Designation: F3181 – 16 (Reapproved 2023)

Standard Test Method for The Un-notched, Constant Ligament Stress Crack Test (UCLS) for HDPE Materials Containing Post- Consumer Recycled HDPE[1]

This standard is issued under the fixed designation F3181; 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 an un-notched constant ligament stress (UCLS) test for use with HDPE materials that contain post-consumer recycled HDPE (PCR-HDPE). Contaminants in the PCR-HDPE can initiate stress cracks at elevated temperatures, and this test method evaluates the response of these materials to a constant applied stress.

1.2 The test method is focused on HDPE corrugated pipe containing PCR-HDPE, but can be used in other applications where PCR-HDPE is used.

1.3 The test utilizes the same devices used to perform the NCTL test (Test Method D5397) and the NCLS test (Test Method F2136), but the test is conducted with different specimens and with the use of water instead of a surfactant solution. The test specimen is larger than standard NCLS and NCTL specimens to increase the number of contaminant particles in the specimen that might grow cracks.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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.*

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]

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products

D4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets

D5397 Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test

D638 Test Method for Tensile Properties of Plastics

F412 Terminology Relating to Plastic Piping Systems

F2136 Test Method for Notched, Constant Ligament-Stress (NCLS) Test to Determine Slow-Crack-Growth Resistance of HDPE Resins or HDPE Corrugated Pipe

2.2 *AASHTO Documents:*[3]

Report 696 National Cooperative Highway Research Program (NCHRP)

3. Terminology

3.1 *Definitions:* Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bi-directional shift constants, n*—Constants used to shift elevated temperature and stress data to service conditions; e.g. Popelar shift constants for HDPE.

3.2.2 *contaminant, n*—inorganic particulate matter or other non-HDPE material that creates inclusions or stress risers in the crystalline structure of HDPE.

[1] This test method is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.40 on Test Methods.

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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] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

3.2.3 *post-consumer recycled HDPE (PCR-HDPE), n*—HDPE materials from products that have served a previous consumer purpose (for example, laundry detergent bottles, milk bottles and other consumer goods).

4. Significance and Use

4.1 This test method is a way to evaluate the effects of contaminant particles found in HDPE products containing PCR-HDPE, primarily corrugated pipe. Particles of significant number, size and shape can reduce the slow crack growth resistance of the products. This test is performed in water without a controlled defect such as a notch. Since there is no notch, it is not necessary to use a surfactant in the water bath. It is a constant load test.

4.2 This test may be used to evaluate various blends of recycled and virgin materials. For example, a material with high stress crack resistance and few contaminants can be blended with materials that are less resistant to cracking to enhance the overall stress crack resistance of the blend.

4.3 The test can be conducted at various temperature and stress conditions. If at least three (3) different temperature/stress conditions are evaluated, an estimate of the service lifetime of the material can be predicted with the use of bi-directional shifting or the rate process method.

4.4 The test can also be performed under a single applied load and a single temperature to create a single point test useful for comparative purposes as well as for quality control.

5. Apparatus

5.1 *Blanking Die*—A die suitable of cutting Test Method D638, Type I tensile specimens. Alternatively, specimens may be prepared by machining.

5.2 *Stress-Crack Testing Device*—A lever-loading machine with a mechanical advantage of up to 10:1. The most common devices used for corrugated pipe resins have a maximum mechanical advantage of 5:1, but higher ratios would allow for testing of thicker specimens. The device is similar or identical to those used for Test Methods D5397 and F2136. The device shall have a timer capable of recording failures within the nearest 0.1 hr. for each individual lever arm. The timer must stop when a test specimen fails. An example of an acceptable device is shown in Fig. 1 and Fig. 2. Fig. 1 shows some test specimens mounted in the testing frame. Fig. 2 shows the frame mounted in a water bath with the weights hung on the lever arms.

5.3 *Water Bath*—A heated and stirred water bath deep enough to cover the test specimens mounted in the frame to a point above the reduced section and into the top tab. The bath must be capable of heating to a constant temperature of 80 °C ± 1 °C.

NOTE 1—Baths that once contained surfactant solutions for other stress crack tests are extremely difficult to clean. Residual surfactant will reduce the failure times of this test and may stay present for many months and after many cleanings.

5.4 *Compression Molding Press and Mold*—A set-up for compression molding a plaque at least 7 in. (178 mm) by 7 in.

