Designation: D 2838 – 95

# Standard Test Method for Shrink Tension and Orientation Release Stress of Plastic Film and Thin Sheeting[1]

This standard is issued under the fixed designation D 2838; 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 This test method covers the determination of the shrink tension and related characteristics, that is, shrink force and orientation release stress, of heat-shrinkable plastic film and sheeting of less than 0.8 mm (0.03 in.) thickness. Two procedures are described that permit the measurement of shrink forces at predetermined temperatures. They are as follows:

1.1.1 *Procedure A* is designed to measure the maximum force exerted by a specimen that is totally restrained from shrinking as it is heated rapidly to a specific temperature.

1.1.2 *Procedure B* is designed to measure the maximum force exerted by a specimen that is permitted to shrink a predetermined amount prior to restraint while being heated rapidly to a specific temperature.

1.2 Orientation release stress can be determined from the data obtained using Procedure A.

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

NOTE 1—There is no equivalent ISO test method.

1.4 *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:*

D 374 Test Methods for Thickness of Solid Electrical Insulation[2]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 1898 Practice for Sampling of Plastics[3]

E 1 Specification for ASTM Thermometers[4]

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *orientation release stress*—the maximum shrink tension developed by a film in a specified direction throughout its range of shrink temperatures while totally restrained from shrinking.

3.1.2 *sheeting*—as defined for this test method, material having a maximum thickness of 0.8 mm (0.03 in.).

3.1.3 *shrink force*—the force per original unit width developed by a film in a specified direction and at a specified temperature in its attempt to shrink while under restraint.

3.1.4 *shrink tension*—the force per original average cross-sectional area developed by a film in a specified direction and at a specified temperature in its attempt to shrink while under restraint.

## 4. Summary of Test Method

4.1 The ends of a 25.4-mm (1-in.) wide strip of film or sheeting are clamped in the arms of a shrink tension holder (see Fig. 1), one arm of which contains strain gages. The holder is immersed in a hot bath and the force exerted by the film is detected by strain gages attached to one arm and recorded by a fast action strip chart recorder. The tests may be carried out with or without free shrinkage of the material before restraint. Other properties may be calculated from the measured forces, sample parameters, and temperatures used.

## 5. Significance and Use

5.1 As a result of the manufacturing process, internal stresses are locked into the film and these can be released by heating. For any given type of film or sheeting, the temperatures at which shrinkage will begin are related to processing techniques employed to manufacture the film and also may be related to a phase transition in the base resin.

5.2 Shrink tension affects the appearance and performance of a film in a shrink-packaging application. It may also be used to determine the degree and direction of orientation. The orientation exerts a great influence upon important physical

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The latest version of this document differs only from the previous document in that Keywords and an ISO equivalency statement have been added.

[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 14.03.

