Florida Method of Test for Determining Stress Crack Resistance of HDPE Corrugated Pipes

Designation: FM 5-572

1. SCOPE

This test method subjects a dumbbell-shaped, notched or un-notched test-specimen to a constant ligament stress in the presence of either a 10% IGEPAL solution or water at an elevated temperature. The method is used to evaluate the stress crack resistance (SCR) of high-density polyethylene (HDPE) corrugated pipe under a constant ligament stress (CLS) in an accelerating environment, which is either 10% IGEPAL solution or water at an elevated temperature. The test consists of three procedures to assess SCR of the pipe liner, corrugation/liner junction, and longitudinal profiles of the corrugated pipes. This test method measures the failure time associated with a given test specimen at a constant, specified, ligament stress level. The values stated in inch-pound units are to be regarded as the standard. The values given in parenthesis are mathematical conversions to SI units, which are provided for information only and are not considered standard.

2. REFERENCED DOCUMENTS

ASTM D638 – Tensile Properties of Plastics

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

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

3. APPARATUS

3.1. Blanking Die – A die suitable for cutting test specimens to the dimensions and tolerances specified in ***Figure* 1** and ***Figure* 2**. ***Figure* 1** shows the dimensions of the die that have the same geometry used for ***ASTM F2136***, which shall be used for specimen thicknesses from 0.040 to 0.125 inch. ***Figure 2*** shows the dimensions of the die that have the same geometry used for ***ASTM D638*** Type IV, which shall be used for specimen thicknesses from 0.126 to 0.25 inch.

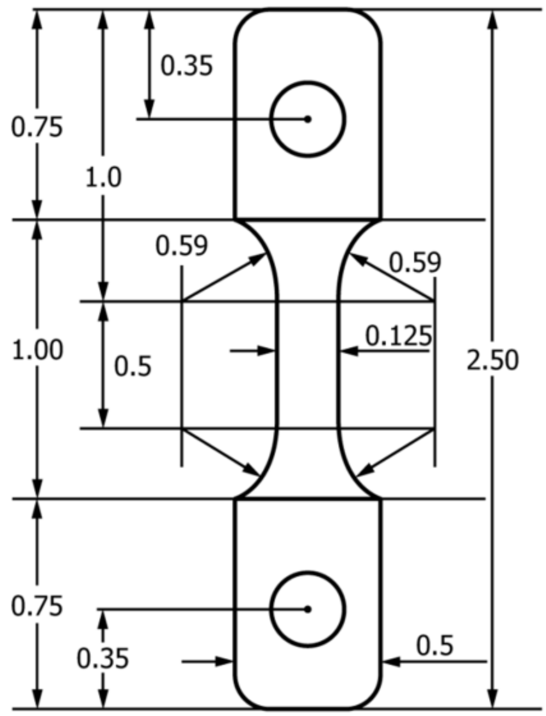


Figure 1: Specimen Geometry – Die Type I Nominal Dimensions.

Note 1: The test specimen is intended to have the same geometry used for ***ASTM F2136*** specimens. The length of the specimen can be changed to suit the design of the test apparatus. However, there should be a constant neck section with a length of at least 0.5 in (13 mm).

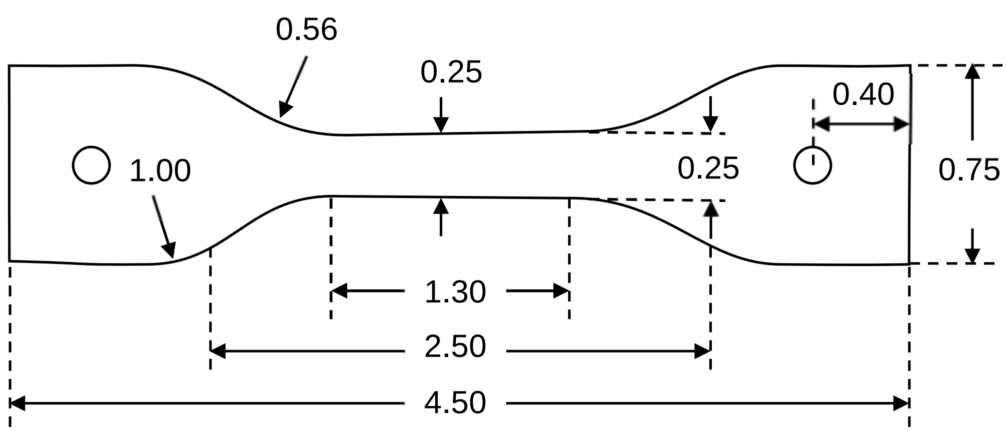


Figure 2: Specimen Geometry – Die Type IV Nominal Dimensions.

