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Standard Practices for Making Heatseals for Determination of Heatsealability of Flexible Webs as Measured by Seal Strength[1]

This standard is issued under the fixed designation F 2029; 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 practices cover laboratory preparation of heatseals and the treatment and evaluation of heatseal strength data for the purpose of determining heatsealability of flexible barrier materials.

1.2 Testing strength or other properties of the heatseals formed by these practices is not included in this standard. Refer to Test Methods F 88 for testing heatseal strength.

1.3 The practices of this standard are restricted to sealing with a machine employing hot-bar jaws. Impulse, high-frequency, and ultrasonic heating methods are not included.

1.4 These practices apply primarily to webs intended to be used on commercial machines employing reciprocating sealing jaws, such as most vertical form-fill packaging machines, platen heatsealers, etc. Conditions of dwell time and sealing pressure on machines of this type typically are different from those on rotary machines by an order of magnitude or more.

1.5 The procedures of these practices with respect to choice of heatsealing conditions apply equally whether the application is to ultimate seal strength or hot tack measurement.

1.6 Seals may be made between webs of the same or dissimilar materials. The individual webs may be homogeneous in structure or multilayered (coextruded, coated, laminated, etc.).

1.7 Strength of the heatseal is the criterion for judging heatsealability employed in these practices.

1.8 Determination of heatsealability as judged by seal continuity, typically measured by air-leak, dye penetration, visual examination, microorganism penetration or other techniques, are not covered by these practices.

1.9 Two variations of the heatsealing procedure are described herein, differing in whether the objective of the testing is to determine, the heatsealability of the surface, or how well the entire web would heatseal in applications where the sealing interface may not reach jaw temperature.

1.9.1 *Practice A, Heatsealability of a Surface*—This method measures sealability of the web surface, or sealant layer if there is one, as a function of interface temperature, which is independent of the influence of other web characteristics, such as total thickness and construction.

1.9.2 *Practice B, Web Sealability at Short Dwell Time*—The test seal is made at a dwell time shorter than required for the sealing interface to reach the jaw temperature level, simulating conditions on high-speed vertical form-fill machines, or on slower machines where the condition of nonequilibrium also exists. The resulting heatseal strength, under nonequilibrium conditions, is then dependent not only on characteristics of the web's sealing surface, but also on web thickness, construction, and other factors affecting rate of heat transfer from jaws to the sealing interface. These include machine factors; (for example, anti-stick jaw treatments, etc).

1.10 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*

F 88 Test Methods for Seal Strength of Flexible Barrier Materials[2]

F 1921 Test Methods for Hot Seal Strength (Hot Tack) of Thermoplastic Polymers and Blends Comprising the Sealing Surfaces of Flexible Webs[2]

3. Terminology

3.1 *Definitions:*

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

3.1.2 *equilibrium dwell time*, *n*—any dwell time in excess of that required for the seal strength to reach its maximum level for the jaw temperature employed.

3.1.2.1 *Discussion*—Applies only when both jaws are at equal temperature (see Annex A1.3).

3.1.3 *heatseal curve*, *n*—a plot of apparent seal strength versus sealing temperature.

3.1.3.1 *Discussion*—This is the basic curve for comparing sealability of materials. It plots the force required to extend a sealed test strip to failure, as a function of sealing temperature. The portion of the curve at higher sealing temperatures may be

[1] These practices are under the jurisdiction of ASTM Committee F2 on Flexible Barrier Materials and are the direct responsibility of Subcommittee F02.30 on Test Methods.

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[2] *Annual Book of ASTM Standards*, Vol 15.09.

affected by failure of the substrate and may not be an accurate representation of seal strength.

3.1.4 *heatseal strength*, *n*—force required to peel the seal apart, per unit width of seal.

3.1.4.1 *Discussion*—In many tests of seal strength it is not the seal that fails, it is the substrate. In those tests, the true heatseal strength may be somewhat higher than the measured force that caused the specimen to fail. Homogeneous materials with fusion seals, for example, commonly break along a line immediately adjacent to the seal, while the seal itself remains intact (see Test Methods F 88).

3.1.5 *heatsealability*, *n*—the property of thermoplastic polymers and blends, when comprising a surface of a flexible web, that defines how well the material heatseals.

3.1.5.1 *Discussion*—How well the material heatseals is expressed quantitatively as seal strength as a function of the sealing conditions of temperature, time, and pressure. Since strength of a heatseal can be measured either while the seal is still hot (hot tack) or after cooling and stabilizing (ultimate strength), a complete evaluation of heatsealability of a material must include both tests.

