Designation: D8314 – 20

Standard Guide for Performance Testing of Applied Stretch Films and Stretch Wrapping[1]

This standard is issued under the fixed designation D8314; 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 guide covers testing of mechanical properties of stretch wrapping films as they have been applied by a stretch wrapper to a unit load or test structure. This guide may be applied to hand-wrapping or to machine-wrapping applications. These tests may be applied to real-world or "field" testing or may be applied to theoretical or "laboratory" testing. This testing does not cover the testing of mechanical properties independent of application by stretch wrapper.

1.2 No statement is made about either precision or bias of any of these test methods since results merely state whether this is in conformation to the criteria for success specified by the user of the test method.

1.2.1 The user is encouraged to establish the precision and bias for their own application.

1.3 The units used in this standard are SI units (metric) with their English equivalents included following them in parentheses.

1.4 These tests are not intended to be applied to agricultural stretch wrapping films and its application.

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.*

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]

D996 Terminology of Packaging and Distribution Environments

D4649 Guide for Use of Stretch Films and Wrapping Application

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E456 Terminology Relating to Quality and Statistics

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E1488 Guide for Statistical Procedures to Use in Developing and Applying Test Methods

E2586 Practice for Calculating and Using Basic Statistics

3. Terminology

3.1 *Definitions*—Terminology found in Terminology D996 shall apply.

4. Summary of Practice

4.1 The purpose of stretch wrapping is to unitize a group of products in order to make handling and transport more efficient.

4.2 There are many comparisons that a user of stretch film or a packaging engineer may want to calculate when comparing an original film to an alternative. They include:

4.2.1 Percent stretch of applied film,

4.2.2 Number of revolutions in a wrap pattern,

4.2.3 Time required to wrap a load,

4.2.4 Film thickness,

4.2.5 Film weight applied to load,

4.2.6 Containment force on load,

4.2.7 Compression force on load,

4.2.8 Film stiffness applied to load,

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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.

4.2.9 Observed tear resistance on load,
4.2.10 Cling applied to load, and
4.2.11 Film cost of applied film to load.

5. Significance and Use

5.1 This guide is for testing the performance applied stretch wrapping film and stretch wrapping equipment during and after the film has been applied to a unit load or structure. These tests are not written with the intention for them to be applied to agricultural stretch wrapping films and its application.

6. Statistical Significance and Redundancy

6.1 This guide does not make any statements as to the statistical significance and redundancy of the tests contained within it except in those statements contained within the individual tests.

6.2 Reference standards regarding statistics and redundancy:
6.2.1 Practice E177.
6.2.2 Terminology E456.
6.2.3 Guide E1488.
6.2.4 Practice E2586.

7. Hazards

7.1 *Physical Exertion*—When performing tests which require the operator to apply a force, use caution that you do not over exert yourself or cause self-injury.

7.2 *Body Awareness*—Take note of the hazards around you and your steadiness in relation to any forces you are exerting, so that you do not lose balance striking or being struck by your surroundings.

7.3 *Sharp Cutting Tools*—Use proper care and protective equipment when handling and using sharp cutting tools.

7.4 *Safe Equipment Operation*—Follow all manufacturers and government safety guidelines when operating equipment.

7.5 Wear appropriate personal protective equipment while performing all tests.

8. Procedure

8.1 Conducting tests in logical order:
8.1.1 Typically non-destructive tests are conducted prior to destructive tests to ensure package integrity and data accuracy.
8.1.2 Non-destructive tests are:
8.1.2.1 Marking Wheel Stretch Test
8.1.2.2 Tapeless Measure Stretch Test
8.1.2.3 Observed Cling Test
8.1.3 Destructive tests:
8.1.3.1 Wrap-In Evaluation
8.1.3.2 Observed Tear Test
8.1.3.3 Cut and Weigh Test
8.1.3.4 Stretch Wrapper Consistency Test
8.1.4 Tests with procedure-dependent destructivity:
8.1.4.1 Pull Plate Evaluation
8.1.4.2 Pull-Bar Evaluation
8.1.4.3 Double (Two) Finger Evaluation

9. Precision and Bias

9.1 *Definitions and Additional Information:*
9.1.1 For precise definitions of statistical terms, refer to Terminology E456.
9.1.2 For more information on calculation methods relating to the use of statistical procedures, refer to Practices E177 and E691.

