INTERNATIONAL

Designation: F1473 – 24

Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins[1]

This standard is issued under the fixed designation F1473; 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 determines the resistance of polyethylene materials to slow crack growth under conditions specified within.

NOTE 1—This test method is known as PENT (Pennsylvania Notch Test) test.

1.2 The standard test is performed at 80 °C and at 2.4 MPa, but it shall be acceptable to conduct tests at a temperature below 80 °C and with other stresses low enough to preclude ductile failure and thereby eventually induce brittle type of failure. The standard test is conducted in an air environment; however, it shall be acceptable to immerse test specimens in an alternate environment such as water or a water/detergent solution, or other liquid or a different environment such as an inert gas to evaluate slow crack growth performance in different environments. Generally, polyethylenes will ultimately fail in a brittle manner by slow crack growth at 80 °C if the stress is at or below 2.4 MPa

NOTE 2—When testing in environments other than air, it is recommended to consider maintaining the efficacy of the test media (for example, a detergent solution) to minimize any effect of aging.

1.3 The test method is for specimens cut from compression molded plaques.[2] See Appendix X1 for information relating to specimens from pipe.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units 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:*[3]

D1600 Terminology for Abbreviated Terms Relating to Plastics (Withdrawn 2024)[4]

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

D5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics

F412 Terminology Relating to Plastic Piping Systems

2.2 *ISO Standard:*[5]

ISO 18553 Method for the assessment of the degree of pigment or carbon black dispersion in polyolefin pipes, fittings and compounds

3. Terminology

3.1 Definitions are in accordance with Terminology F412. Abbreviations are in accordance with Terminology D1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *brittle failure, n*—a failure mode which exhibits no visible (to the naked eye) permanent material deformation (stretching, elongation, or necking down) in the area of the break.

3.2.2 *slow crack growth, n*—the slow extension of the crack with time.

[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] Lu, X., and Brown, N., "A Test for Slow Crack Growth Failure in Polyethylene Under a Constant Load," *Journal of Polymer Testing*, Vol 11, pp. 309–319, 1992.

[3] 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] The last approved version of this historical standard is referenced on www.astm.org.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

***A Summary of Changes section appears at the end of this standard**

4. Summary of Test Method

4.1 Specimens are prepared from compression molded plaques, precisely notched and then exposed to a constant tensile stress at elevated temperatures in air. Time on test is recorded for tests conducted against a minimum time before failure requirement or the time to complete failure is recorded.

NOTE 3—Minimum time before failure requirements are found in material or product specifications, codes, etc.

5. Significance and Use

5.1 This test method is useful to measure the slow crack growth resistance of molded plaques of polyethylene materials at accelerated conditions such as 80 °C, 2.4 MPa stress, and with a sharp notch.

5.2 The testing time or time to failure depends on the following test parameters: temperature; stress; notch depth; and specimen geometry. Increasing temperature, stress, and notch depth decrease the time to failure. Material parameters, not controlled by the laboratory, that could impact the test results (time to failure) are: pigment (color or carbon black) and the carrier resin for the pigment, or both. Thus, in reporting the test time or time to failure, all the conditions of the test shall be specified.

NOTE 4—Time to failure can also be affected by the degree of pigment (color or carbon black) dispersion and distribution within the test specimen. Test Method D5596 and ISO 18553 provide methods for assessing the degree of dispersion and distribution of the pigment

6. Apparatus

6.1 *Lever Loading Machine,* with a lever arm ratio of about 5:1 to produce a constant tensile load on the specimen. The tensile load may also be applied directly using dead weights or any other method for producing a constant load. The pull rods on the grips shall have universal action to prevent bending. The grips shall be serrated to prevent slippage. The load on the specimen shall be accurate to ±0.5 %.

6.2 *Furnace,* a chamber of sufficient size to house one or more samples for testing and heated by ordinary incandescent light bulbs covered with aluminum foil or any other suitable heating element.

6.3 *Temperature Controller,* shall be able to control the temperature within ± 0.5 °C with respect to the set point.

6.4 *Temperature-Measuring Device,* a thermometer or a thermocouple which can measure the temperature with an accuracy of ± 0.1 °C.

6.5 *Timer,* shall have an accuracy of at least 1 % and shall automatically stop when the specimen fails.

6.6 *Alignment Jig,* as shown in Fig. 1, which aligns the grips and the specimen when the specimen is being tightened in the grips. Alternate alignment jigs which produce the same function may be used.

6.7 *Notching Machine,* for notching the specimen is shown in Fig. 2 or other machines which produce the same results shall be acceptable. The notching machine presses a razor blade into the specimen at a speed less than 0.25 mm/min. The depth of the notch is controlled within ±0.01 mm. The machine is designed so that the main notch and the side notches will be coplanar and the plane of the notching is perpendicular to the tensile axis of the specimen. The thickness of the razor blade is approximately 0.2 mm.

