



Standard Practices for Making Laboratory Heat Seals for Determination of Heat Sealability of Flexible Barrier Materials as Measured by Seal Strength¹

This standard is issued under the fixed designation F2029; 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 heat seals. These practices also cover the treatment and evaluation of heat seal strength data for the purpose of determining heat sealability of flexible barrier materials. It does not cover the required validation procedures for the production equipment.

1.2 Testing of seal strength or other properties of the heat seals formed by these practices is not included in this standard. Refer to Test Method [F88](#) for testing heat seal strength. This practice does not apply to hot tack testing, which is covered in [F1921](#).

1.3 The practices of this standard are restricted to preparing heat seals using a sealer employing hot-bar or impulse sealing methods, or both.

1.4 This practice is intended to assist in establishing starting relationships for sealing flexible barrier materials. Additional guidance may be needed on how to set up sealing conditions for flexible barrier materials on commercial/production sealing equipment.

1.5 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, and so forth).

1.6 Strength of the heat seal as measured by Test Method [F88](#) is the sole criterion for assessing heat sealability employed in these practices.

1.7 Other aspects of heat sealability, such as seal continuity, typically measured by air-leak, dye penetration, visual examination, microorganism penetration, or other techniques, are not covered by these practices.

1.8 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

¹ These practices 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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1.9 *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:²

[F88](#) Test Method for Seal Strength of Flexible Barrier Materials

[F1921](#) Test Methods for Hot Seal Strength (Hot Tack) of Thermoplastic Polymers and Blends Comprising the Sealing Surfaces of Flexible Webs

[D4332](#) Practice for Conditioning Containers, Packages, or Packaging Components for Testing

3. Terminology

3.1 Definitions:

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

3.1.2 *heat seal curve, n*—a plot of measured seal strength as a function of sealing temperature at a fixed dwell time and sealing pressure.

3.1.3 *heat seal strength, n*—force per unit width of seal required to progressively separate a flexible material from a rigid material or another flexible material, under the conditions of the test. Also known as seal strength.

3.1.4 *heat sealability, n*—the ability of thermoplastic polymers and blends, when comprising a sealing surface of a flexible web, that defines how well the material bonds to itself or a dissimilar material upon the application of pressure, heat, and dwell (time), as judged by the heat seal curve.

3.1.4.1 *Discussion*—Since heat seal strength can be measured either while the seal is still hot (hot tack) or after cooling

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.

and stabilizing (ultimate seal strength), a complete evaluation of heat sealability of a material may include both tests.

3.1.5 *hot tack, n*—a measure of the seal 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 **F1921**.

3.1.6 *seal initiation temperature, n*—on a heat seal curve, the sealing temperature/dwell pressure at which heat seal strength first begins to trend upward from zero heat seal strength.

3.1.7 *sealing interface, n*—the interface of the two web surfaces being sealed.

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

3.1.9 *sealing temperature, n*—the set point of each temperature-controlled sealing jaw. The set point temperature is the controller setting which will produce the desired surface temperature. Often, the set point temperature will be higher than the surface temperature.

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

3.1.10.1 *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 This practice facilitates the determination of laboratory heat sealability of flexible barrier materials. While it is necessary to have a heat seal layer that provides adequate seal strength for the application, other material properties, such as the overall construction and thickness, will impact the sealing properties of the material. This practice allows the impact of changes in material properties on heat sealability to be measured.

4.2 Due to differences between a laboratory sealer and manufacturing equipment (for example, scale, size of sealing area, and processing speed), there may be a significant difference between the capability and output of a laboratory heat sealer and that of manufacturing equipment. Hence, care must be taken when applying a heat seal curve study as outlined in these practices to manufacturing equipment. The heat seal curve and the corresponding seal strength data are intended to provide a starting point for determination of sealing conditions for full scale manufacturing equipment.

5. Apparatus

5.1 Continuous Heat Bar Sealer:

5.1.1 *Sealing Jaws*—Temperature-controlled jaw or jaws with appropriate sealing surfaces to provide a flat seal. If only one heated jaw is used, the unheated jaw should be covered with a gasket material such as a silicone rubber (to prevent the test specimen from adhering to the sealing jaws) of known durometer and, optionally, an anti-stick coating or covering.