9.2 *Statement of Precision and Bias:*
9.2.1 This document makes no statement as to the precision and bias of the test methods herein.

TEST METHODS

10. Scope for General Evaluations and Calculations for Applied Stretch Wrapping Films

10.1 These test methods are intended to be used as a means of comparing the performance of applied stretch wrapping films.

10.2 A typical pallet load frame used to conduct these test is 1219 mm (48 in.) in length by 1016 mm (40 in.) wide by 1270 mm (50 in.) tall.

10.3 Changing load sizes may affect test results and should be considered when making comparisons.

10.4 In most cases, upon wrapping initiation, the load should be centered on or in the wrapping area.

10.5 It is important to conduct the film tests using the same time interval after the load is wrapped and at the same temperature, to obtain the most reproducible results.

11. Methods for Determining Stretch of Applied Film

11.1 *Scope:*
11.1.1 The following section contains three methods of evaluating percent stretch of applied film.
11.1.2 Stretch testing is conducted because there is often a difference between machine settings and actual applied film stretch.
11.1.3 Each test method may yield different results and it may be beneficial to test by multiple methods to determine a range of performance or average results.

11.2 *Methods:*
11.2.1 *Marking Wheel Method (interval marking, star wheel)*—The marking wheel tool places marks of a known interval on the unstretched film (see Fig. 1). The film is then applied to the load and the distance between the marks changes as the film is stretched and applied. This distance is used to spot check the percent stretch of the applied film. The change in distance obtained from this procedure corresponds to one specific location on the load, not the average applied film stretch of the load.
11.2.1.1 *Significance and Use:*
(1) This method can be used to measure stretch during different parts of the wrap cycle. These readings can be averaged or considered alone.
(2) This method is not typically used to measure average stretch throughout the entire wrap cycle.

FIG. 1 Marking Wheel Used for Determining Percent Applied Stretch (see 11.2.1)

(3) This method is most commonly used with turntable wrappers; however there are mounting devices for rotary and ring wrappers. Can be used in hand wrapping if the application of the marks does not interfere with the wrapping process.

(4) Apply at least 2 and no more than 4 marks ($2 \leq x \leq 4$, if possible) to avoid overlapping or confusing film marking on transparent film.

(5) Ensure to have enough ink to apply 4 clear marks.

(6) Ensure to keep consistent contact between the marking wheel and the film before the film separates from the roll.

(7) Ensure the units of measure (length) are consistent.

11.2.1.2 *Recommended Marking Wheel Procedure:*

(1) With load in place and desired machine settings, begin wrapping cycle.

(2) As the film carriage approaches the target area to be measured, press marking wheel to center of film roll.

(3) Allow wheel to apply at least 2 and no more than 4 marks ($2 \leq x \leq 4$, if possible) and release wheel.

(4) If additional target areas are desired to be measured, repeat steps 2 and 3 as needed. Be sure to avoid overlapping marks on transparent film to avoid layer confusion.

(5) Be sure to measure the distance between the same location/position within each adjacent mark (center to center, left to left, right to right).

(6) Use the measured distances in conjunction with Eq 1.

11.2.1.3 *Report:*

(1) Record the results from Eq 1.

(2) Record the number of replicates.

11.2.1.4 *Marking Wheel Calculation:*

$$s_1 = \frac{m_f - m_i}{m_i} \times 100 \quad (1)$$

where:

s_1 = stretch on load (%),
m_f = final marker interval on film that has been stretched and applied, and
m_i = original marker interval.

11.2.2 *Tapeless Measure Method (length counter)*—A tapeless measure is used to measure the total film length that is applied to the load (see Fig. 2). As the load is being wrapped, the average perimeter of the load is multiplied by the number of turntable revolutions to obtain the total wrapped length. The total wrapped length is compared to the total unstretched film to calculate the percentage stretch of the load.