3.1.6 *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. Refer to Test Methods F 1921.

3.1.7 *seal initiation temperature*, *n*—the sealing temperature at which a heatseal of significant strength (0.5 N/cm; 125 g/25 mm; 0.3 lb/in.) is produced.

3.1.8 *sealing interface*, *n*—the interface between two web surfaces being sealed.

3.1.9 *sealing pressure*, *n*—the force per unit area of seal applied to the material during the sealing process.

3.1.9.1 *Discussion*—During the dwell time, the sealing pressure pulse rises from zero usually to a plateau level and then drops to zero. Frequently, there is an initial spike. Very short dwell times may not have a plateau. Sealing pressure is completely described by the curve of pressure versus time, but two parameters from the curve commonly are used instead to characterize the pressure variable. One is a calculated average pressure, that excludes the initial rise, as well as, the terminal fall of pressure, and the other is the maximum value reached either during any initial impact spike or later.

NOTE 1—A common error is to report air pressure in the cylinder applying the force as the sealing pressure.

3.1.10 *sealing temperature*, *n*—maximum temperature reached at the sealing interface during the dwell time of a sealing cycle.

3.1.10.1 *Discussion*—Sealing temperature will equal jaw temperature (both jaws at same temperature) if the dwell time is long enough for the interface to reach temperature equilibrium with the jaws. This point has been reached when seal strength no longer rises with increasing dwell time.

3.1.11 *ultimate seal strength*, *n*—the final value of strength that is reached after the heatseal has both cooled to ambient temperature and achieved stability in strength.

3.1.11.1 *Discussion*—Some materials, when cooling from a melt, continue to change in strength over extended periods of time after reaching ambient temperature.

4. Significance and Use

4.1 *Practice A, Surface Heatsealability*—This practice leads to determining the heatsealability of a surface, or sealant layer if there is one, as a function of interface temperature, free of the influence of other web properties. Commercially, its applications are in development of improved polymers and blends to be used as the sealant layer in coextruded films and laminated and coated web constructions. Also it is the appropriate method for quality control in manufacture of those films and laminations, since a QC test should be affected by the property being tested for, for example, heatsealability of the surface, and, so far as possible, not by other properties of the web, for example, total thickness, that are measured independently by other methods.

NOTE 2—Sealant-layer thickness may affect surface heatsealability.

4.2 *Practice B, Web Sealability*—While it is necessary to have a heatseal surface layer that has adequate seal strength for the application, the web also will have a specific construction and total thickness, both chosen to satisfy requirements other than heatsealability. Practice B compares specific web constructions for their suitability for applications where the dwell time may be too short for the sealing interface to reach jaw temperature. With this test method, both web construction and thickness, in addition to properties of the sealant layer, affect sealing performance. If the rate of heat transfer through the web due to its construction or total thickness is too slow for the production rate required, it may be necessary to use a sealant layer with a lower seal-inception temperature or fusion temperature.

5. Apparatus

5.1 *Heatsealer*:

5.1.1 *Sealing Jaws*—Two-heated jaws with flat sealing surfaces. Two-heated jaws are required to conduct Practice A. Practice B may be used with one-heated jaw only when the application is to commercial sealers with like configuration.

5.1.1.1 *Jaw Temperature Control*—Each jaw must have independent temperature control. The recommended minimum precision of control is ± 1°C.

5.1.1.2 *Jaw Coatings or Coverings*—Anti-stick or compressible jaw coatings or coverings, such as TFE-fluorocarbon, TFE-fluorocarbon/glass cloth, silicone rubber or other heat-resistant rubbers, polyester film, etc., are admissible, although test conditions may require adjustment in some cases.

5.1.1.3 *Jaw Sealing Surfaces*, must be capable of being aligned for parallelism.

5.1.1.4 *Capability for Quick Jaw Change* to serrated or other jaw styles is desirable to increase the machine's range of simulation testing.

5.1.2 *Dwell Time*—Variable control and readout of dwell time, with minimum range of 100 to 10 000 ms.

5.1.2.1 Time of jaw closure should be measured directly (as by force sensor output, micro switch, optically, etc.), and controlled therefrom.

5.1.2.2 Precision of dwell time control should be ± 10 ms or better.

5.1.3 *Pressure*, variable control, with readout of sealing pressure.