Note 2: The test specimen is intended to have the same geometry used for ***ASTM D638*** Type IV specimens. The length of the specimen can be changed to suit the design of the test apparatus. However, there should be a constant neck section with a length of at least 1.3 in (33 mm).

3.2. Stress Crack Testing Apparatus – A lever loading machine, with a lever arm ratio of 3:1, 4:1 or 5:1 similar to that described in ***ASTM D5397***. Alternatively, the tensile load may be applied directly using dead weights or any other method for producing a constant load. The bath solution temperature shall be set at the desired test temperature to an accuracy of ±2 °F (±1 °C). (Testing apparatus is available from: BT Technology, Inc. 320 N. Railroad Street, Rushville, IL 62681; Materials Performance, Inc. 2151 Harvey Mitchell Pkwy, S. Suite 208, College Station, TX 77840; Satec Systems, 900 Liberty Street, Grove City, PA 16127; or equivalent.)

3.3. Notching Device – Notch depth is an important variable that must be controlled. **Section 5.2** describes the notching procedure and type of apparatus used. The approximate thickness of blade should be 0.008 to 0.012 in (0.2 to 0.3 mm).

Note 3: A round robin program was conducted to determine the effect of blade types on the notch depth. In this study several types of steel blades (single edge, double edge etc.) from various manufacturers were used by the round robin participants. The round robin program consisted of seven laboratories using 2 types of resins molded into plaques. The standard deviation of the test results within laboratories is less than ±10%. (Notching apparatus is available from: BT Technology, Inc. 320 N. Railroad Street, Rushville, IL 62681; Satec Systems, 900 Liberty Street, Grove City, PA 16127; or equivalent.)

3.4. Micrometer and caliper capable of measuring to ±0.0005 in (±0.0127 mm).

3.5. Electronic scale for measuring shot weight tubes capable of measuring to ±0.0002 lbs. (±0.1 g).

3.6. Timing device capable of recording failure time to the nearest 0.1 hr.

4. PROCEDURE A – PIPE LINER TEST

4.1. Specimen Preparation

4.1.1. Test specimens are to be die cut from the inner liner of the corrugated pipe. The specimens shall be oriented along the longitudinal axis of the pipe, as shown in Figure 3.

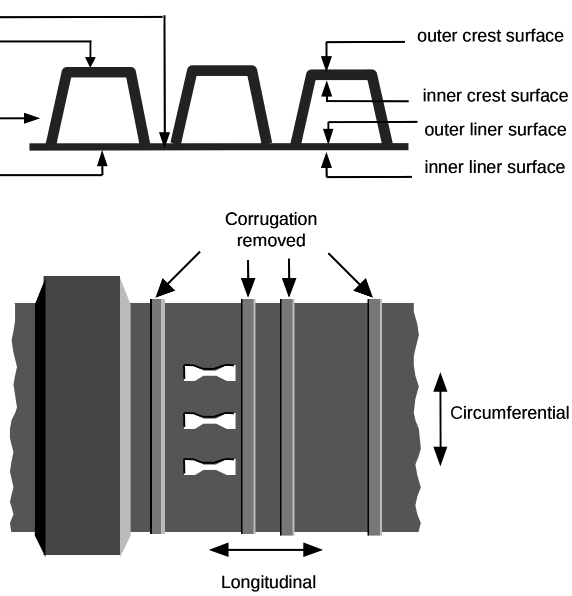
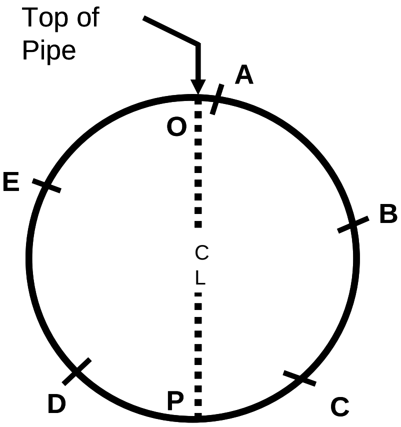


Figure 3: Location of test specimens taken from the liner part of the pipe.