5.1.1.1 *Jaw Temperature Control*—Each temperature-controlled jaw should have independent temperature control

and the precision of the controlling unit should be known and calibrated. The temperature should be verified periodically using a calibrated pyrometer adequate for the range of use.

5.1.1.2 *Jaw Coatings or Coverings*—For the heated jaw(s), anti-stick or compressible jaw coatings or coverings, such as silicone rubber, TFE-fluorocarbon, TFE-fluorocarbon/glass cloth, or oriented PET film are often used to prevent the test specimen from adhering to the sealing jaws. For an unheated jaw, silicone or other heat-resistant rubbers of known durometer may be used. The rubber may be covered with TFE-fluorocarbon, TFE-fluorocarbon/glass cloth, or oriented PET film.

NOTE 1—Thick or heat flow-resistant materials will impact the rate of heat transfer from jaws to sealing surface. It is important to inspect the quality of these materials periodically to prevent loss of properties that may cause unwanted temperature fluctuations in the sealing process.

5.1.1.3 *Jaw Sealing Surfaces*—Ideally, the jaw sealing surfaces should be parallel when actuated and can be aligned, if needed. The uniformity of pressure across the sealing jaws should be checked. This may be done using pressure-indicating materials or devices by actuating the sealing jaws while at ambient temperature or at elevated temperatures, as appropriate.

5.1.2 *Dwell Time*—Variable control and readout of dwell time. A range of 0.1 to 10 seconds is desirable. The precision of the dwell time control unit should be known and calibrated.

NOTE 2—Jaw closure time and set dwell time may be different depending on heat sealer equipment.

5.1.3 *Pressure*—Variable control, via a pressure gage or load cell, with readout of the air supply pressure or the sealing pressure, respectively.

5.1.3.1 The applied sealing pressure for machines that have only an air pressure gauge on the air supply line and whose cylinder size is known should be calculated (neglecting any losses due to mechanical work). The following formula may be used for this calculation.

$$P_{actual} = \left(\frac{A_{cyl}}{A_{contact}} \right) P_{line} \quad (1)$$

where:

P_{actual} = actual or applied pressure of the sealing jaw,
 P_{line} = pressure of the incoming air line,
 $A_{contact}$ = area of the sealing jaw in contact with material,
 and
 A_{cyl} = sum of the cross-sectional areas of all cylinders.

5.1.3.2 When materials are being sealed under pressure and silicone rubber is used on one or both of the jaws, the silicone rubber will compress. When thin materials being sealed are narrower than the full length of the sealing jaw, the compression can be significant enough to change the contact to the full area of the jaw. As a result, the pressure is then distributed across the entire surface and this area is what should be used in the pressure calculation. When sealing thick materials, only the area of the seal should be used to calculate the sealing pressure since contact is limited to the surface of the thicker materials.

5.2 Impulse Sealer

5.2.1 *Impulse Sealing Jaws*—Impulse sealing jaw or jaws with an impulse band applied to it and with appropriate sealing

surfaces to provide a flat seal. If only one impulse sealing jaw is used, the other jaw should be covered with a gasket material such as a silicone rubber (to prevent the test specimen from adhering to the sealing jaws) of known durometer and, optionally, an anti-stick coating or covering.

5.2.1.1 Impulse Sealing Jaw Temperature Control—Each impulse jaw with an impulse band applied to it should have independent and calibrated controls. The location and precision of the controlling unit (such as a thermocouple or calibrated heater band) should be known. The output temperature should be verified periodically.

NOTE 3—Some impulse sealers also include a “cooling” cycle to ensure that the seal is undisturbed mechanically after the seal is formed and before the jaws open.

5.2.1.2 Jaw Coatings or Coverings—Each impulse jaw with an impulse band applied to it may be covered with an anti-stick covering, such as TFE-fluorocarbon or TFE-fluorocarbon/glass cloth, to prevent the test specimen from adhering to the sealing jaws. For an unheated jaw, silicone or other heat resistant rubbers of known durometer may be used. The rubber may be covered with TFE-fluorocarbon, TFE-fluorocarbon/glass cloth.

