Designation: F2648/F2648M – 13

# Standard Specification for 2 to 60 inch [50 to 1500 mm] Annular Corrugated Profile Wall Polyethylene (PE) Pipe and Fittings for Land Drainage Applications[1]

This standard is issued under the fixed designation F2648/F2648M; 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 specification covers requirements and test methods for annular corrugated profile wall polyethylene pipe and fittings with an interior liner. The inside diameters covered are 2 to 60 in. [50 to 1500 mm].

1.2 The requirements of this specification are intended to provide non-pressure (gravity flow) pipe and fittings suitable for underground use for subsurface and land drainage systems, which do not operate under surcharge pressure heads.

NOTE 1—Pipe and fittings produced in accordance with this specification are be installed in compliance with Practice D2321 or Practice F449 based on diameter limitations within the respective standards.

NOTE 2—Subsurface and land drainage systems pertain principally to non-municipal or private facilities for water table control, storm drainage and agricultural drainage applications. The products supplied under this specification are not intended for any sanitary sewer or municipal storm sewer applications.

1.3 This specification covers pipe and fittings with an interior liner using an annular exterior corrugated profile (Fig. 1).

1.4 This specification permits the use of recycled materials for pipe in accordance with the requirements in Section 5.

1.5 *Units*—The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system may not be exact equivalents: therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.6 *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:*[2]

D618 Practice for Conditioning Plastics for Testing

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2321 Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications

D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading

D2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials

D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique

D5630 Test Method for Ash Content in Plastics

D7209 Guide for Waste Reduction, Resource Recovery, and Use of Recycled Polymeric Materials and Products (Withdrawn 2015)[3]

D7399 Test Method for Determination of the Amount of Polypropylene (PP) in Polypropylene/LDPE Mixtures Using Infrared Spectrophotometer (FTIR)

F412 Terminology Relating to Plastic Piping Systems

F449 Practice for Subsurface Installation of Corrugated Polyethylene Pipe for Agricultural Drainage or Water Table Control

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

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.65 on Land Drainage.

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

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

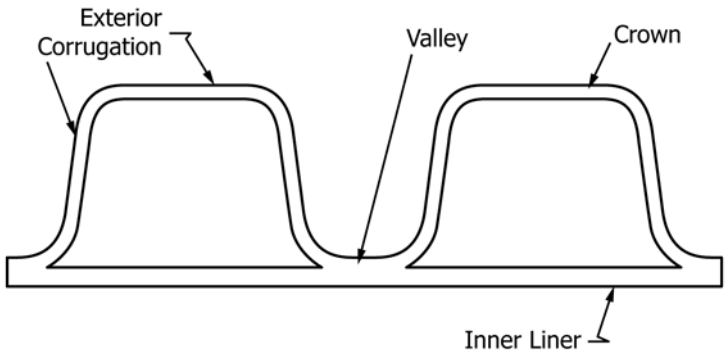


**FIG. 1 Annular Corrugated Profile Wall Polyethylene Pipe with Interior Liner**

**TABLE 1 Pipe Stiffness and Pipe Dimensions**

| Pipe Inside Diameter[A] | | Minimum Pipe Stiffness at 5% Deflection | | Minimum Inner Liner Thickness | |
|---|---|---|---|---|---|
| inch | [mm] | lb/in/in | [kPa] | Inch | [mm] |
| 2 | [50] | 50 | [345] | 0.020 | [0.5] |
| 3 | [75] | 50 | [345] | 0.020 | [0.5] |
| 4 | [100] | 50 | [345] | 0.020 | [0.5] |
| 6 | [150] | 50 | [345] | 0.020 | [0.5] |
| 8 | [200] | 50 | [345] | 0.024 | [0.6] |
| 10 | [250] | 50 | [345] | 0.024 | [0.6] |
| 12 | [300] | 50 | [345] | 0.035 | [0.9] |
| 15 | [375] | 42 | [290] | 0.040 | [1.0] |
| 18 | [450] | 40 | [275] | 0.051 | [1.3] |
| 21 | [525] | 38 | [260] | 0.060 | [1.5] |
| 24 | [600] | 34 | [235] | 0.060 | [1.5] |
| 27 | [675] | 30 | [205] | 0.060 | [1.5] |
| 30 | [750] | 28 | [195] | 0.060 | [1.5] |
| 36 | [900] | 22 | [150] | 0.067 | [1.7] |
| 42 | [1050] | 20 | [140] | 0.071 | [1.8] |
| 48 | [1200] | 18 | [125] | 0.071 | [1.8] |
| 54 | [1350] | 16 | [110] | 0.079 | [2.0] |
| 60 | [1500] | 14 | [97] | 0.079 | [2.0] |