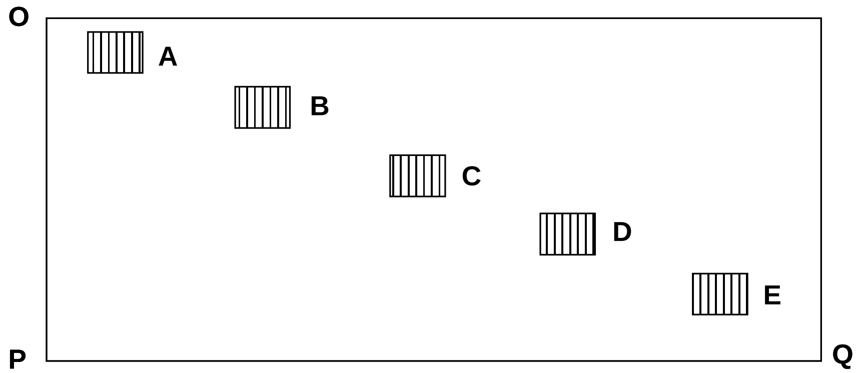
4.1.2. The die cut shall start from the inner liner surface (i.e., the inner liner surface shall face up towards the die).

Note 4: Select the appropriate die (either ***ASTM F2136*** or ***ASTM D638*** Type IV) for the test (see ***Section 4.1***)

4.1.3. Mark five locations in a helical pattern along the pipe. These five locations should be 70° apart from each other in the circumferential direction and they should be evenly spaced along the longitudinal direction, as shown in ***Figure*** **4**. The first specimen at Section-A should be taken from the liner of the pipe.



A, B, C, D, and E shall be 70º apart



OP = the circumferential of the pipe
PQ = the entire length of the pipe

Figure 4: Location of the five test specimens around the pipe.

4.1.4. The average thickness of each test specimen shall be determined by averaging three thickness measurements of the constant neck section.

4.2. Notching

4.2.1. Specimens shall be notched across the center of the constant neck section on the outer liner surface, as shown in ***Figure* 5**. The notch shall be cut at a maximum rate of 0.2 in/min (5.0 mm/min) to a depth of (a) that is equal to 20% of the average thickness of the liner (see ***Section 5.1.4***). Notch depth shall be controlled to ±0.0005 in (±0.0127 mm) by measuring the notch depth with the aid of a microscope.

