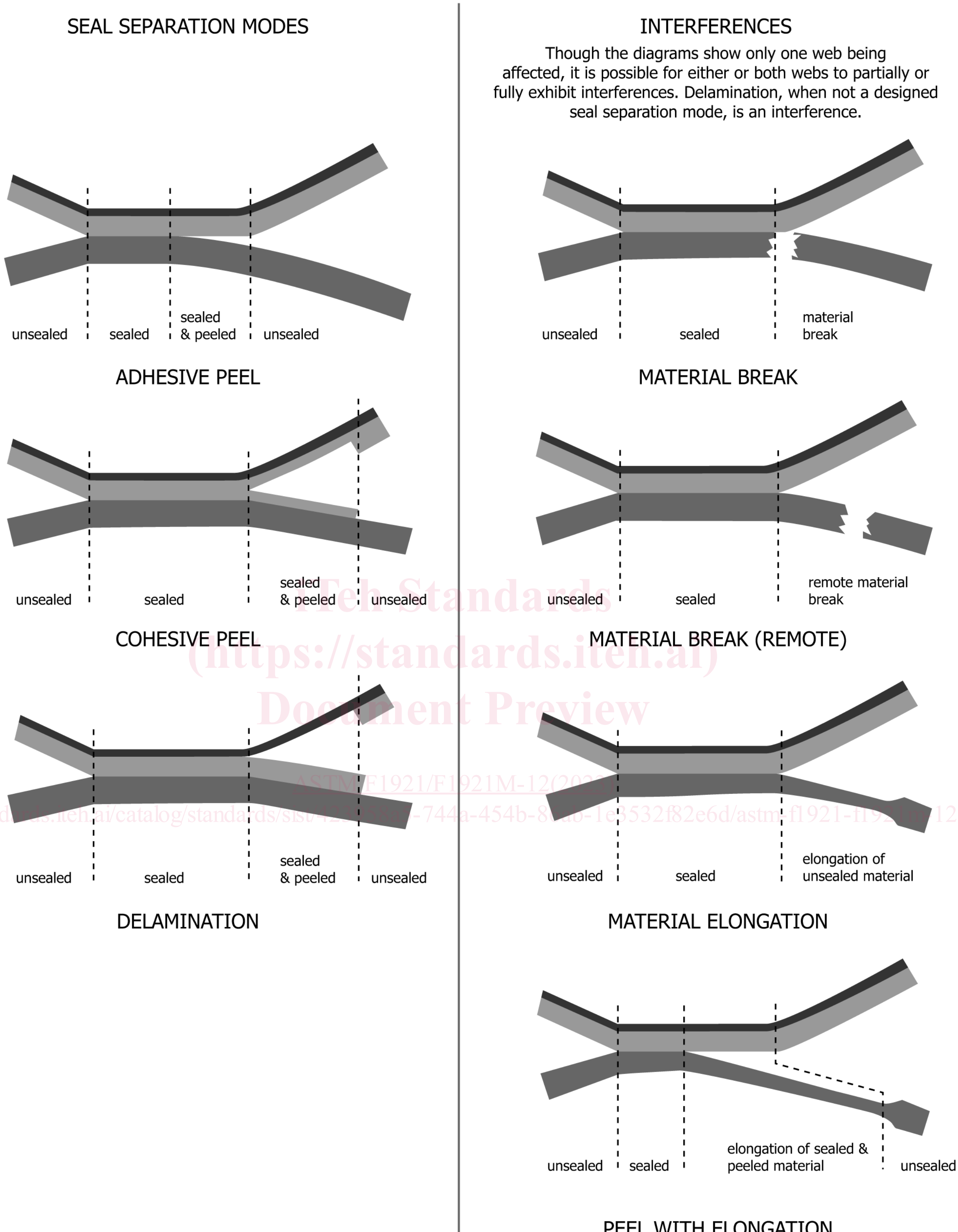
4.1 Two sample strips are sealed by applying pressure from seal jaws under defined conditions of temperature, contact time and pressure. The strips may be either the same film or dissimilar films. Some instrument designs allow the use of a single strip of film which is cut during the sealing phase to 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.