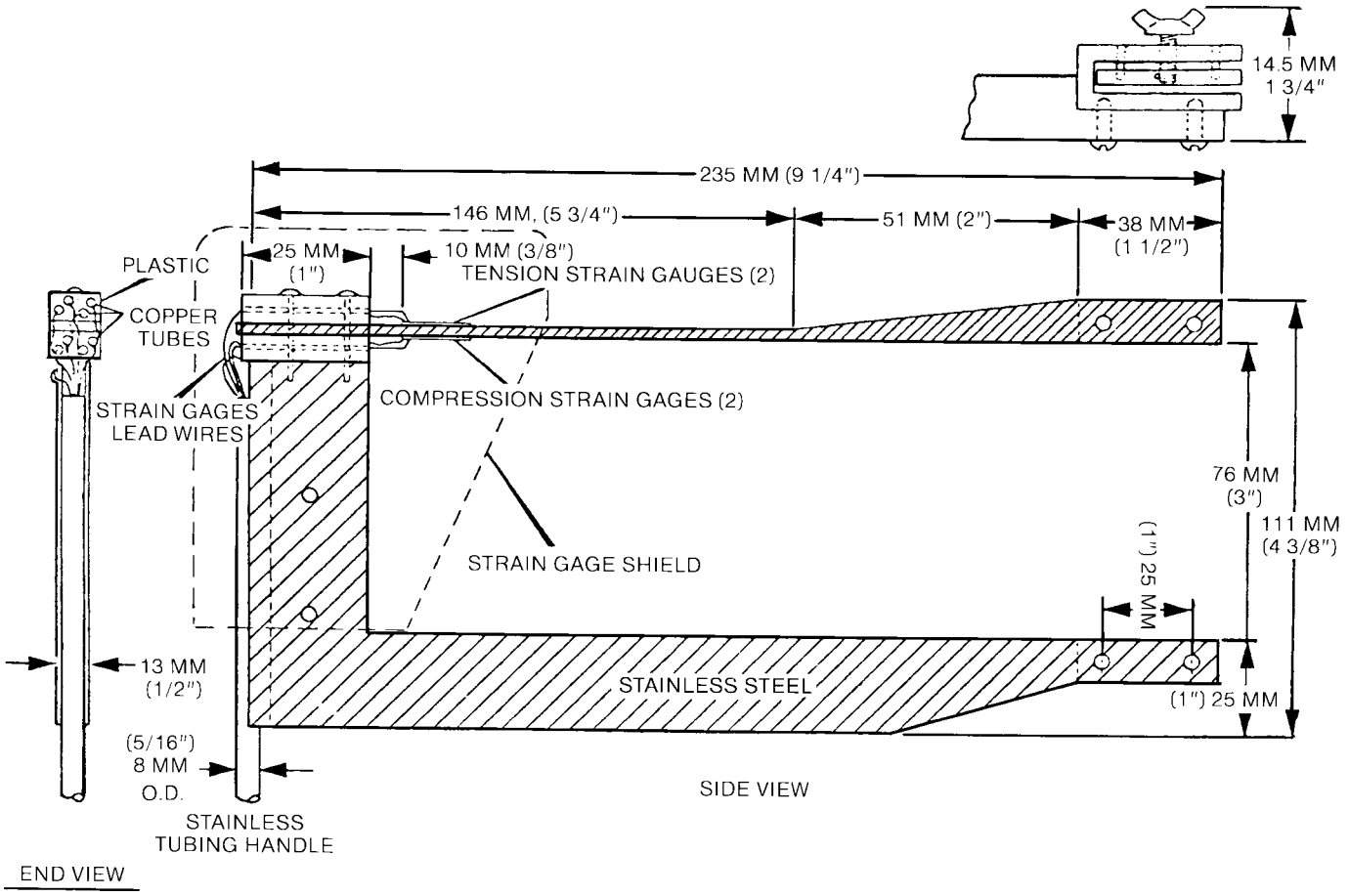



**FIG. 1 Design for Shrink Tension Holder**

characteristics such as tensile strength, stiffness, tear resistance, and impact strength.

5.3 Data from Procedure A are most useful for determining the degree and direction of orientation, orientation release stress, and the maximum force that the film can exert at a given temperature.

5.4 Since, in actual applications, film is seldom, if ever, totally restrained, data from Procedure B are useful in estimating the force an item to be packaged will actually receive and in predicting appearance of packaged items.

5.5 The characterization of shrink tension as a function of temperature, and the resultant determination of orientation release stress and its corresponding temperature, is usually carried out only on an audit basis for a particular material of specified thickness for a defined fabrication process. For purposes of quality control and of determining conformity to specification limits, the measurement of shrink tension at only one or two specified temperatures is normally sufficient.

## 6. Apparatus

6.1 *Shrink Tension Holder*[5]—A suggested design is portrayed in Fig. 1 and Fig. 2.

6.2 *Strain Gage Conditioner*,[6] applicable to a 120-Ω four-arm bridge.

6.3 *Recorder*,[6] having a pen response of no more than 30 ms from 10 to 90 % of full-scale deflection. A chart width of at least 100 mm is preferable.

6.4 *Sample Cutter*, capable of cutting 25.4 ± 0.2-mm (1 ± 0.01-in.) wide strips of at least 127 mm (5 in.) in length.

6.5 *Constant-Temperature Liquid Bath*, capable of controlling accurately to ±0.5°C and covering the range of interest, usually from 50 to 175°C.

6.6 *Thermometer*, covering the range of interest and conforming to the requirement of Specification E 1.

6.7 *Liquid Bath*, which will not plasticize or react with specimens. Polyethylene glycol, glycerin, and water have been found to have wide applicability. Silicone oils are useful for samples requiring temperatures above 175°C.