[A] Inside Diameters for metric (SI) sizes are in direct Imperial equivalent dimensions

2.2 *American Association of Highway and Transportation Officials*[4]

(AASHTO) AASHTO LRFD Bridge Design Specifications

2.3 *Federal Standards:*[5]

Fed. Stds. No. 123 Marking for Shipment (Civil Agencies)

2.4 *Military Standard:*[6]

MIL-STD-129 Marking for Shipment and Storage

2.5 *NCHRP (National Cooperative Highway Research Program) Report:*[7]

NCHRP Report 631 Updated Test and Design Methods for Thermoplastic Drainage Pipe

[4] 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.

[5] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

[6] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

[7] Transportation Research Board, The National Academies 500 Fifth Street, NW Washington, DC 20001. http://www.TRB.org.

## 3. Terminology

3.1 Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation for polyethylene is PE.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *buckling, v*—Any reverse curvature or deformation in the pipe wall or profile element that reduces the load-carrying capacity of the pipe. For testing evaluations in this standard, buckling is defined as the buckling deflection limit, the point where the pipe no longer sustains increasing or constant load with increasing deflection.

3.2.2 *inside diameter, n*—The manufacturer's stated pipe inside diameter (Table 1).

3.2.3 *mold line, n*—A line formed on the product as a result of the mold blocks parting during manufacturing, also referred to as a parting line.

3.2.4 *profile wall, n*—A pipe wall construction that presents an interior liner in the waterway but includes ribs, corrugations, or other shapes, which can be either solid or hollow, that helps brace the pipe against diametrical deformation.

## 4. Ordering Information

4.1 Orders for product made to this specification should include the following information to adequately describe the desired product:

4.1.1 This ASTM designation,

4.1.2 Perforations:

4.1.2.1 With perforations,

4.1.2.2 Without perforations,

4.1.3 Diameters,

4.1.4 Total footage of each pipe diameter involved,

4.1.5 Pipe length,

4.1.6 Fitting type(s):

4.1.6.1 Size and type of fittings, including mainline and branch diameters, and

4.1.6.2 Number of fittings per diameter,

4.1.7 Material designation,

4.1.7.1 Virgin resin, and

4.1.7.2 Recycled resin.

## 5. Materials and Manufacture

5.1 *Virgin Resin Products:*

5.1.1 *Pipe and Fittings*—The pipe and fittings shall be made of PE virgin plastic compound meeting the requirements of the following cell classifications as defined and described in Specification D3350:

5.1.1.1 Pipe Diameter 2 through 10-inch: Cell Class 424420C or 424420E (ESCR Test Condition B),

5.1.1.2 Pipe Diameter 12 through 60-inch: Cell Class 435420C or 435420E (ESCR Test Condition B).

5.1.1.3 Environmental crack resistance shall be determined in accordance with 7.8. When carbon black is used, the carbon black content shall be equal to or greater than 2.0 % but not exceed 4.0 % when tested in accordance with Test Method D4218. In all cases, the density of the PE plastic without pigment shall not be less than 0.945gm/cc nor greater than 0.955 gm/cc. Compounds that have a higher cell classification in one or more properties shall be permitted provided all other product requirements are met.