5.1.3.1 *Machines*, that have only an air pressure gage from which sealing pressure must be calculated, should be provided with nomographs from which sealing pressure can be read directly from air pressure measurements.

6. Test Specimen

6.1 The number of test specimens shall be chosen to permit an adequate determination of representative performance. When heatseal strength will be 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 will not be part of a series where an identifiable trend is expected, a minimum of five replicates shall be employed.

6.2 In planning the number of specimens required, note that only one strength test should be made from each heatseal.

6.3 Specimens for heatsealing can be prepared by cutting the test material into pieces 15 by 15 cm [6 by 6 in.]. Mark the transverse direction and the seal side of each piece. Superimpose the two pieces to be sealed, with the transverse directions parallel and the seal surfaces facing each other. If a group of specimens is to be prepared prior to sealing, it is convenient to staple the pairs, with caution to avoid staples in the areas to be sealed and from which the test strip will be cut subsequently. Seal the specimens with the jaws parallel to the transverse direction. A strip for seal-strength testing will subsequently be cut perpendicular to the seal at its center, and the seal will be peeled by pulling the strip in the machine direction of the web.

NOTE 3—The seal must be located on the specimen so the legs of the strip on each side of the seal will be long enough to span the distance between the grips of the testing machine.

6.4 Alternatively to sealing a wide specimen and then cutting a strip for strength testing, strips of the width for strength testing may be cut in the machine direction and sealed, either to strips of similar material or to dissimilar strips. The sealed strip may then be tested for strength without further preparation. This alternative is mandatory for hot-tack testing. Comparisons should be made only among specimens sealed by the same procedure.

6.4.1 When using sealing machines that automatically load and seal a specimen strip without operator intervention, sealing of dissimilar materials is accomplished by preparing a specimen strip that is a composite of the two materials to be sealed, taped together at the center. Refer to the machine manufacturer's recommendations for details appropriate to the machine used.

NOTE 4—**Caution:** Be sure to adjust the seal area factor in calculating sealing pressure when switching from a wide seal to a strip seal.

6.4.2 Common strip widths are 25 mm (1.00 in.) and 15 mm (0.59 in.).

6.5 If the material is anisotropic and the data are expected to apply to situations where the seal may be stressed transversely, specimens cut perpendicular to those described in 6.3 also shall be taken.

7. Procedure

7.1 *Calibration and Alignment*—Prior to starting testing, insure that the heatsealer is in proper calibration and that the jaws have been aligned for parallelism.

7.2 *Sealing Conditions*, for heatsealability testing, either ultimate seal strength or hot tack, shall be within the ranges specified below for all makes and types of heatsealers.

7.2.1 *Practice A, Surface Sealability:* Heatsealability of the web surface as a function of interface temperature.

7.2.1.1 *Temperature*—Both jaws shall be set at the same temperature.

7.2.1.2 *Dwell Time*—The dwell time must be long enough for the sealing interface to come to the known temperature of the jaws. This depends on the thickness and construction of the web, as well as on jaw configuration factors. Typical minimum dwell times (without anti-stick jaw covering):

Films: 1 mil (25µ) and under: dwell time, 500 ms (.5 s).
Films: 1 to 2.5 mil (64µ): dwell time, 1000 ms (1 s).

The minimum required dwell time can be determined from a few trial sealing cycles. Refer to Annex A3.1. This procedure usually will be necessary for thicker films, structures containing paper or foil, or when anti-stick jaw coverings are used.

7.2.1.3 *Sealing Pressure*—Set pressure in the range of 138–413 kPa (20–60 psi). See Appendix X1 for discussion of effect of pressure on heatseal strength.

7.2.1.4 *Jaw Configuration*—Use flat metal jaws, either bare or covered (see 5.1.1.2). Jaws may be steel, copper, or aluminum. Choice of metal, as well as use of a covering, may affect the minimum dwell time required for the interface to reach equilibrium with jaw temperature.

7.2.2 *Practice B, Web Sealability*—Sealability under commercial conditions.

7.2.2.1 *Temperature*—Choice of temperature setting of each jaw (including unheated) is dependent on application of the data. In the absence of reasons to the contrary, it is recommended both jaws be set to the same temperature.

7.2.2.2 *Dwell Time*—Set dwell time at 100 ms to simulate high-speed sealing or other jaw-closure interval depending on specific application.

7.2.2.3 *Sealing Pressure*—Set pressure in the range of 138–413 kPa (20–60 psi), or at other level depending on specific application. See Appendix X1 for discussion of effect of pressure on heatseal strength.