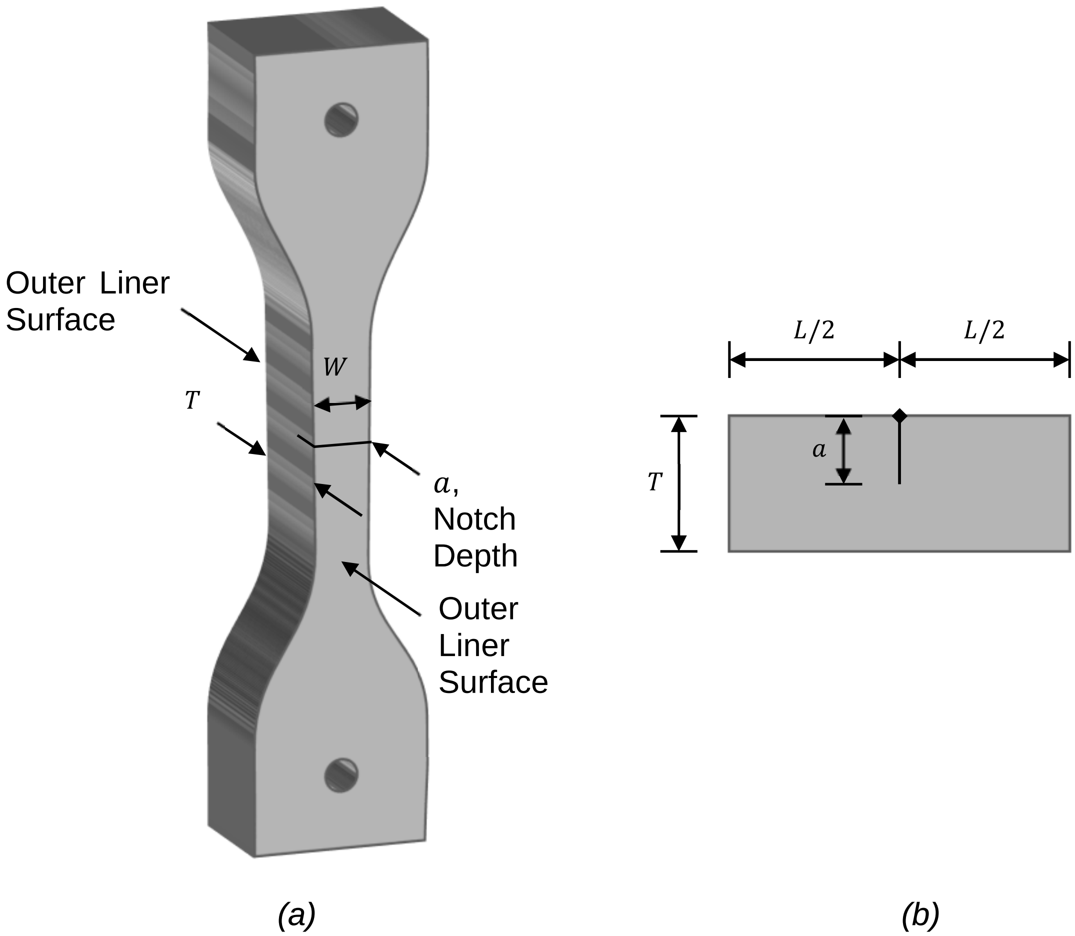


Figure 5: Notch position with respect to the geometry of the specimen. (a) Front view of the notched specimen, (b) side view of the notched specimen.

4.2.2. No single razor blade shall be used for more than 20 test specimens.

4.3. Calculation of Test Load

4.3.1. For each specimen, measure the reduced section width W and thickness T, to the nearest ±0.0005 in (±0.0127 mm) using a micrometer (or caliper), and calculate the notch depth a.

4.3.2. At each loading point, using **Equation 1**, determine the load P that must be hung on the appropriate lever arm to produce the required ligament-stress. The necessary load shall be prepared accurately enough that the ligament-stress does not vary by more than ±0.5%. The appropriate applied load is:

$$P = \frac{S \cdot W \cdot (T - a) - C_F}{M_A}$$ *Equation 1*

Where:

P : load to be applied to the lever arm (lbs.)

S : specified ligament stress (600 psi)

W : cross sectional width of the test specimen (in)

T : thickness of the test specimen (in)

a : the depth of the notch (in)

C_F : correction factor for individual lever weights, based on unit average of lever arm minus weight of sample holding rod. (lbs.)

M_A : mechanical advantage of the test apparatus lever

4.3.3. Each test weight so determined is to be labeled (or otherwise correlated to each test position) and applied to the appropriate lever arm on the test apparatus.

4.4. Reagent

4.4.1. The stress cracking reagent shall consist of 10% nonylphenoxy poly (ethyleneoxy) ethanol (IGEPAL CO-630 from Rhone-Poulenc or equivalent) by volume in 90% de-ionized water. Solution level is to be checked daily, and de-ionized water used to keep the bath at a constant level.

4.4.2. Maintain temperature in the bath at 122 ±2 °F (50 ±1 °C).

4.5. Testing

4.5.1. Determine the weight to be placed on each specimen and load the weight tubes with shot. Do not attach the shot tube to the lever arm.