11.2.2.1 *Significance and Use:*

(1) Most commonly used with turntable wrappers; however there are mounting mechanisms for rotary and ring wrappers. Can be used in hand wrapping if the measuring of length does not interfere with the wrapping process.

(2) Ensure to keep consistent contact between the tapeless measure and the film before the film separates from the roll.

(3) Ensure the units of measure (length) are consistent.

11.2.2.2 *Recommended Tapeless Measure Procedure:*

(1) Reset tapeless measure to zero length.

(2) Make sure that the tapeless measure is in correct orientation to count forward.

(3) With load in place and desired machine settings, begin wrapping cycle.

(4) For entire cycle, press tapeless measure to center of film roll.

(5) Count the number of revolutions required to complete the entire wrapping pattern.

(6) Use the tapeless measure value in conjunction with Eq 2.

11.2.2.3 *Report:*

(1) Record the results from Eq 2.

(2) Record the number of replicates.

11.2.2.4 *Tapeless Measure Calculation:*

$$s_1 = \frac{(t_r \cdot l_p) - f_u}{f_u} \times 100 \quad (2)$$

FIG. 2 Tapeless Measure for Evaluating Total Percent Stretch (see 11.2.2)

where:

s_1 = stretch on load (%),
t_r = number of turntable revolutions (number),
l_p = average length of perimeter, and
f_u = length of unstretched film (tapeless measure reading).

11.2.3 *Cut and Weigh Method*—The cut and weigh procedure requires the film to be removed from the load after the wrap cycle has finished, at which point the film is weighed and recorded. The cut film weight is compared to the theoretical weight of the film if it were not stretched in order to obtain the percentage film stretch of the load. This process can be used on loads wrapped with any style wrapper because all of the data is collected and calculations are done after wrapping is completed.

11.2.3.1 *Significance and Use:*

(1) When comparing multiple films on a manual or semi-automatic machine ensure that any excess from the film tail is cut short and is consistent in length.

(2) Ensure the units of measure are consistent between weight, length, thickness and density.

11.2.3.2 *Recommended Cut and Weight Procedure:*

(1) With load in place and desired machine settings, begin wrapping cycle.

(2) Count the number of revolutions required to complete the entire wrapping pattern.

(3) Cut film from load after wrapping sequence has finished.

(4) Roll film into a tight ball.

(5) Tare (zero out) scale.

(6) Weigh the ball of applied stretch film.

11.2.3.3 *Report:*

(1) Record the results from Eq 4.

(2) Record number of replicates.

11.2.3.4 *Cut and Weigh Calculations:*

(1) First, calculate the theoretical weight of the unstretched film applied to the load shown in Eq 3 (theoretical unstretched weight of applied stretch film without stretch equation).

$$UW = (N \cdot P) \cdot W \cdot t \cdot (\rho) \quad (3)$$

where:

UW = theoretical unstretched weight of film (g or lb),
N = number of turntable revolutions,
P = average length of perimeter (cm or in.),
W = unstretched film width (cm or in.),
t = unstretched film thickness (cm (cm = micron/10 000) or in. (in. = gauge/100 000)), and
ρ = density of film (0.92 g/cm^3 or 0.0332 lbs/in^3 for average LLDPE).

(2) Second, use the *UW* value to calculate the percent stretch shown in Eq 4 (cut and weigh equation).

$$s_1 = \frac{(UW) - (SW)}{SW} \times 100 \quad (4)$$

where:

s_1 = stretch on load (%),
UW = theoretical unstretched weight of film, and
SW = stretched weight of applied film.

12. Stretch Wrapper Consistency Test

12.1 *Scope*—This test can be used to judge the consistency with which a stretch wrapper and a film perform together. Results from testing of different machines or films can be used to determine their relative performance.

12.2 *Procedure*—Wrap the load frame with the desired wrap pattern, keeping film attachment and cut off points consistent. After wrap cycle has completed cut all film from the frame and weigh. Repeat process at least five times and record results.