NOTE 4—Thick or heat flow-resistant materials will impact the rate of heat transfer from jaws to sealing surface. It is important to inspect the quality of these materials periodically to prevent loss of properties that may cause unwanted temperature fluctuations in the sealing process.

5.2.1.3 Jaw Sealing Surfaces—Ideally, the jaw sealing surfaces should be parallel, and can be aligned if needed. The uniformity of pressure across the sealing jaws should be checked. This may be done using pressure-indicating materials or devices by actuating the sealing jaws while at ambient temperature or at elevated temperatures, as appropriate.

5.2.2 Dwell Time—Variable control and readout of heating dwell time, and cooling dwell time, if appropriate. A range of 0.1 to 10 seconds is desirable. The precision of the dwell time control unit(s) should be known and calibrated.

NOTE 5—Jaw closure time and heating dwell time may be different depending on impulse sealer equipment.

5.2.3 Pressure—Variable control, via a pressure gage or load cell, with readout of the air supply pressure or the sealing pressure, respectively.

5.2.3.1 The applied sealing pressure for machines that have only an air pressure gauge on the air supply line and whose cylinder size is known should be calculated. [Eq 1](#) can be used for this calculation. If jaw closure is through a cantilevered mechanism, consult with your equipment manufacturer or supplier to determine applied pressure.

5.2.3.2 When materials are being sealed under pressure and silicone rubber is used on one or both of the jaws, the silicone rubber will compress. When thin materials being sealed are narrower than the full length of the sealing jaw, the compression can be significant enough to change the contact to the full area of the jaw. As a result, the pressure is then distributed across the entire surface and this area is what should be used in the pressure calculation. When sealing thick materials, only the area of the seal should be used to calculate the sealing pressure since contact is limited to the surface of the thicker materials.

6. Test Specimen

6.1 The number of test specimens shall be chosen to permit an adequate determination of representative performance based on an appropriate rationale. When heat seal strength will be measured at a series of sealing temperatures, an adequate or agreed upon number of 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 separate determination of the number of replicates should be made.

6.2 Mark the machine or transverse direction (if known and relevant to the test outcome) and the seal side of each sample to be evaluated. Superimpose the two pieces to be sealed, with the transverse directions parallel and the seal surfaces facing each other. Seal each specimen with the jaws parallel to either the machine or transverse direction noting the orientation of the sample. To minimize variability, perform the heat seal process at the same location relative to the sealing jaws. One or more strips for seal-strength testing will subsequently be cut perpendicular to the seal where the sealing temperature profile is known to be consistent (commonly near the center of the sealed strip). The seal(s) may then be peeled by pulling the strip according to [Test Method F88](#).

NOTE 6—The seal must be located on the specimen such that 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.

6.3 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 or transverse direction (noting the orientation of the sample) and sealed. The sealed strip may then be tested for heat seal strength without further preparation. Comparisons should be made only among specimens sealed by the same procedure.

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

7. Procedure

7.1 Calibration and Alignment—Prior to starting testing, ensure that the heat sealer is properly calibrated and that the jaws have been aligned for parallelism.

7.2 Temperature—Choice of temperature setting of each jaw is determined by the materials being evaluated and the objectives of the test. It is recommended both jaws be set to the same temperature.

7.3 Dwell Time—Set the dwell time to the desired period. See [Appendix X1](#) for a discussion of the effect of dwell time on heat seal strength.

7.4 Sealing Pressure—Set pressure in the range of 276 to 483 kPa (40 to 70 psi), or at other level depending on specific application. See [Appendix X2](#) for discussion of effect of pressure on heat seal strength.

7.5 Jaw Configuration—If possible, choose jaw coatings or coverings consistent with the commercial application being simulated. In absence of specific information on this point, flat steel jaws covered with TFE-fluorocarbon/glass cloth are recommended.

7.5.1 *Sticking of Specimen to Jaws*—Specimens having a melting range of the sealing interface that is significantly lower than its outer surface can be sealed directly with bare metal jaws over most of the desired sealing temperature range without sticking (for example, sealing a PET/LDPE film to itself).