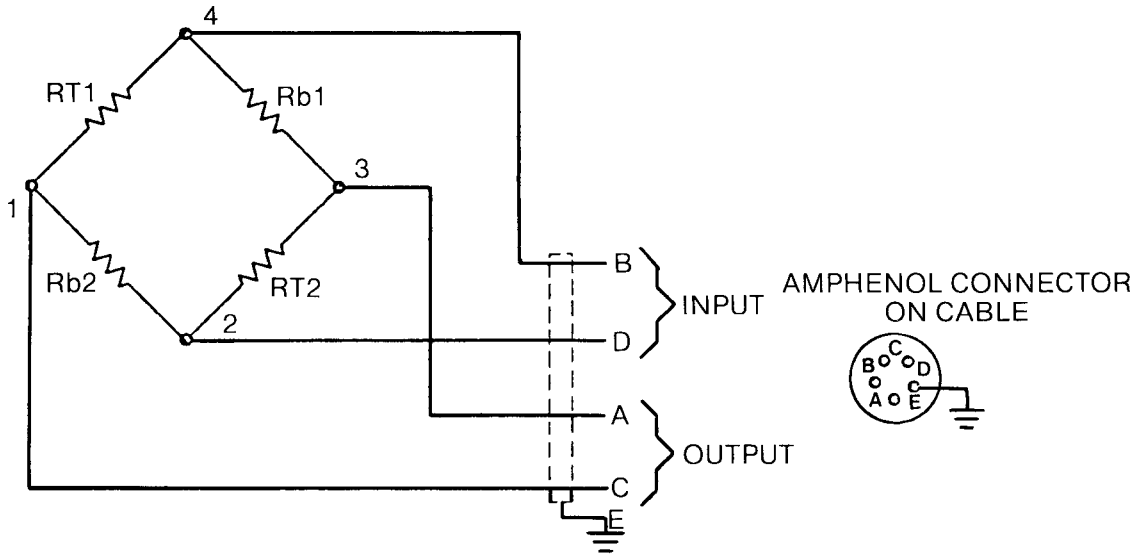
6.8 *Thickness Gage*, capable of measuring the thickness of samples in compliance with Test Methods D 374.

## 7. Sampling

7.1 Sampling must be performed in a manner that ensures

[5] Model CS-205 Shrink Tension Holder, supplied by Custom Scientific Instruments, 13 Wing Drive, Whippany, NJ 07981, has been found satisfactory for this purpose.

[6] The following systems have been found satisfactory: Daytronics Model 9005 Mainframe equipped with a Model 9178 strain gage conditioner, a Model 9259 peak-track-hold unit, and a Model 9530 digital indicator interfaced to an appropriate recorder. Honeywell Model 1858 Recorder equipped with a Model 1885A strain gage control module. Other systems may function equally well.




RT 1 and 2 Top Strain Gages
Rb 1 and 2 Bottom Strain Gages

**FIG. 2 Circuit Diagram for Shrink, Tension Holder**

that the kind of information desired will be obtained. No single procedure for all situations can be given, but Practice D 1898 provides guidelines for use in planning sampling procedures.

## 8. Test Specimens

8.1 The test specimens shall consist of strips of uniform width and thickness. The width of the specimens shall be 25.4 ± 0.2 mm (1.0 ± 0.01 in.).

8.2 *Length of Test Specimens*:

8.2.1 Specimens for Procedure A shall be at least 127 mm (5 in.) in length.

8.2.2 Length of specimens for Procedure B is dependent upon the amount of shrink desired prior to restraint. At least 50 mm shall be allowed for clamping. The remaining length required can be calculated by solving for $L$ in the following equation:

$$L = (d/(100 - s)) \times 100 \quad (1)$$

where:

$L$ = specimen length required between clamps, mm or in.,
$d$ = distance between clamps, mm or in., and
$s$ = percent shrink desired prior to restraint.

Measure a distance equivalent to $L$, *leaving at least 25.4 mm (1 in.) at either end of the strip for clamping and mark the beginning and termination of the distance with a line perpendicular to the edge and across the width of the strip.*

8.3 Measure the thickness of the specimen to the nearest 0.0025 mm (0.0001 in.) at a minimum of four positions, but at least at each 25.4 mm (1 in.) along the length of the specimen that will be between the clamps. Record the thicknesses. Calculate and record their average.

8.4 For each measurement of shrink tension at a given temperature, take at least four specimens from each direction of interest with respect to the machine direction of the sample. This would normally amount to at least eight specimens, four in the longitudinal or machine direction of the film and four in the transverse direction.

## 9. Preparation of Apparatus

9.1 Set up constant-temperature bath and equilibrate at the temperature chosen for the test. Shrink tension will normally be observed near the softening temperature of polymeric material.

9.2 Connect shrink-tension holder to recorder. Balance and set at zero in accordance with the manufacturer's instructions.

## 10. Calibration

10.1 Place the shrink holder vertically on a solid level tabletop with the handle pointing down toward the floor and set the recorder at zero.

10.2 Place a weight (normally 4.45 N, 454 gf, 1 lbf) equal to the chosen full-scale value for the measurements to be made on the top clamp which is attached to the strain gages and center the weight over the position where the film is clamped. Adjust the recorder to full scale in accordance with the manufacturer's instructions for the recorder.

10.3 Check linearity by placing weights of less mass on the arm, centering, and noting the recorder pen position. If response is nonlinear, have equipment repaired to make response linear.

10.4 Return shrink holder to horizontal position in which it is used and set the recorder at zero. The equipment is now calibrated and ready for making measurements.

## 11. Conditioning

11.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 40 h prior to test, in accordance with Procedure A of Practice D 618. In cases of disagreement, the tolerances shall be± 1°C (±1.8°F) and ±2 % relative humidity.

11.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity, unless otherwise specified in the applicable material specification. In cases of disagreement, the tolerances shall be ±1°C (±1.8°F) and ±2 % humidity.