7.2.2.4 *Jaw Configuration*—Same as the commercial application being simulated. In absence of specific information on this point, flat steel jaws covered with TFE-fluorocarbon/glass cloth are recommended.

7.2.3 *Sticking of Specimen to Jaws*—Specimens having a heatsealing surface where the melting range is significantly lower than its opposite surface, usually can be sealed directly with bare metal jaws over most of the desired sealing temperature range.

7.2.3.1 If the specimen is homogeneous throughout, or of ABA construction, enclose it in a folded piece of 10–15µ (approx 0.5 mil) polyester film during the sealing cycle to avoid sticking to the jaws. Alternatively, cover the jaws with 75µ (3 mil) TFE-fluorocarbon/glass cloth, or tape. See Annex A2.

7.3 *Heatseal Curve*—To generate the curve, temperature is typically varied in 5–10° intervals, although to locate maxima or other features, smaller steps may be desirable locally. The first temperature point typically is at about the seal initiation temperature. Commonly, testing is continued at increasing temperature levels until the web suffers excessive stretch, distortion, shrinkage, or burnthrough.

7.3.1 Make a minimum of three seals at each jaw temperature selected.

7.4 *Single-Point Measurements (Quality Control Testing)*—Refer to Annex A1 for guidelines for selecting temperature.

7.5 *Conditioning*—The seal shall not be tested until its strength no longer changes with time. Maintain standard laboratory atmosphere of 23°C and 50 % RH during conditioning period.

7.6 *Strength Testing*—See Test Methods F 88.

8. Report

8.1 The report shall contain the following information concerning specimens tested:

8.1.1 *General Information*:

8.1.1.1 Date of sealing,

8.1.1.2 Operator,

8.1.1.3 Heatsealer; type and model, and

8.1.1.4 Ambient temperature and humidity.

8.1.2 Complete identification of materials sealed, as appropriate.

8.1.3 Thickness and width of specimens and web construction, if known.

8.1.4 Orientation of seal with respect to machine direction.

8.1.5 *Data Table*—After strength of the sealed specimens has been tested by Test Methods F 88, prepare a data table showing sealing conditions, force to failure, and failure mode for each replicate. Show also arithmetic mean and standard deviation for each replicate set. Identify data by test Practice A or B.

8.1.6 *Heatseal Curves*—Plot heatseal curve for each material. Graphically identify failure mode at each test point (Fig. 1). Identify each curve by test practice. Where appropriate, several curves comparing various materials may be shown on the same plot.

8.1.7 *Practice B*—Typically, certain materials will be tested by both Practices A and B. In those cases, show both curves on the same plot (see Figs. 2 and 3).