4.5.2. Attach the specimens to the loading frame. Make sure that bending the specimen does not activate the notch. Lower the specimen into the bath and condition the specimens in the bath for at least 30 minutes.

4.5.3. Reset the specimen timer to zero.

4.5.4. Check that the weight is the correct weight for the particular specimen and carefully connect the weight tube to the appropriate lever arm for the specimen. Apply the load gradually within a period of 5 to 10 seconds without any impact on the specimen.

4.5.5. Start the specimen timer immediately after loading.

5. PROCEDURE B – CORRUGATION/LINER JUNCTION TEST

5.1. Specimen Preparation

5.1.1. Pipe samples should be seven regular corrugations (not including the first three corrugations of the pipe on the bell or spigot ends).

5.1.2. Mark five locations in a helical pattern along the pipe. These five locations should be 70° apart from each other in the circumferential direction and they should be evenly spaced along the longitudinal direction, as shown in Figure 4. The first specimen at Section-A should be taken from the liner of the pipe.

5.1.3. Starting at the stripe mark, use a reciprocating saw to make radial cuts to remove 70° sections of the pipe. If no stripe mark is present start at the seam.

5.1.4. Use a band saw to perform the cuts listed below. If the three corrugated ribbed sections are too wide to fit in the bandsaw, angular samples will have to be cut down to two corrugated ribs.

a. Section-A: Count the first three corrugated ribs from the top. Cut off the bottom four remaining corrugated ribs and discard. Use the remaining material for the sample.

b. Section-B: Cut off the first corrugated rib from the top and discard. Then count three corrugated ribs and cut off the remaining ribs and discard. Use the remaining material for the sample.

c. Section-C: Cut off two corrugated ribs from the top and discard. Then count three corrugated ribs and cut off the remaining ribs and discard. Use the remaining material for the sample.

d. Section-D: Cut off three corrugated ribs from the top and discard. Then count three corrugated ribs and cut off the remaining rib and discard. Use the remaining material for the sample.

e. Section-E: Cut off four corrugated ribs from the top and discard. Use the remaining material for the sample.

f. Remove outer corrugations on all five angular samples (A, B, C, D, E) from the liner.

5.1.5. The corrugation side must be placed upwards so that it is facing the die.

5.1.6. The **ASTM D638** Type IV die shall be used to die cut specimens from the junction region of the pipe. The junction shall be positioned within the constant neck section of the die. If the valley width is narrower than the constant neck section of the die, both junctions can be tested simultaneously, as shown in **Figure 6**. When the length of the valley is longer than the constant neck section, each junction shall be tested separately, as shown in **Figure 7**.