7.5.2 However, if the specimen is homogeneous throughout, or in the case of multilayered materials where the external construction is the same (such as in an ABA structure), enclose the specimen in a folded piece of 10 to 15 μm (approx. 0.5 mil) polyester film during the sealing cycle to avoid sticking to the jaws. Alternatively, cover the jaws with TFE-fluorocarbon/glass cloth, or tape. The choice of coverings or coatings should be made according to 7.5.

7.6 *Heat Seal Curve*—To generate the heat seal curve, temperature is typically varied in 5 to 10° intervals. The first temperature point typically is at about the seal initiation temperature. Testing may be continued at increasing temperatures until the web suffers excessive stretch, distortion, shrinkage, or burn-through. See Fig. 1 and Fig. 2 for example heat seal curves.

7.6.1 Make the number of test specimens chosen to permit an adequate determination of representative performance based on an appropriate rationale.

7.6.2 Dwell time can also be used as the independent variable by fixing the temperature and sealing pressure at which the test is performed.

7.7 *Conditioning*—If conditioning before testing is appropriate, normal, or desirable, then condition the test specimens in accordance with Practice D4332.

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

7.8 *Strength Testing*—The seal may be tested according to Test Method F88 or Test Method F1921.

8. Report

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

8.1.1 *General Information*:

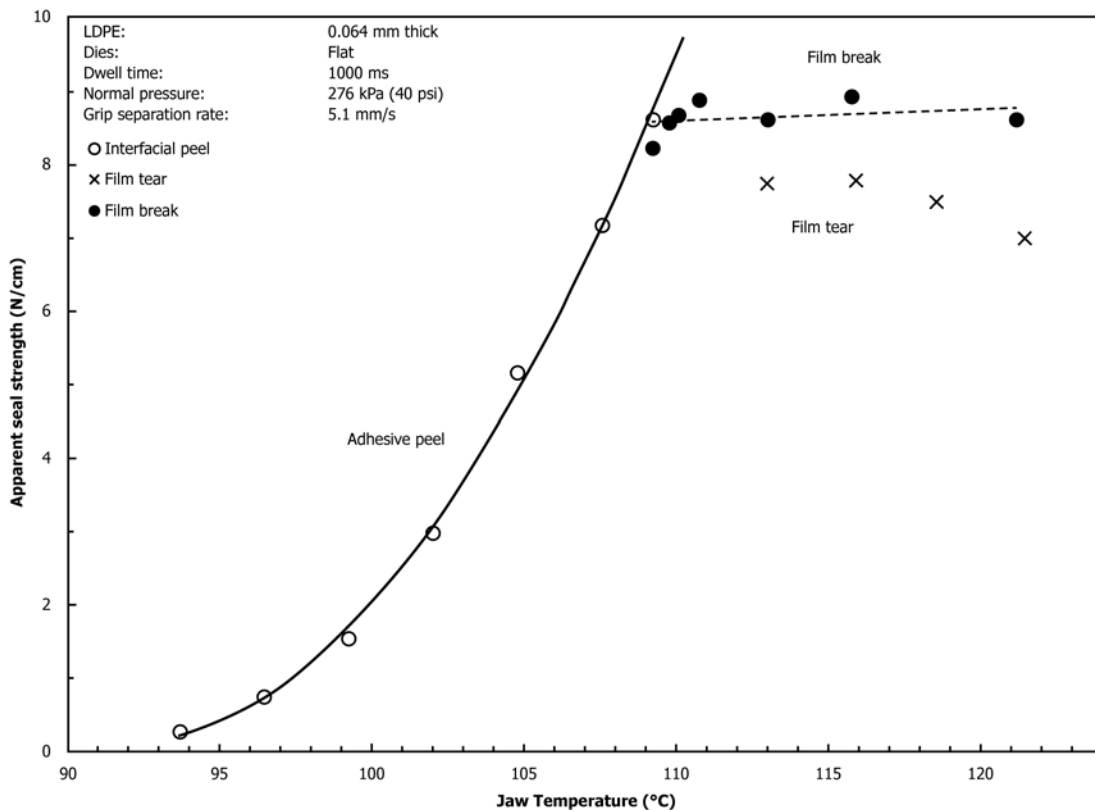
8.1.1.1 Date of sealing,

8.1.1.2 Operator,

8.1.1.3 Heat sealer; type and model,

8.1.1.4 Number of heated jaws and type of coating or covering on each, and

8.1.1.5 Where applicable, ambient temperature and humidity.



NOTE 1—Fig. 1 is a heat seal 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 by a tensile failure. 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.