5.1.2 *Rotationally Molded Fittings and Couplings*—Compounds used in the manufacture of rotationally molded fittings and couplings shall be made of virgin PE plastic compound meeting the requirements of cell classification 213320C or 213320E (ESCR Test Condition B) as defined in Specification D3350, except that the carbon black content shall be equal to or greater than 2.0 % but not exceed 4 % when tested in accordance with Test Method D4218. Compounds that have a higher cell classification in one or more properties shall be permitted provided all other product requirements are met.

5.1.3 *Injection and Blow Molded Fittings and Couplings*—Compounds used in the manufacture of injection molded fittings and couplings shall be made of virgin PE plastic compound meeting the requirements of cell classification 414420C or 414420E (ESCR Test Condition B) as defined in Specification D3350, except that the carbon black content shall be equal to or greater than 2.0 % but not exceed 4 % when tested in accordance with Test Method D4218. Compounds that have a higher cell classification in one or more properties shall be permitted provided all other product requirements are met.

5.1.4 *Rework Material*—Clean rework material generated from the manufacturer's own pipe and fittings production shall be permitted to be used by the same manufacturer provided that the material meets the same or higher Specification D3350 cell classification as the material required for the intended part and pipe or fittings to be produced under this specification.

5.2 *Recycled Resin Products:*

5.2.1 *Recycled Resin Pipe*—The pipe containing any post-consumer or industrial recycled materials shall be made of PE plastic compound as defined in Guide D7209 meeting the requirements of the following cell classifications as defined and described in Specification D3350:

5.2.1.1 Pipe Diameter 2 through 10-inch: Cell Class 424400C or 424400E,

5.2.1.2 Pipe Diameter 12 through 60-inch: Cell Class 435400C or 435400E.

5.2.1.3 When carbon black is used, the carbon black content shall be equal to or greater than 2 % but not exceed 4 % when tested in accordance with Test Method D4218. Compounds that have a higher cell classification in one or more properties shall be permitted provided all other product requirements are met. For slow crack growth resistance, extruded pipe shall be evaluated using the notched constant ligament stress (NCLS) test according to the procedure described in 7.9. The average failure time of the five test specimens shall exceed 12 h with no single test specimen's failure time less than 9 h. Maximum level of polypropylene present by volume shall not be greater than 5 percent when tested in accordance with the procedures in 7.10. Maximum ash content shall not be more than 2 % in accordance with the procedures in 7.11.

5.2.2 *Recycled Resin Fittings*—Fittings made from recycled resins are not permitted under this standard.

## 6. General Requirements

6.1 *Workmanship*—The pipe and fittings shall be homogeneous throughout and be as uniform as commercially practical in color, opacity and density. The pipe walls shall be free of cracks, holes, blisters, voids, foreign inclusions, or other defects that are visible to the naked eye and that may affect the wall integrity. There shall be no delamination or separation of the inner liner and the profile. The ends shall be cut squarely and cleanly. Holes intentionally placed in perforated pipe shall be permitted.

6.1.1 Visible defects, cracks, creases, splits, obstruction to flow in perforations, or in pipe are not permissible.

6.2 *Dimensions and Tolerance:*

6.2.1 *Inside Diameter*—The average measured inside diameter for pipe and fittings shall not vary more than (+/−) 1.0 % from the inside diameter when measured in accordance with 7.4.1.

NOTE 3—The outside diameters and the corrugation pitch of products manufactured to this specification are not specified; therefore, compatibility between pipe and fittings from different manufacturers or the same manufacturer shall be verified.

6.2.2 *Length*—The pipe shall be supplied in any length agreeable to both the owner and manufacturer. Length shall not be less than 99 % of stated quantity when measured in accordance with 7.4.2.

6.2.3 *Minimum Inner Liner Thickness*—The minimum inner liner thickness of the pipe shall meet the requirements given in Table 1 when measured in accordance with 7.4.3.