7. Precautions

7.1 The load shall be carefully added to avoid shocking the specimen. When the specimen is inserted in the grips, bending and twisting shall be avoided in order to prevent the premature activation of the notch. For standard testing in air, avoid exposure to fluids such as detergents.

8. Test Specimens

8.1 Specimens are machined from a compression molded plaque of the polyethylene material.

8.2 *Specimen Geometry*—A representative geometry for compression molded plaque specimens is shown in Fig. 3.

8.3 *Dimensional Requirements:*

8.3.1 The side groove shall be 1.0 mm ± 0.10 mm for all plaque thicknesses.

8.3.2 The overall length is not critical except that the distance between the notch and the end of a grip should be more than 10 mm. Thicker specimens should have a greater

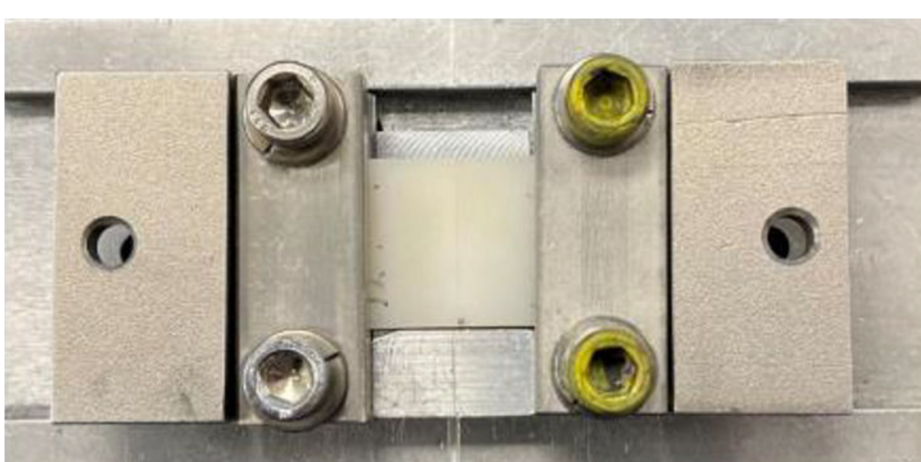


FIG. 1 Alignment Jig

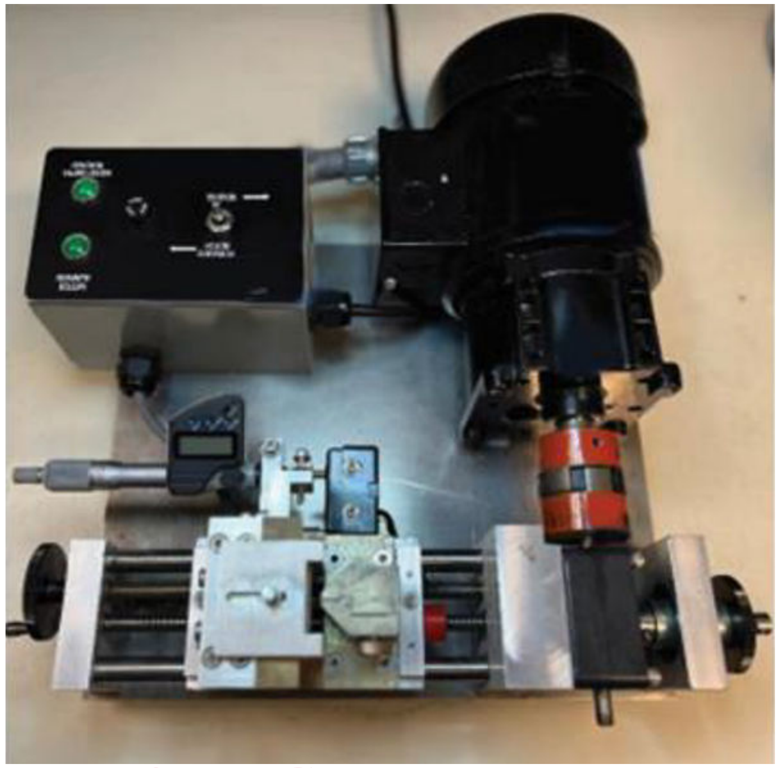
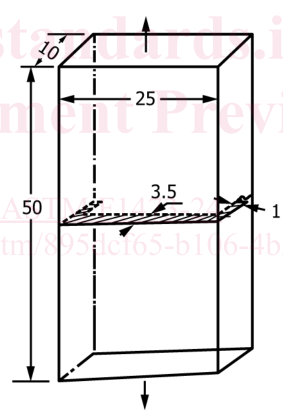


FIG. 2 Notching Machine



Legend:
Arrows designate direction of tensile stress.
All dimensions are in millimetres.

FIG. 3 Representative Geometry for Compression-Molded Specimen

overall length so that the gripped area will be greater in order to avoid slippage in the grip.