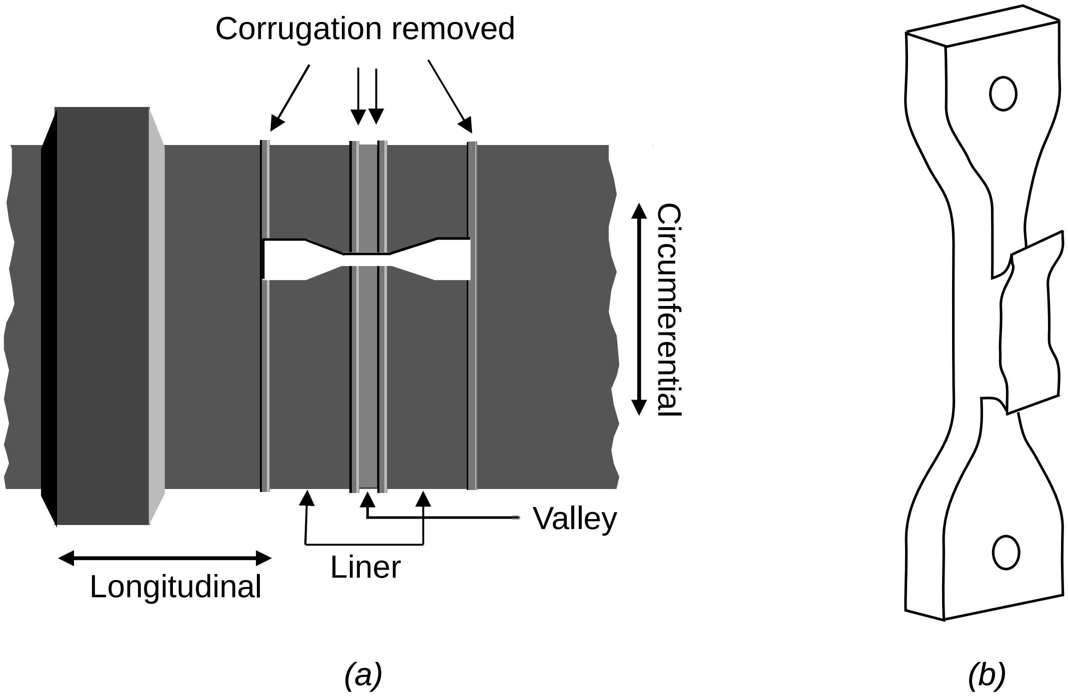
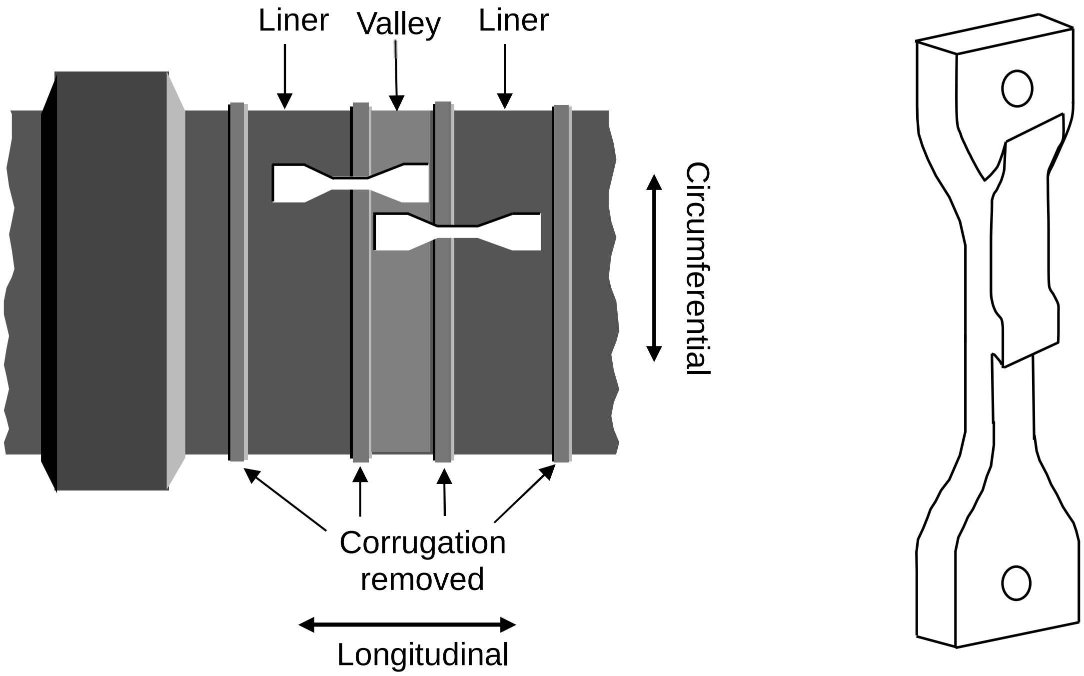


Figure 6: (a) Location of the test specimen when the width of valley is narrower than the constant neck section of the die, (b) a schematic diagram of the test specimen.

Note 5: The specimen shall be removed from the die carefully to avoid imposing stress at the junction.



(a) *(b)*

Figure 7: (a) Locations of the specimen taken from each side of the junction, (b) a schematic diagram of the test specimen.

5.1.7. Measure the specimen dimensions using a single side ball end micrometer or a caliper. Avoid indenting or damaging the specimens with the measurement tool.

5.1.8. Measure the thickness of the liner section of the specimen. Three measurements shall be recorded, and the lowest value shall be used in the applied load calculation.