## 12. Procedure A—Totally Restrained

12.1 Clamp the first specimen in the holder under the minimum positive loading force achievable. Under no circumstances should it exceed the maximum force observed after immersion of the specimen. The holder must be at ambient temperature.

12.2 Turn on the recorder chart and immerse the holder into the bath, taking special care to lower it in such a manner that the specimen remains in a horizontal position. Immerse smoothly and quickly without bumping or jerking the holder. Keep the specimen in the bath long enough to reach a peak or plateau and 2 to 3 s thereafter.

NOTE 2—Slight variations from the horizontal will generally produce a negligible error. The error, however, will increase in significance as the shrink force approaches zero. A jig may be used to aid in maintaining the proper alignment of the holder while immersing the specimen.

12.3 Turn off the recorder chart and immerse the holder in a beaker of cold water until it returns to ambient temperature. Then remove the specimen.

12.4 Record the specimen identification on the chart paper.

12.5 Repeat 12.1-12.4 for each specimen in the set.

12.6 Repeat 12.1-12.5 for temperature increments of no more than 10°C through the shrink temperature range of the film or sheeting under test. This is usually the softening temperature range of the material.

## 13. Procedure B—Predetermined Shrink Before Restraint

13.1 Clamp the specimen in the holder so that the lines marked in 8.2.2 coincide with the inside edges of the clamps.

13.2 Follow the instructions given in 12.1-12.6.

## 14. Calculation

14.1 Determine the maximum force recorded after immersion from the strip chart (peak or plateau whichever is greater) to the nearest 0.045 N (0.01 lbf or 4.5 gf).

14.2 *Shrink Force*—Divide the maximum force by the specimen width to obtain shrink force. Express shrink force in either newtons per metre or pounds-force per inch.

14.3 *Shrink Tension*—Divide the maximum force in newtons by the product of the thickness in metres and the specimen width in metres to obtain the shrink tension in pascals, or divide the maximum force in pounds by the product of the thickness in inches and the specimen width in inches (set at 1.0 in.) to obtain shrink tension in pounds-force per square inch.

14.4 Use the conversion factors in Table 1, as required, to calculate shrink force, N/m (lbf/in.), and shrink tension, kPa (psi).

**TABLE 1 Conversion Factors for Shrink Force and Shrink Tension**

| To convert from | to | Multiply by[A] |
|---|---|---|
| inch (in.) | metre (m) | 0.0254 |
| millimetre (mm) | metre (m) | 0.001 |
| pound-force (lbf) | newton (N) | 4.45 |
| gram-force (gf) | newton (N) | 0.00981 |
| newton/metre$^2$(N/m$^2$) | pascal (Pa) | 1.000 |
| pascal (Pa) | kilopascal (kPa) | 0.001 |
| pound-force/inch (lbf/in.) | newton/metre (N/m) | 175.0 |
| pound-force/in.$^2$(psi) | kilopascal (kPa) | 6.90 |

[A] Factors are accurate to 0.1 % or better.

## 15. Orientation Release Stress

15.1 Prepare plots of shrink tension as a function of temperature for each film direction of interest, using data obtained by Procedure A.

15.2 The maximum shrink tension developed for each direction of interest, as determined by the plots prepared in 15.1, is the orientation release stress.

## 16. Report

16.1 Report the following information:

16.1.1 Complete sample identification,

16.1.2 Procedure used,

16.1.3 Percent shrink prior to restraint,

16.1.4 Test temperature,

16.1.5 Film direction,

16.1.6 Number of specimens tested,

16.1.7 Thickness of each specimen,

16.1.8 Shrink force of each specimen,

16.1.9 Shrink tension of each specimen,

16.1.10 Average results, standard deviation, and confidence limits where applicable, and

16.1.11 Orientation release stress, film direction, and temperature where it occurs, plus plots used to obtain it.

## 17. Precision and Bias

17.1 *Repeatability*—The standard deviation of measurements of shrink force within a laboratory is usually a function of the magnitude of the measurement between the limits of 9.8 N/m (0.056 lbf/in.) and 175 N/m (1.0 lbf/in.). The standard deviation will increase with the magnitude of the measurement. The percent coefficient of variation ($\sigma / \bar{X} \times 100$) will generally not exceed 10 %.

17.2 *Reproducibility*—The standard deviation of averages of shrink force obtained by different laboratories is relatively constant for measurements between the limits of 9.8 N/m (0.056 lbf/in.) and 175 N/m (1.0 lbf/in.) and generally will not exceed 5.8 N/m (0.034 lbf/in.).

17.3 *Bias*—The bias of this test method cannot be assessed since applicable accepted reference materials are not available.

## 18. Keywords

18.1 film; orientation release stress; shrink force; shrink tension; thin sheeting