8.4 *Preparation of Compression Molded Plaques—*

8.4.1 Polyethylene resins shall be evaluated by using specimens that are machined from compression molded plaques using Practice D4703, except for the following procedures. After the resin is heated to 140 °C to 160 °C, apply and remove the pressure three times. Increase the temperature to 170 °C to 190 °C for 10 min to 15 min without pressure. Then apply and remove the pressure three times. The specific temperatures that are used depend on the melt index of the resin, that is, a higher temperature for a lower melt index. The purpose of applying and removing the pressure is to eliminate voids. Turn off the heat and apply pressure. The time to cool between 130 °C and 90 °C shall be greater than 80 min. Alternatively, the time to cool from the molding temperature to about room temperature shall be greater than 5 h. During cooling the pressure is allowed to decrease naturally.

8.5 *Specimen Notching—*The specimen has two types of notches, the main notch and two side notches. The side notches are usually referred to as "side grooves." The depth requirements for these notches are given in Table 1. The main notch

TABLE 1 Notch Depth as a Function of Specimen Thickness[A]

This table is based on the stress intensity being the same for all thicknesses.

Thickness, mm	Notch Depth, mm
4.00	1.90
5.00	2.28
6.00	2.50
7.00	2.80
8.00	3.09
9.00	3.30
10.00	3.50
11.00	3.70
12.00	3.90
13.00	4.18
14.00	4.39
15.00	4.48
16.00	4.65
17.00	4.88
18.00	4.95
19.00	5.09
20.00	5.20

[A] For an intermediate thickness, linearly interpolate to obtain the notch depth. The notch depth in the specimen shall be within± 0.05 mm of the interpolated value.

is produced by pressing a razor blade into the specimen at a speed of less than 0.25 mm/min. A fresh razor blade shall not be used for more than three specimens and shall be used within one day. The rate of notching for the side grooves is not important. It is important to make the side grooves coplanar with the main notch. Specimens shall be notched at room temperature.

9. Conditioning

9.1 Unless otherwise specified, condition the test specimens for at least 1 h at the test temperature prior to loading. The length of time between notching and testing is not important.

10. Procedure

10.1 *Calculation of Test Load:*

10.1.1 Calculate the test load, *P*, as follows:

$$P = \sigma \times w \times t \tag{1}$$

where:

σ = stress,
w = specimen width, and
t = specimen thickness.

The variables *w* and *t* are based on the specimens prior to notching.

10.1.2 If σ has the units of megapascals and *w* and *t* are in millimetres, and *A* is in square millimetres, then *P* has the units of Newtons. If a lever-loaded machine is used, divide *P* by the lever arm ratio. The load on the specimen shall be ±0.5 % of the calculated load.

NOTE 5—To convert the test load to pounds, multiply the load (in Newtons) by 0.225.

10.2 *Gripping the Specimen*—Using an alignment jig (Fig. 1), center the specimen in the grips so that the axis of the specimen is aligned with the grips. When the grips are tightened, it is important not to activate the notch by bending or twisting the specimen. The ends of the grips shall be at least 10 mm from the notch.

10.3 *Loading the Specimen*—When the specimen in the grips is removed from the alignment jig and transferred to the testing machine, take care that the notch is not activated by bending the specimen. Apply the load after the specimen has been held for at least 1 h at the test temperature. Apply the load gradually within a period of about 5 s to 10 s without any impact on the specimen.

10.4 *Temperature Measurement*—Place the thermocouple or thermometer near the notched part of the specimen. Periodically record the temperature with a frequency that depends on the length of the test.

10.5 When testing is stopped before failure or when the specimen fails, record the time on test, or the time to failure. Failure occurs when the two halves of the specimen separate completely or extensive deformation occurs in the remaining ligament. Failure mode shall be visually examined and shall be brittle only except for the remaining ligament (opposite of the face notch) where ductility is allowed.

NOTE 6—A failure that is majority ductile may indicate that either the test temperature or applied stress is too high.

11. Report

11.1 Compression-molded test specimens shall be identified by the polyethylene material source (resin manufacturer or other source) lot number as well as information of the color (for example, natural, black, blue etc.) of the specimen being tested.

11.2 Stress based on the unnotched area.

11.3 Depth of main notch and side grooves.

11.4 Calculated load and cross-sectional dimensions of the specimen.

11.5 Test temperature.

11.6 Time on test or time to failure.

11.7 Date and time for the beginning and ending of the test.

11.8 Media type (for example, air, water, etc.) used for testing. If a media other than air is used, a description of steps to maintain the composition of the media throughout the period of testing shall be included.

12. Precision and Bias

12.1 *Precision*—A round robin was conducted with seven laboratories and used three resins from different producers using an air environment at 80 °C and a stress of 2.4 MPa. The standard deviation of the average values within laboratories is ±16 %. The standard deviation of the average values between laboratories is ±26 %.

12.2 *Bias*—No statement on bias can be made because there is no established reference value. The test method originated at the University of Pennsylvania. If the test results from about eight years of testing at the University of Pennsylvania can be used as reference values, then there is no bias in the results from the different laboratories with respect to the results at the