FIG. 1 Failure Modes of Seals made with LDPE Film

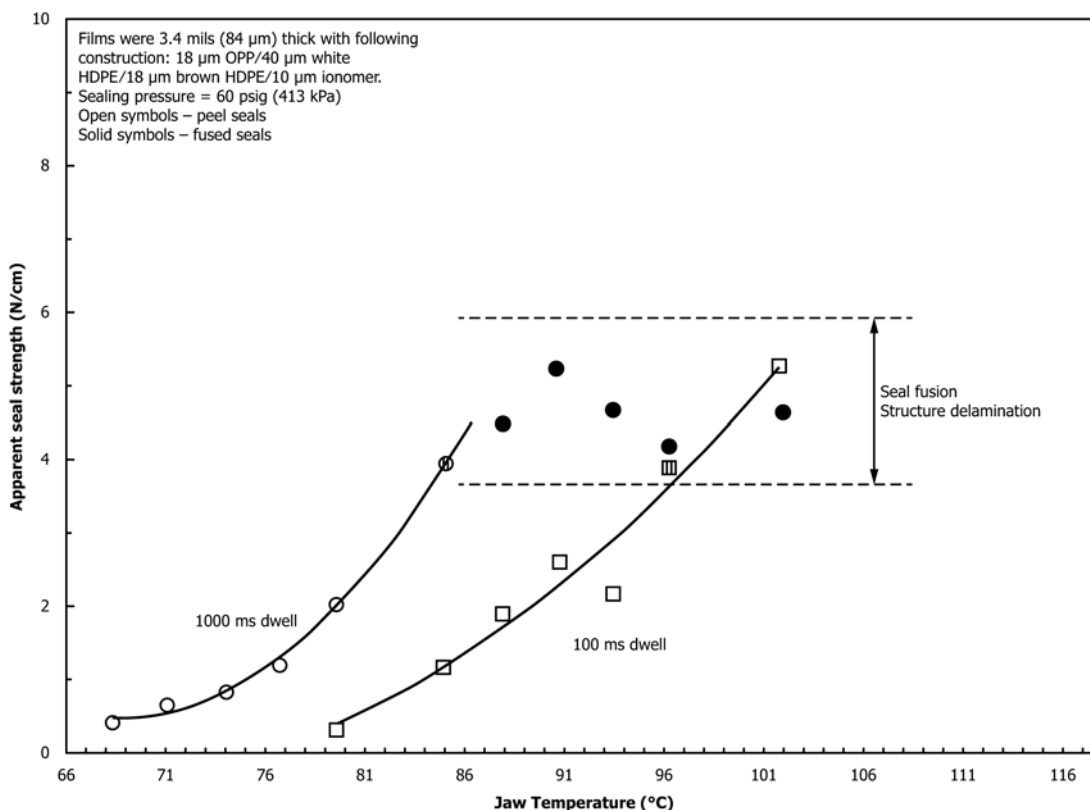


FIG. 2 Heat Sealability Example

8.1.1.6 Sealing conditions (time, temperature, and pressure).

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, if known and relevant to the test outcome.

8.1.5 *Data Table*—After strength of the sealed specimens has been tested by Test Method F88 or Test Method F1921, 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. Include applicable report items from Test Method F88 or Test Method F1921 not covered above.

8.1.6 *Heat Seal Curves*—Plot heat seal curve for each material. Identify on the graph the single failure mode or changes in the failure mode (such as in Fig. 1 and Fig. 2). Where appropriate, several curves comparing various materials may be shown on the same plot.

8.1.6 *Heat Seal Curves*—Plot heat seal curve for each material. Identify on the graph the single failure mode or changes in the failure mode (such as in Fig. 1 and Fig. 2). Where appropriate, several curves comparing various materials may be shown on the same plot.