12.2.1 The greater the number of cycle repetitions tested the more statistically significant the results.

12.3 *Report*—Report the total repetitions, the average, and standard deviation of the results as well as any film breaks or other problems which occur.

12.3.1 High standard deviation may indicate a stretch wrapping machine or a stretch film which performs inconsistently, or both.

12.3.2 Film breaks can be the result of either machine or film problems.

13. Observed Cling on Load Test

13.1 *Scope*—This test provides a method to determine the approximate cling level of a film as it has been wrapped to a load.

13.1.1 The correct amount of cling required is the amount that prevents the unwrapping of the load in the normal shipping environment and allows the wound film layers to act together as a package.

13.1.2 The amount of cling observed is affected by the film properties and the amount of tension and prestretch of the applied film.

13.1.3 Wrinkles and high tension left in the tail negatively affect cling.

13.2 *Procedure:*

13.2.1 *Preparation*—Note that for single sided cling film, ensure that the cling side of the film is wrapped inward. If the cling side is not known, fold the film over on itself in each direction and determine which side has more cling.

13.2.2 *Passive Evaluation for Cling*—Wrap load in normal manner ensuring consistent film-tail application method and let set 5 min. Observe the film behavior:

13.2.2.1 GOOD: The film does not separate from the load at any point.

13.2.2.2 FAIR: The film tail may partially separate but not reach the first corner of the load.

13.2.2.3 POOR: The film peels off the load to the first corner and stops.

13.2.2.4 VERY POOR: The film peels off the load past the first corner.

13.2.3 *Active Evaluation for Cling*—If further testing of cling levels is desired the film tail may be pulled away from the load surface manually so that the cling characteristics may be observed. Notable differences in cling may be force to peel and uniformity of peel.

14. Observed Tear Test (Zippering)

14.1 *Scope*—This test provides a method to determine the resistance to tear propagation a film exhibits.

14.2 *Procedure:*

14.2.1 After the load has been wrapped, make a 127 mm (5.0 in.) slit in the film vertical to the load using a sharp razor or knife to ensure a clean cut through all layers of film.

14.2.1.1 Locations could include near corners, center line of faces, center of top or bottom wraps, or user specified; ensure that locations are repeatable and consistent across all tests being compared.

14.2.2 Allow the slit to propagate for 10 min.

14.2.3 Measure the resultant vertical distance of the slit, convert to a percentage using Eq 5.

14.3 *Report:*

14.3.1 Record the results of Eq 5.

14.3.1.1 If the slit propagates through to either edge of the load report it as a zipper failure.

14.3.2 Record the number of replicates.

14.4 *Observed Tear Test Calculation:*

$$P = \frac{C_f - C_i}{C_i} \times 100 \quad (5)$$

where:

P = film tear propagation percentage,
C_f = final length of cut (mm or in.), and
C_i = initial length of cut in film (127 mm or 5 in.).

15. Containment Force Testing

15.1 *Scope*—The following section contains four methods to evaluate the containment force of stretch film as applied to the load. These tests do not need to be used exclusively of each other.

15.2 *Significance and Use:*

15.2.1 Containment force is the primary measurement to determine load containment.

15.2.2 The containment force required to stabilize a unit load is influenced by load and handling characteristics. Some common variables affecting load containment requirements:

15.2.2.1 Load weight,

15.2.2.2 Inherent load stability, and

15.2.2.3 Load handling and transportation stresses.

15.2.3 The test methods are calibrated differently and the values obtained from each test will vary. Values can be compared within their own test method's results but cannot be directly compared with other test methods' results.

15.3 *Methods:*

15.3.1 *Pull-Plate Evaluation Method:*

15.3.1.1 *Background:*

(1) The pull plate is a non-yielding metal disc. It is shown in Fig. 3 and recommended features include:

(a) 152 mm (6.0 in.) diameter.

(b) A central eyelet or hook to allow a force measurement gauge to be attached to the plate and pulled from the load.