9. Keywords

9.1 heatsealability; heatsealing; hot tack; seal strength

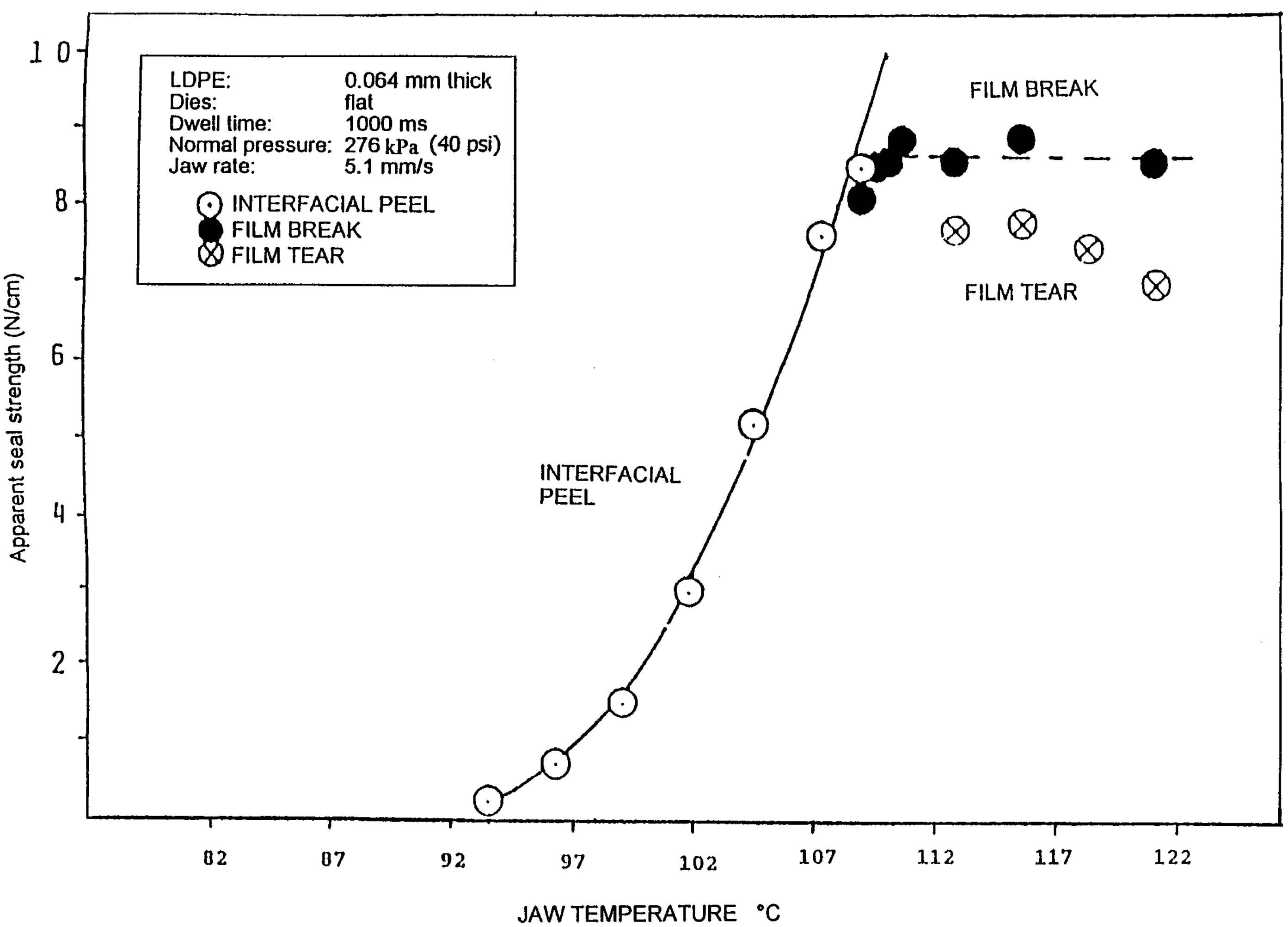

FIG. 1 Failure Modes of Seals made with LDPE Film

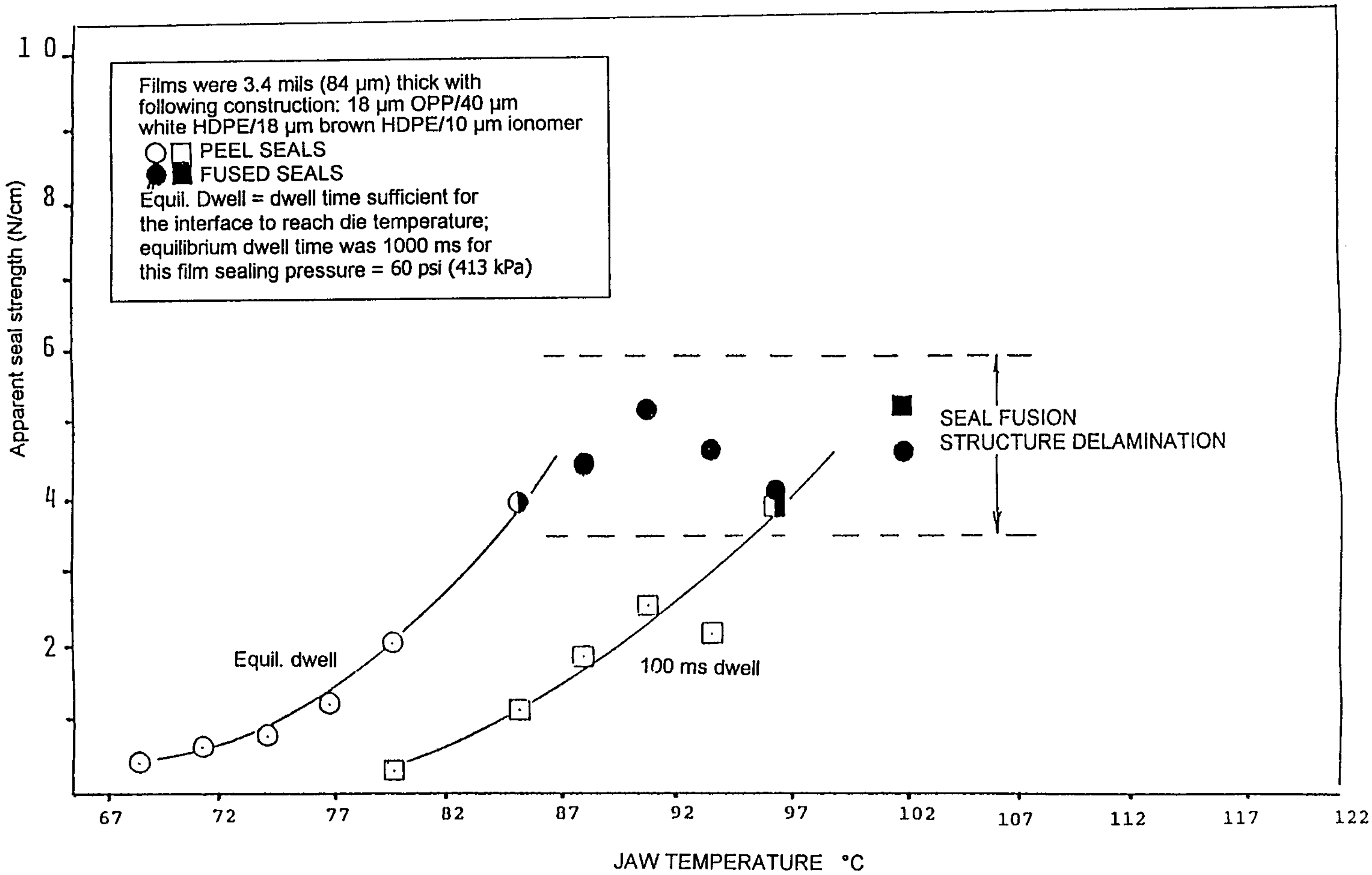

FIG. 2 Heatsealability Test Method Example

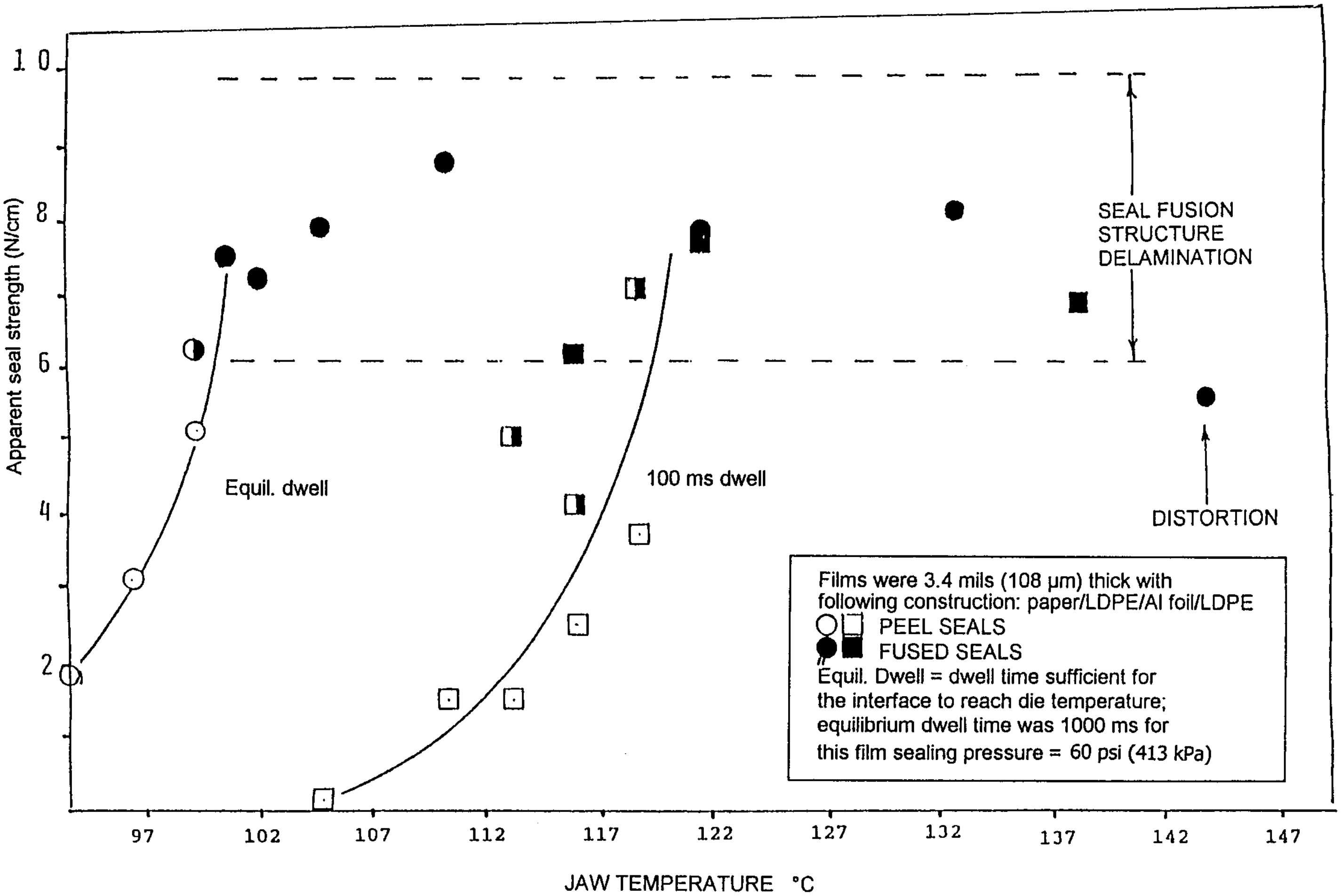

FIG. 3 Heatsealability Test Method Example

ANNEXES

(Mandatory Information)

A1. SINGLE-POINT MEASUREMENTS

A1.1 For quality-control testing, a critical sealing temperature should be identified from the heatseal curve of each material, where all testing for that material will be done. Normally, the point should be chosen close to the fusion temperature of the seal layer, which typically is at the juncture between the rapidly rising peel portion of the curve and the plateau portion. If the application for the material under test calls for a fused seal, the test temperature should be on the plateau side of the break point in the