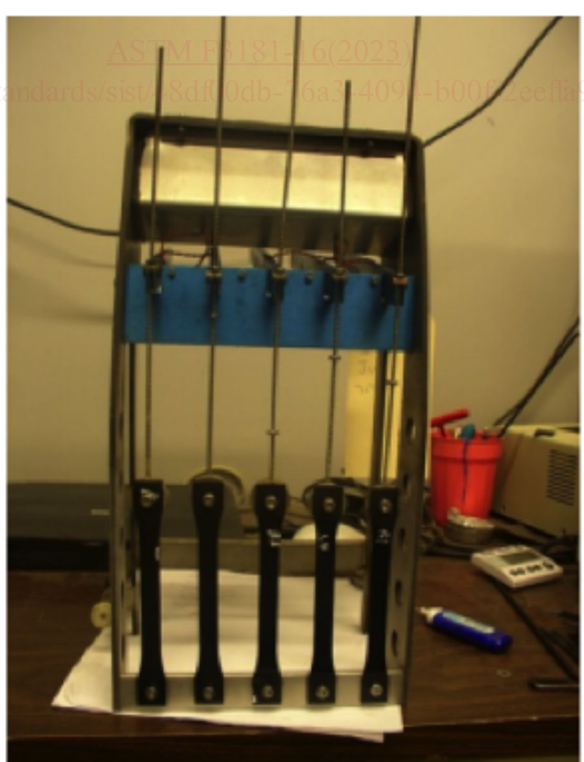

FIG. 1 Test Apparatus

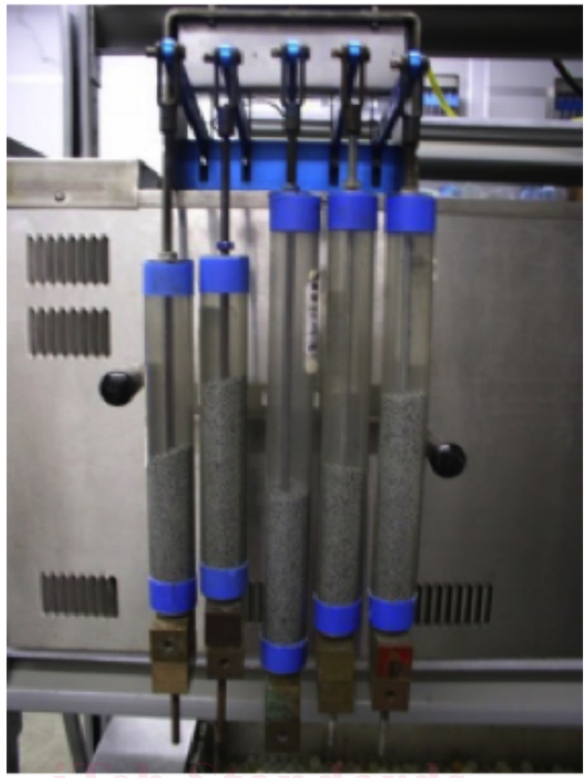

FIG. 2 Hanging Weights

(178 mm) and cooling it at 15°C per minute in accordance with Practice D4703. The mold shall be designed in a way to allow the removal of at least five Test method D638, Type I tensile specimens with the geometry described in Section 6.

6. Test Specimen

6.1 *Plaque*—A compression molded plaque manufactured in accordance with Practice D4703 with a cooling rate of 27 °F (15 °C) per minute. A flash picture-frame mold or a flash mold with machined cavity can be used. The mold must be capable of producing a plaque that is 0.04 in. ± 0.005 in. (1.0 mm ± 0.1 mm) thick for a width of 2.25 in. (57.1 mm), then transitions to a thickness between 0.090 in (2.3 mm) and 0.095 in (2.4 mm). The transition must occur across 1.125 in. (28.6 mm) on either side of the narrow section and stay constant for the full length of the test specimen 6.5 in. (170 mm). This will result in a narrow area for the test specimen that is 0.50 in. (12.7 mm) wide and 2.25 in. long (57.1 mm) and 0.04 in. ± 0.005 in. (1.0 mm ± 0.1 mm) thick. The end tabs must be between 0.090 in. and 0.095 in. (2.3 mm and 2.4 mm) thick. The thickness will transition from the narrow section to the ends across 1.125 in. (28.6 mm) on either side.

NOTE 2—It is important that the material is adequately homogenized prior to compression molding into a plaque. This may be done via melt blending with a twin screw lab extruder or other methods that are deemed effective at homogenizing blends of plastic materials.

6.2 *Test Specimen*—The test specimen produced from the plaque described in 6.1. The specimen is prepared by cutting out a Test Method D638 Type I specimen from a compression molded plaque prepared according to 5.4. Next, a hole, 0.219 in. (5.6 mm) is placed in each tab with the use of a 7⁄32 in. drill bit. The finished specimen and associated dimensions are shown in Fig. 3 and Table 1. At least five (5) specimens are recommended for each material tested.