6.2.4 *Perforations*—Perforations shall be cleanly cut, placed in the valley of the corrugation rib, and uniformly spaced along the length and circumference of the pipe. Dimensions of the perforations and the minimum perforation inlet area shall be as listed in Table 2. Other perforation dimensions and configurations shall be permitted where required to meet the needs of the specifier. All measurements shall be made in accordance with 7.4.4. Pipe connected by bell and spigot joints shall not be perforated in the area of the bells and spigots.

6.3 *Pipe Stiffness*—Minimum pipe stiffness at 5 % deflection shall meet the requirements given in Table 2 when tested in accordance with 7.5.

NOTE 4—The 5 % deflection criterion, which was selected for testing convenience, is not a limitation with respect to in-use deflection. The engineer is responsible for establishing the acceptable deflection limit.

6.4 *Pipe Flattening*—There shall be no evidence of splitting, cracking, breaking, separation of seams, separation between the exterior corrugation and inner liner, or combinations thereof, when tested in accordance with 7.6.

6.5 *Pipe Impact Strength*—There shall be no evidence of splitting, cracking, breaking, separation of seams, separation of the outer and inner wall, or combinations thereof, when tested in accordance with 7.7.

6.6 *Fittings and Joining Systems:*

6.6.1 Only fittings supplied or recommended by the pipe manufacturer shall be used. Fittings shall be installed in accordance with the manufacturer's recommendations.

6.6.2 The joining system(s) shall be of a design that preserves alignment during construction and prevents separation at the joints. Bell and spigot, external snap or split couplers are examples of typical designs.

NOTE 5—The ability of a joint to resist soil infiltration (soil tightness) shall be considered. Soil tightness is a function of opening size, channel length, and backfill particle size. A backfill material containing a high percentage of Class III and Class IVA material as defined in Practice D2321 requires consulting with the manufacturer for the specific type of joint to be used to guard against soil infiltration. Alternatively, the joint shall be wrapped with a geotextile designed to prevent migration of soils into the pipe.

## 7. Test Methods

7.1 *Conditioning:*

7.1.1 *Referee Testing*—When conditioning is required for referee tests, condition the specimens in accordance with Procedure A of Practice D618 at 73.4 ± 3.6° F [23 ± 2° C] at 50 % relative humidity for not less than 24 hours prior to test. Conduct tests under the same conditions of temperature.

7.1.2 *Quality Control Testing*—Condition specimens prior to test at 73.4 ± 3.6° F [23 ± 2° C] for a minimum of 4 hours without regard to relative humidity or 1 h in water.

7.2 *Test Conditions*—Conduct tests other than those for routine quality control purposes in the Standard Laboratory Atmosphere of 73.4 ± 3.6° F [23 ± 2° C] and 50 ± 5 % relative humidity in the referenced test method or in this specification.

7.3 *Sampling*—The selection of the sample or samples of the pipe and fittings shall be as agreed upon between the owner and the seller. In case of no prior agreement, any samples selected by the testing laboratory shall be permitted.

7.4 *Dimensions:*

7.4.1 *Inside Diameter*—Measure the inside diameter in accordance with Test Method D2122.

7.4.2 *Length*—Measure pipe length in accordance with Test Method D2122. Length shall be measured at ambient temperature.

7.4.3 *Minimum Inner Liner Thickness*—Measure the thickness of the inner liner in accordance with Test Method D2122. Each specimen shall be cut perpendicular to the seam line of the pipe directly through a corrugation allowing a plain view of the inner wall 360 degrees around the circumference in order to