curve; if it calls for a peel seal, testing should be done on the peel side of the break at a point chosen based on application requirements for the material.

A2. STICKING

A2.1 If the specimen to be sealed is homogeneous throughout, or of ABA construction, provision must be made to avoid its sticking to the jaws at temperatures within or above its melting range. Various jaw coatings and coverings can be used but at a sacrifice of rate of heat transfer from jaws to sealing interface. This is not serious in Practice A, Surface Sealability, since a longer dwell time can be used without affect on seal strength. In Practice B, each change that affects rate of heat transfer rate changes the test results. The best solution for Practice A is to enclose the specimen in a folded piece of 10–15μ (approximately 0.5 mil) polyester film during the sealing cycle. Polyester film at this thickness has minimal effect on heat transfer. The film can be reused several times. Anti-stick treatment in Practice B depends on the commercial procedure being simulated.

A3. DWELL TIME

A3.1 As dwell time is increased at a selected die temperature, heatseal strength rises from zero to a value characteristic of the material and the temperature, and then levels off (Fig. A3.1). While any dwell time on the plateau should be usable for the strength/temperature curve, since in that range the interface has reached die temperature, excessive dwell times should be avoided.

A3.2 *Method A; Determination of Dwell Time*—For thick materials and constructions with paper or foil, set jaw temperature to a level to yield a peel seal. Make seals at increasing dwell times, for example, 1 s, 2 s, 4 s, 6 s) and measure their strength until successive measurements are about equal. Use the lowest dwell time where a significant increase develops no further consistent increase in strength.