5.1.9. Measure the width of the specimen.

5.2. Calculation of Test Load

5.2.1. For each specimen, measure the reduced section width W, and the lowest liner thickness T.

5.2.2. At each loading point, using Equation 2, determine the load P that must be hung on the appropriate lever arm to produce the required ligament-stress. The necessary load shall be prepared accurately enough that the ligament-stress does not vary by more than ±0.5%. The appropriate applied load is:

$$P = \frac{(S \cdot W \cdot T) - C_F}{M_A}$$ *Equation 2*

Where:

P : load to be applied to the lever arm (lbs.)

S : specified ligament stress (600 psi)

W : cross sectional width of the test specimen (in)

T : thickness of the test specimen (in)

a : the depth of the notch (in)

C_F : correction factor for individual lever weights, based on unit average of lever arm minus weight of sample holding rod. (lbs.)

M_A : mechanical advantage of the test apparatus lever

5.2.3. Each test weight so determined is to be labeled (or otherwise correlated to each test position) and applied to the appropriate lever arm on the test apparatus.

5.3. Reagent

5.3.1. The stress cracking reagent shall be de-ionized or distilled water. The water level is to be checked daily and kept at a constant level.

5.3.2. Maintain temperature in the bath at ±2 °F (±1 °C) of the set temperature.

5.4. Testing

5.4.1. Determine the weight to be placed on each specimen and load the weight tubes with shot. Do not attach the shot tube to the lever arm.

5.4.2. Attach the specimens to the loading frame. Lower the specimen into the bath and condition the specimens in the bath for at least 30 minutes.

5.4.3. Reset the specimen timer to zero.

5.4.4. Check that the weight is the correct weight for the particular specimen and carefully connect the weight tube to the appropriate lever arm for the specimen. Apply the load gradually within a period of 5 to 10 second without any impact on the specimen.

5.4.5. Start the specimen timer immediately after loading.

5.4.6. Record the time to failure of each specimen to the nearest 0.1 hr.

6. PROCEDURE C – LONGITUDINAL PROFILE TEST

6.1. Definition of longitudinal profile - Longitudinal profile(s) includes features that run along the longitudinal axis of the pipe in either continuously or repeating in regular intervals. These features may be a part of the pipe design (for example vent holes or mold line) or those generated by extrusion defects.

6.2. Specimen preparation

6.2.1. The ASTM D638 Type IV die shall be used to die cut specimens from the profile region of the pipe. The orientation of the specimen shall align with the circumference of the pipe. The profile feature shall be positioned at the center position of the constant neck section of the die.

6.2.2. For the vent-hole profile, the vent-hole shall be positioned at the center of the specimen. The crown-portion of the vent hole shall be removed, as shown in Figure 8.

6.2.3. For each profile, five specimens shall be cut from the test pipe at locations evenly distributed along the longitudinal direction.

6.2.4. For vent-hole specimens, measure the thickness of the liner portion T_L of the vent hole using a single side ball end micrometer or calipers. Two measurements shall be recorded, and the lowest value shall be used in the applied load calculation.

6.2.5. Measure the width of the specimen at the liner portion T_L using a caliper. The tips of the caliper shall be positioned at the midpoint of the thickness of the specimen. Avoid indenting or damaging the specimen with the caliper tips.

6.2.6. For other longitudinal profiles, such as mold line, the thickness of the constant neck section of the specimen shall be measured using a single side ball end micrometer or calipers. Three measurements shall be recorded, and the lowest value shall be used in the applied load calculation.

6.2.7. Measure the width of the specimen using a caliper at the lowest thickness location. The tips of the caliper shall be positioned at the midpoint of the thickness of the specimen. Avoid indenting or damaging the specimen with the caliper tips.

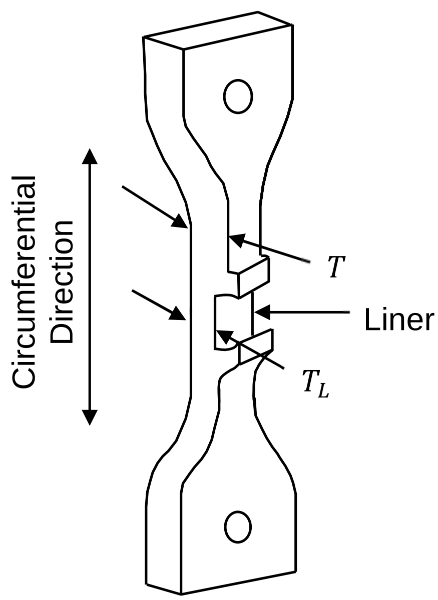


Figure 8: A side-view of a vent hole test specimen with crown part being removed.