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

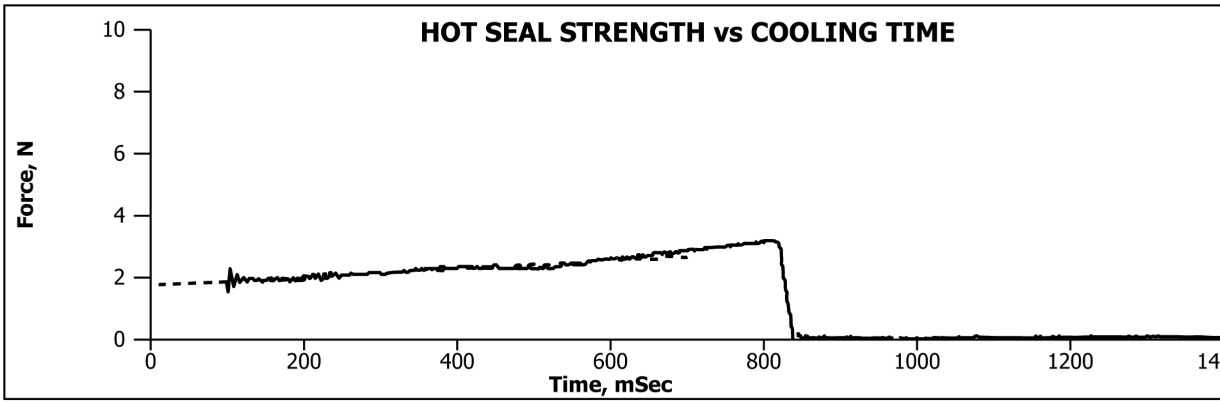


FIG. 2 Cooling Curve

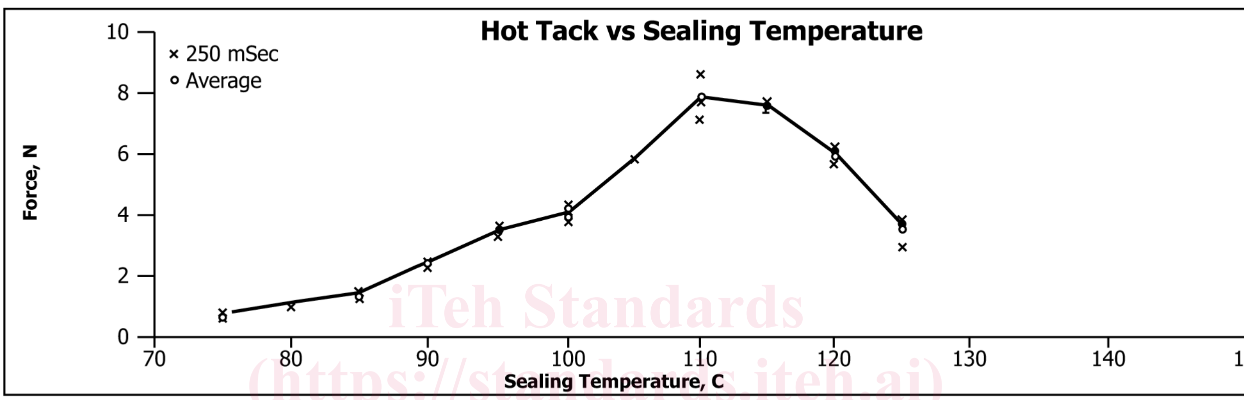


FIG. 3 Hot Tack Curve

4.6 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).

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

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

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.

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 cm to 35 cm; 10 in. 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 mil to 2.5 mil): dwell time, 1000 ms (1 s).

9.1.3 *Sealing Pressure*—Set pressure in the range of 15 N⁄cm2 to 30 N⁄cm2 (22 psi 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

[4] Force per unit area of seal.