(c) Two slots located near the center of the plate, 51 mm (2.0 in.) in length and 12 mm (0.50 in.) in width, to allow for a tape measure to be placed through the pull plate and to allow airflow.

(d) Edges that will not damage the film during the test.

(e) A surface covered in a polymer (ex. box tape) that prevents stretch film from slipping off the plate during the evaluation.

15.3.1.2 *Pull-Plate Evaluation:*

(1) Scope—The objective of this test is to measure the containment force of applied stretch film at a given location on the load.

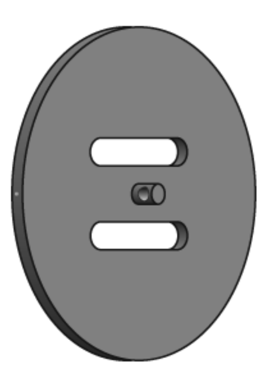
(a) Containment force is a measurement that's affected by multiple film characteristics, most notably compressive force and film stiffness (tensile forces). Annex A1 contains a method which allows the compressive and tensile forces to be separated and reported through calculation.

(2) Recommended Procedure for Pull-Plate Evaluation:

(a) Wrap the load with the desired film and machine settings.

(b) Choose a consistent time interval to let the wrapped load stand undisturbed between the end of the wrap cycle and starting the test. 5 min is recommended.

(c) On the longer side of the load, insert the pull plate between the film and the product and position it at a measured location 254 mm (10.0 in.) from the top of the product and 457 mm (18.0 in.) from the vertical edge of the left side of the product.



NOTE 1—Holes for ruler access and airflow prevent vacuum behind film during evaluation (see 15.3.1.1).
NOTE 2—Other features and designs may be used and are acceptable.

FIG. 3 Pull Plate Used for Pull Evaluation

(i) Take care that the plate is placed behind all layers of film and does not catch on any other packaging.

(ii) If this testing position is not ideal another location may be specified so long as the chosen position is kept consistent across all samples.

(d) Cut a 25 mm (1.0 in.) wide horizontal slit in film to allow eyelet to protrude through the film.

(e) Cut a second horizontal slit at the tape measure insertion slot equal to its width. Insert end of tape measure through slot so that it rests against the product surface.

(f) Cut third horizontal slit in the remaining air flow slot equal to the slot width.

(g) Attach the film scale hook through the eyelet of the pull plate.

(h) Using the scale, pull the attached pull plate away from the product so that the film is pulled 102 mm (4.0 in.) away from its resting position, taking care to not pull beyond 102 mm (4.0 in. (see Fig. 4)).

(i) Measurement should be taken from as close to the center of the pull plate as possible.

(ii) Take care that the scale be pulled out perpendicular to the load face and parallel to the floor.

(iii) Take care that the scale be pulled at a steady and consistent rate.

(3) Report:

(a) Record the maximum force required to pull the plate 102 mm (4.0 in.) from the load in kilograms force (pounds).

(b) Record the number of replicates.

(4) Tips and Cautions for Testing:

(a) Changes may be made to the testing procedures and instruments as required for individual circumstances but all test details should be held consistent across all samples.

(i) Annex A2 contains a modification to this method which modifies the testing procedures in order to better compare results between loads of differing size.

(b) To obtain a more complete evaluation of containment forces testing may be conducted at the top, middle, and bottom of the wrapped load. Containment forces can vary due to wrap pattern settings and the amount of film wrapped onto each portion of the load.

(c) On loads that have non-uniform or non-linear faces, take care that the film is pulled 102 mm (4.0 in.) out from its tangent line (or resting line) to ensure accurate and comparable results.

(d) Accuracy of results is highly dependent on the distance the film is pulled from its resting position. A variation of even a few millimeters may create a significant deviation in the resulting values.

15.3.2 *Pull-Bar Evaluation:*

15.3.2.1 *Background:*

(1) The pull-bar is a non-yielding metal bar. It is shown in Fig. 5 and recommended features include:

(a) 254 mm (10.0 in.) length.

(b) A central eyelet or hook to allow a force measurement gauge to be attached to the bar and pulled from the load.