**TABLE 2 Perforation Dimensions**

| Pipe Inside Diameter | | Type of Perforation | | | |
|---|---|---|---|---|---|
| | | Circular | | | |
| | | Maximum Diameter | | Minimum Inlet Area | |
| in. | [mm] | in. | [mm] | $In^2/ft$ | $cm^2/m$ |
| 2 | [50] | 0.187 | [4.75] | 1.0 | [20] |
| 3 | [75] | 0.187 | [4.75] | 1.0 | [20] |
| 4 | [100] | 0.187 | [4.75] | 1.0 | [20] |
| 6 | [150] | 0.187 | [4.75] | 1.0 | [20] |
| 8 | [200] | 0.256 | [6.25] | 1.0 | [20] |
| 10 | [250] | 0.315 | [8.00] | 1.0 | [20] |
| 12 | [300] | 0.375 | [10] | 1.5 | [30] |
| 15 | [375] | 0.375 | [10] | 1.5 | [30] |
| 18 | [450] | 0.375 | [10] | 1.5 | [30] |
| 21 | [525] | 0.375 | [10] | 2.0 | [40] |
| 24 | [600] | 0.375 | [10] | 2.0 | [40] |
| 27 | [675] | 0.375 | [10] | 2.0 | [40] |
| 30 | [750] | 0.375 | [10] | 2.0 | [40] |
| 36 | [900] | 0.375 | [10] | 2.0 | [40] |
| 42 | [1050] | 0.375 | [10] | 2.0 | [40] |
| 48 | [1200] | 0.375 | [10] | 2.0 | [40] |
| 54 | [1350] | 0.375 | [10] | 2.0 | [40] |
| 60 | [1500] | 0.375 | [10] | 2.0 | [40] |

obtain a minimum of eight measurements in accordance with Test Method D2122. As an alternative to Test Method D2122, minimum liner thickness is allowed to be determined with the use of a calibrated ultrasonic thickness gauge.

NOTE 6—Test Method D2122 also permits the use of alternate measurement methods such as ultrasonic gauges.

7.4.4 *Perforations*—Measure dimensions of perforations on a straight specimen without external forces applied. Linear measurements shall be made with an instrument with calibration increments of 0.01 in. [0.25 mm].

7.5 *Pipe Stiffness*—Select three pipe specimens and test for pipe stiffness in accordance with Test Method D2412, except for the following conditions:

7.5.1 The test specimens shall be a minimum of the lesser of one diameter or 24 inches but not less than three full corrugations in length.

7.5.2 Each specimen shall be cut mid valley to mid valley while still meeting or exceeding the minimum length requirement.

7.5.3 Locate the first specimen in the loading machine in line with the mold line. The specimen must lie flat on the plate within 0.125 in. [3 mm] and shall be straightened by hand bending at room temperature. Use the first location as a reference point for rotation and testing of the other specimen. Rotate the subsequent specimen 90 degrees, respectively, from the original orientation. Test each specimen in only one position.

7.5.4 Test cross head speed shall be 0.5 in./min [12.5 mm/min] for all diameter specimens, until deflection reaches 5 % of initial inside diameter.

7.6 *Flattening*—Flatten the three test specimens from 7.5 between parallel plates until the pipe inside diameter is reduced by 40 %. The rate of loading shall be 0.5 in/min [12.5 mm/min]. For pipe with inside diameters greater than 10-in., test speed may be increased to a maximum of 5 % of the inside diameter per minute, once deflection has reached 5 % of inside diameter. The specimen shall have no splitting, cracking, breaking, or separation of ribs, seams, or corrugations where observed under normal light with the unaided eye. Additionally, at or below the deflection limit defined in Eq 1, the specimen shall be considered as failing this flattening test when the load does not increase continuously with increasing deflection. This value shall be considered the point of buckling failure.

Buckling Deflection Limit:

$$\Delta b = \frac{6.15\% \cdot 0.5 \cdot D}{D_f \cdot 0.6 \cdot h_p} \quad (1)$$

where:

$\Delta b$ = minimum buckling deflection limit (%)
$D$ = mean diameter (centroid) of pipe (in [mm])
$D_f$ = shape factor (dimensionless fixed value of 4.27 for parallel plate test)
$h_p$ = corrugation height (in [mm])

NOTE 7—Field deflection limits are typically taken at 5 %. Eq 1 is based on the results from NCHRP Report 631 and is defined as being derived from the standard parallel plate test equation. The constant value 6.15 % (0.0615) in Eq 1 is the factored combined strain limit for HDPE pipe per AASHTO LRFD Section 12. The constant value 0.6 in this equation is an estimated centroidal distance for typical profiles produced per this specification.