7. Procedure

7.1 Measure the width and thickness of each test specimen to an accuracy of 0.001 in. (0.03 mm) in accordance to D5397. Calculate the load necessary to apply a tensile stress of 650 psi (4.48 MPa) onto the test specimen with the following equation:

$$AL = \frac{[(\sigma)(t)(w)] - lw + gw}{MA} \tag{1}$$

where:

AL	=	applied load (lbs)
σ	=	applied stress (psi)
t	=	thickness (in.)
w	=	width (in.)
lw	=	lever weight (lbs)
gw	=	grip weight (lbs)
MA	=	mechanical advantage

7.2 Attach five test specimens to the load frame and place the frame into the water bath that has been pre-heated and stabilized at the test temperature.

7.3 Prepare each weight tube to the weight necessary to apply the proper stress to each individual lever arm. Include the attachment pin as part of the applied load. Apply the weight tubes to the lever arms, taking care to apply the load gently. Reset the timers to zero to start the test.

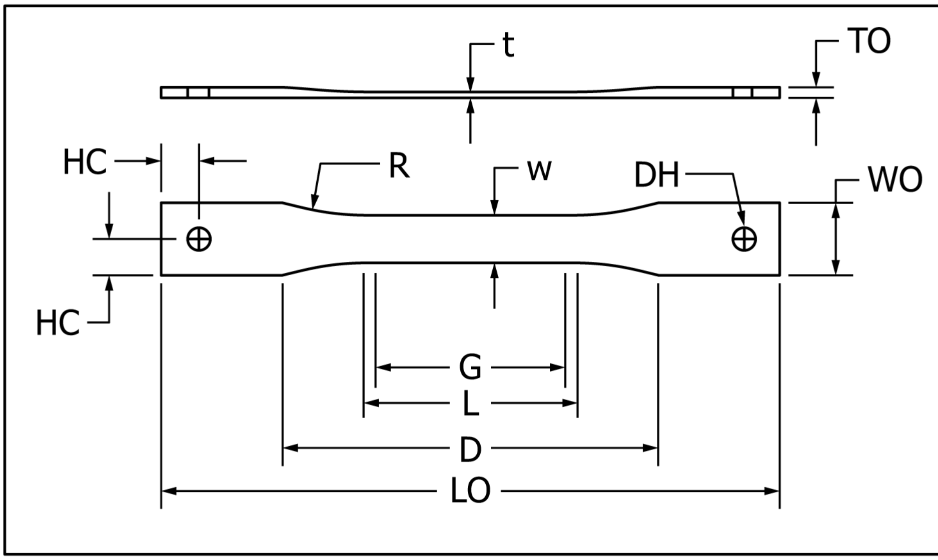

FIG. 3 UCLS Test Specimen (Dimensions shown below)

TABLE 1 Dimensions for Test Specimen Shown in Fig. 3

Description (see Fig. 1)	Dimension in. (mm)	Description (see Fig. 1)	Dimension in. (mm)
LO – Overall length	≥6.50 (170)	w – Width of narrow section	0.50 ± 0.02 (13 ± 0.5)
L – Length of narrow section	2.25 ± 0.02 (57 ± 0.5)	TO – Maximum thickness of specimen	≥ 0.90 (23)
D – Distance between taper	3.96 ± 0.04 (100 ± 1)	t – Thickness of test section	0.040 ± 0.005 (1 ± 0.1)
R – Radius of fillet	3.00 ± 0.04 (76.2 ± 1)	HC – Distance to hole center	0.375 ± 0.020 (9.5 ± 0.5)
G – Gage length	2.00 ± 0.01 (50.8 ± 0.3)	DH –Hole diameter	0.219 ± 0.020 (5.6 ± 0.5)
WO – Overall width	0.75 ± 0.25 (19 ± 6)	...	...

7.4 Once the test has been terminated, record all the failure times and make note of whether the failure occurred in the reduced area or near the grip. Specimens that fail near the grip shall be classified as a non-test and shall not be considered in any data analysis. Also note whether the crack started at an edge (one ductile "horn") or in the center of the specimen (2 ductile "horns"). See Fig. 4 and Fig. 5 for illustrations of typical failures that occur in this test.

8. Single Stress and Single Temperature Test for Quality Assurance

8.1 The standard conditions for quality control or quality assurance testing is a temperature of 176 °F ± 2 °F (80.0 °C ± 1.0 °C) and an applied initial stress of 650 psi (4.48 MPa).

FIG. 4 Contaminant That Caused Stress Cracking in Test Specimen