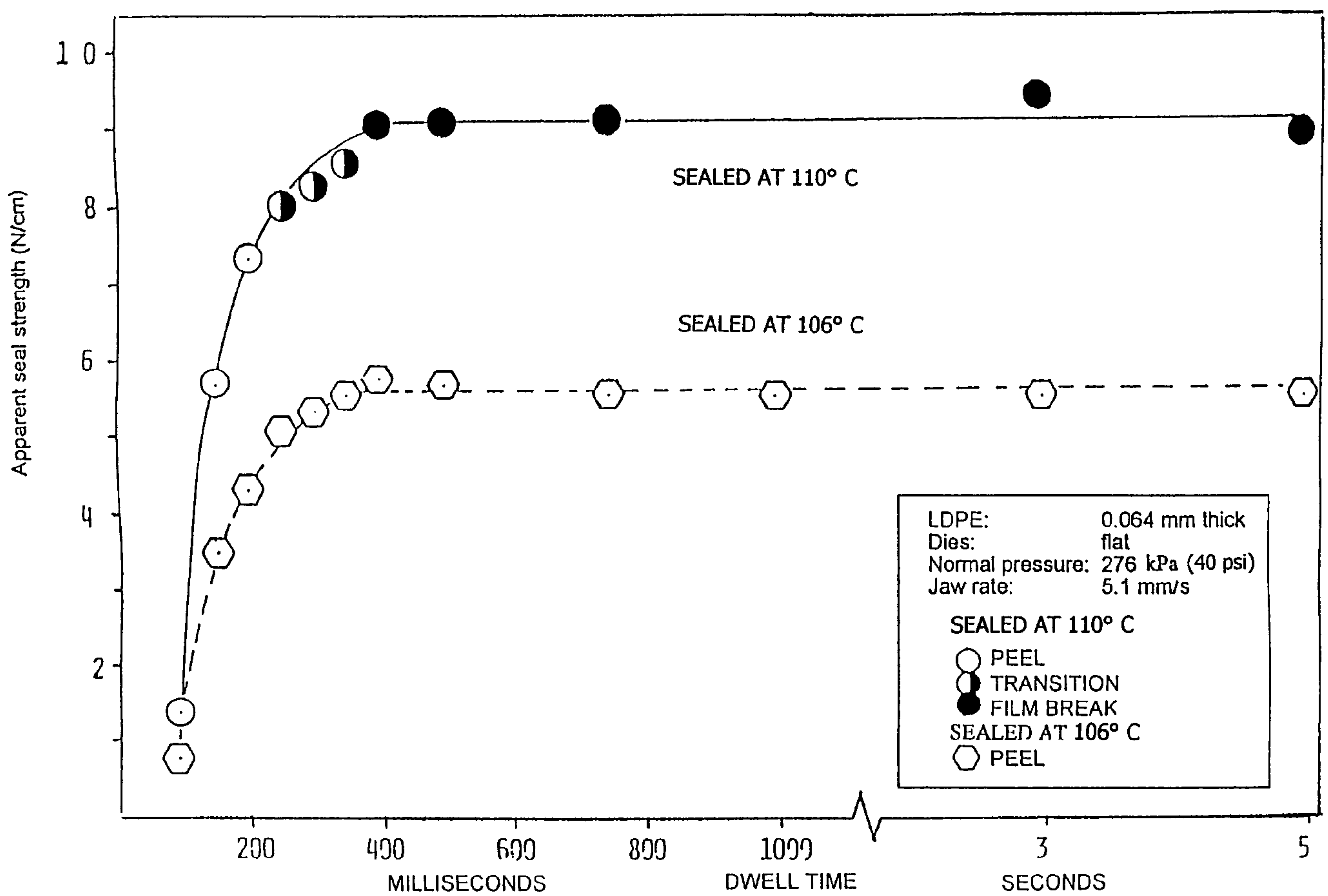

FIG. A3.1 Effect of Dwell Time on the Seal Strength of LDPE Film

APPENDIXES

(Nonmandatory Information)

X1. EFFECT OF SEALING PRESSURE

X1.1 Literature[3,4] presents test results, as well as the theoretical basis indicating that pressure has little effect on heatseal strength, with some qualifications. First, there must be enough pressure on the webs being sealed to flatten them as much as possible, to develop intimate contact over the entire seal area. Second, above the melting point of the polymer surfaces being sealed, pressure tends to cause outward flow of material, resulting in an undesirable thickening at the seal edges. Third, films that shrink on heating may exhibit a significant effect of sealing pressure on seal strength, probably related to maintaining static contact of the two surfaces during the dwell period.

X1.2 In sealing with flat metal jaws, small deviations from parallelism of the jaw sealing surfaces can create areas of very low pressure, where there is inadequate contact of the surfaces to achieve the seal that would otherwise occur. This can be alleviated to a degree by coating one of the jaw surfaces with rubber of about 60 durometer, but still maintaining temperature control of its surface.

[3] Meka, P., and Stehling, F. C., *Journal of Applied Polymer Science*, Vol 51, 89(1994).

[4] Theller, H. W., *Journal of Plastic Film & Sheeting*, Vol 5, 66(1989).

X2. HEATSEAL CURVE

X2.1 Fig. 1 is a heatseal curve of low density polyethylene. It shows the typical initial increase in seal strength as temperature is raised past seal initiation, indicated by a peeling failure mode. As sealing temperature is increased to the melting range of the polymer, the seal no longer peels apart; instead, the web material fails. The curve levels off, and the values of failure force are usually less repeatable than during seal failure. In this area of the curve, seal strength may be in excess of the observed strength values.