9. Keywords

9.1 heat sealability; heat sealing; hot tack; seal strength

APPENDIXES

(Nonmandatory Information)

X1. EFFECT OF DWELL TIME ON SEAL STRENGTH

X1.1 As dwell time is increased at a selected die temperature, heat seal strength rises from zero to a value characteristic of the material and the temperature, and then

typically levels off (Fig. X1.1). This curve may be generated by choosing a sealing temperature and increasing the dwell time incrementally.

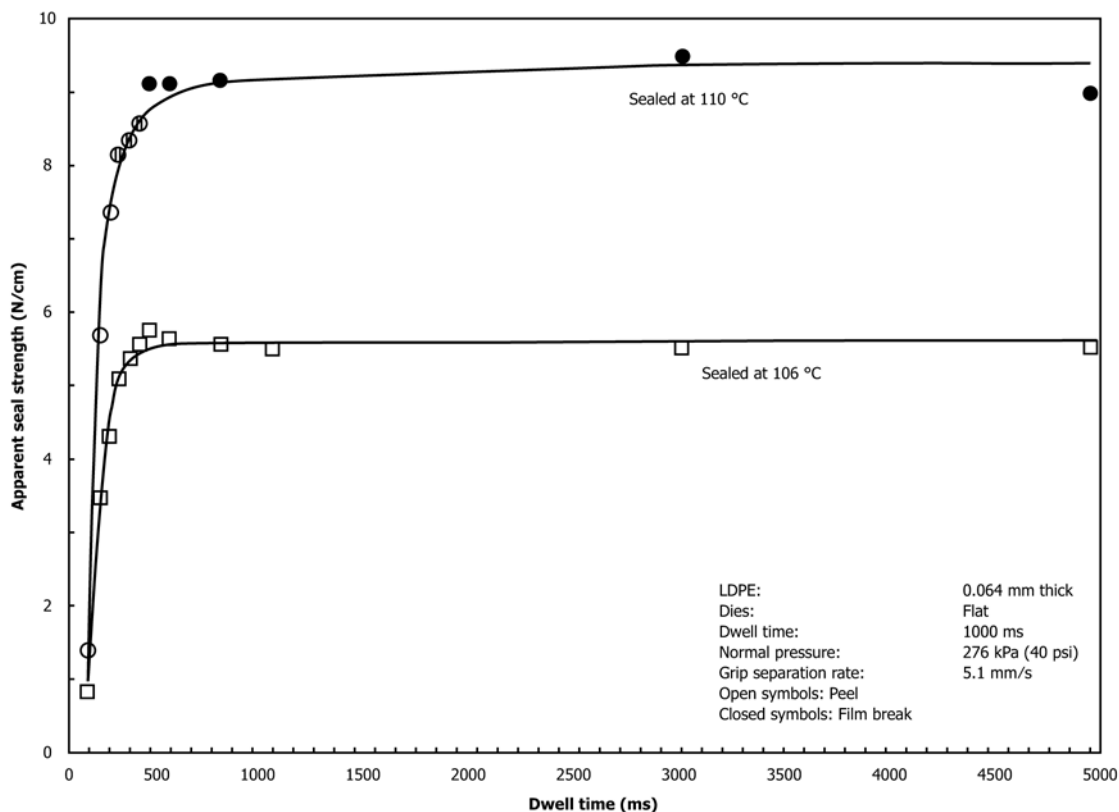


FIG. X1.1 Effect of Dwell Time on the Seal Strength of LDPE Film

X2. EFFECT OF SEALING PRESSURE

X2.1 Literature^{3,4} presents test results, as well as the theoretical basis indicating that pressure has little effect on heat seal strength, with some qualifications. First, there must be enough pressure on the webs being sealed to flatten them as much as possible and 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.

X2.2 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 as noted in 5.1.1, but still maintaining temperature control of its surface.

³ Meka, P., and Stehling, F. C., *Journal of Applied Polymer Science*, Vol 51, No. 89, 1994.

⁴ Theller, H. W., *Journal of Plastic Film & Sheeting*, Vol 5, No. 66, 1989.

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