(c) No sharp or burred edges and ends that might damage the film during the test.

15.3.2.2 *Scope*—The objective of this test is to measure the containment force of applied stretch film at a given location on the load.

(1) Containment force is a measurement that's affected by multiple film characteristics, most notably compressive force and film stiffness (tensile forces). Annex A1 contains a method which allows the compressive and tensile forces to be separated and reported through calculation.

15.3.2.3 *Recommended Procedure for Pull-Bar Evaluation:*

(1) Wrap the load with the desired film and machine settings.

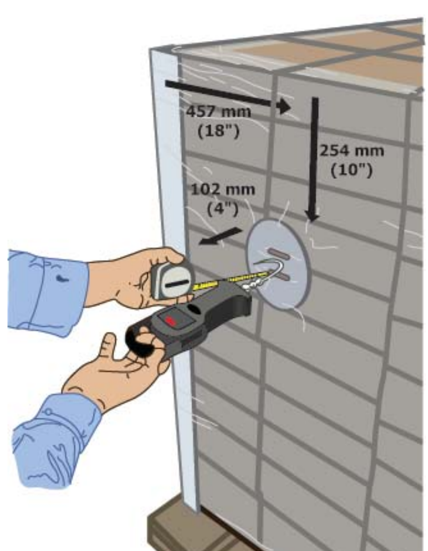


FIG. 4 Pull Plate Positioning Following Recommended Procedures (see 15.3.1.2*(2)*)

NOTE 1—Pull-bar shown per details contained in 15.3.2.1*(1)*.

NOTE 2—Other features and designs may be used and are acceptable.

FIG. 5 Pull-Bar Positioning Following Recommended Procedures (see 15.3.2)

(2) Choose a consistent time interval to let the wrapped load stand undisturbed between the end of the wrap cycle and starting the test. 5 min is recommended.

(3) On the longer side of the load, cut a horizontal film slit at a measured location 254 mm (10.0 in.) from the top of the product and 457 mm (18.0 in.) from the vertical edge of the left side of the product.

(a) Slit should be wide enough to insert the pull-bar behind the film and should not exceed much more than half the pull-bar length at most.

(b) If this testing position is not ideal another location may be specified.

(c) Slit width and testing location should be consistent across all samples.

(4) Insert the pull-bar through the slit behind the film and rotate to a vertical position.

(a) Take care that the bar is placed behind all layers of film and does not catch on any other packaging.

(5) Insert end of tape measure (if required) through slit so that it rests against the product surface.

(6) Attach the film scale hook through the eyelet of the pull-bar.

(7) Using the scale, pull the attached pull-bar away from the product so that the film is pulled 102 mm (4.0 in.) away from its resting position, taking care to not pull beyond 102 mm (4.0 in.) (see Fig. 5).

(a) Measurement should be taken from as close to the center of the pull-bar as possible.

(b) Take care that the scale be pulled out perpendicular to the load face and parallel to the floor.

(c) Take care that the scale be pulled at a steady and consistent rate.

15.3.2.4 *Report:*

(1) Record the maximum force required to pull the bar 102 mm (4.0 in.) from the load in kilograms force (pounds).

(2) Record the number of replicates.

15.3.2.5 *Tips and Cautions for Testing:*

(1) Changes may be made to the testing procedures and instruments as required for individual circumstances but all test details should be held consistent across all samples.

(a) Annex A2 contains a modification to this method which modifies the testing procedures in order to better compare results between loads of differing size.

(2) To obtain a more complete evaluation of containment forces testing may be conducted at the top, middle, and bottom of the wrapped load. Containment forces can vary due to wrap pattern settings and the amount of film wrapped onto each portion of the load.

(3) On loads that have non-uniform or non-linear faces, take care that the film is pulled 102 mm (4.0 in.) out from its tangent line (or resting line) to ensure accurate and comparable results.

(4) Accuracy of results is highly dependent on the distance the film is pulled from its resting position. A variation of even a few millimeters may create a significant deviation in the resulting values.