6.3. Calculation of Test Load

6.3.1. For each specimen, measure the reduced section width W, and the lowest thickness for the specimen T or liner portion T_L.

6.3.2. At each loading point, using Equation 3 or Equation 4, determine the load P that must be hung on the appropriate lever arm to produce the required ligament-stress. Equation 3 is applied to vent-hole profile only; all other longitudinal profiles shall use Equation 4 to calculate the load. The necessary load shall be prepared accurately enough that the ligament-stress does not vary by more than ±0.5%. The appropriate applied load is:

$$P = \frac{(S - B_S) \cdot W \cdot T_L - C_F}{M_A}$$ *Equation 3*

$$P = \frac{(S - B_S) \cdot W \cdot T - C_F}{M_A}$$ *Equation 4*

Where:

P : load to be applied to the lever arm (lbs.)
S : specified stress (see specification table)
W : cross sectional width of the test specimen (in)
T : thickness of the test specimen (in)
T_L : minimum thickness of the liner (in)
a : the depth of the notch (in)
C_F : correction factor for individual lever weights, based on unit average of lever arm minus weight of sample holding rod. (lbs.)
M_A : mechanical advantage of the test apparatus lever
B_S : bending stress which varies with the profile of the pipe

$$B_S = \left(\frac{T_L/2}{R}\right) \cdot E$$ for vent hole test

$$B_S = \left(\frac{T/2}{R}\right) \cdot E$$ for other longitudinal profiles

where: R : inside radius of the pipe
E : long term modulus (20,000 psi)

6.3.3. Each test weight so determined is to be labeled (or otherwise correlated to each test position) and applied to the appropriate lever arm on the test apparatus.

6.4. Reagent

6.4.1. The stress cracking reagent shall be de-ionized or distilled water. The water level is to be checked daily and kept at a constant level.

6.4.2. Maintain temperature in the bath at ±2 °F (±1 °C) of the set temperature.

6.5. Testing

6.5.1. Determine the weight to be placed on each specimen and load the weight tubes with shot. Do not attach the shot tube to the lever arm.

6.5.2. Attach the specimens to the loading frame. Lower the specimen into the bath and condition the specimens in the bath for at least 30 minutes.

6.5.3. Reset the specimen timer to zero.

6.5.4. Check that the weight is the correct weight for the particular specimen, and carefully connect the weight tube to the appropriate lever arm for the specimen. Apply the load gradually within a period of 5 to 10 second without any impact on the specimen.

6.5.5. Start the specimen timer immediately after loading.

6.5.6. Record the time to failure of each specimen to the nearest 0.1 hr.

7. REPORT

Test report shall include the following information:

7.1. All details necessary for complete identification of the material tested (density, melt index, lot number, etc.).

7.2. Test information shall be recorded according to Table 1 for test Procedure A and Table 2 for test Procedures B and C.

7.3. Report the failure time for each of the five specimens and the arithmetic average of the five specimens.

Table 1: Recommended Data Record Template for Test Procedure A.

Date: Sample Identification: Pipe Region being Evaluated: Test Procedure: Test Temperature: Solution:						
Applied Stress σ (psi)	Average Thickness T (in)	Notch Depth a (in)	Ligament Thickness $T - a$ (in)	Specimen Width W (in)	Applied Load P (lbs.)	Failure Time t (hr.)

Table 2: Recommended Data Record Template for Test Procedures B and C.

Date: Sample Identification: Pipe Region being Evaluated: Test Procedure: Test Temperature: Solution:				
Applied Stress σ (psi)	Minimum Thickness T or T_L (in)	Specimen Width W (in)	Applied Load P (lbs.)	Failure Time t (hr.)