7.7 *Impact Resistance*—Test pipe specimens in accordance with Test Method D2444 except six specimens shall be tested, or six impacts shall be made on one specimen. In the latter case, successive impacts shall be separated by 120 ± 10° for impacts made on one circle, or at least 12 in. [305 mm] longitudinally for impacts made on one element. Impact points shall be at least 6-inches [150 mm] from the end of the specimen. Impact strength shall not be less than 100 ft-lbs [136 J]. Tup B shall be used and use a flat plate specimen holder. Condition the specimens for 24 h at a temperature of 24 ± 3.5 °F [–4 ± 2 ºC], and conduct all tests within 120 s of removal from this atmosphere. The center of the falling tup shall strike on a corrugation crown for all impacts. All impacts shall be made at the center line of the specimen.

7.7.1 In sizes 2 to 18 in. [50 to 450 mm] the test specimens shall be equal in length to the greater of 12-in. [300 mm] or the nominal diameter. In sizes 21 to 60 in. [750 to 1500 mm] the test specimens shall be equal in length to one-half of the nominal diameter but not less than 18 in. [457 mm]. Minimum lengths of test specimens must be adequate to meet the multiple test positions required in Section 7.7.

7.8 *Slow Crack Growth Resistance of PE plastic without pigment*—Test PE plastic without pigment in accordance with Test Method F2136.

7.9 *Slow Crack Growth Resistance of Recycled PE plastic pipe*—Pipe test specimens shall be taken from extruded pipe in the pipe liner area or be molded into test specimens from the pipe. Test 5 pipe specimens using the same protocol for molded bars in Test Method F2136, except for the following modifications:

7.9.1 The applied stress for the NCLS test shall be 600 psi [4138 kPA].

7.9.2 The test specimen is taken from the extruded pipe liner if the size allows. If not, the extruded pipe is chopped and molded into a specimen. The average failure time for these molded test specimens shall exceed 16 h with no single test specimen's failure time less than 12 h.

7.10 *Determination of Percent Polypropylene for Recycled Resin Compounds*—Test samples of the recycled resin compound in accordance with Test Method D7399.

7.11 *Determination of Ash Content in Recycled Materials*—Test a one gram sample at 800°C in accordance with Test Method D5630.

## 8. Inspection

8.1 *General*—Inspection of the product shall be as agreed upon between the owner and the manufacturer as part of the purchase contract. Unless otherwise specified in the contract or purchase agreement, the manufacturer is responsible for the performance of all inspection and test requirements specified herein.

8.2 *Notification*—If inspection is specified by the owner, the manufacturer shall notify the owner in advance of the date,

time, and place of testing of the pipe or fittings, or both, so that the purchaser may be represented at the test.

8.3 *Access*—The inspector shall have free access to those parts of the manufacturer's plant and testing laboratory that are involved in work and testing performed under this specification. The manufacturer shall afford the inspector all reasonable facilities for determining whether the pipe or fittings, or both, meet the requirements of this specification.

8.4 *Production Lot*—The manufacturer shall maintain records to identify the production line, date, resin compound and production run for any pipe selected by the inspector for testing. When agreed upon by the owner and manufacturer under Section 8.1, the pipe inspected shall be taken from a lot shipped to the owner's project.

## 9. Rejection and Retesting

9.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) shall be conducted again on pipe from the same production lot with an agreement between the owner and the manufacturer. There shall be no agreement to lower the minimum requirement of the specification by such means as omitting tests that are a part of the specification, substituting or modifying a test method, or by changing the specification limits. In retesting, the product requirements of this specification shall be met, and the test methods designated in this specification shall be followed. If, upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

## 10. Certification

10.1 When specified in the purchase order or contract, a manufacturer's certification shall be furnished to the owner that the products were manufactured, sampled, tested, and inspected at the time of manufacture in accordance with this specification and have been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 11. Product Marking

11.1 *Virgin Resin Pipe*—Each length of pipe in compliance with this specification shall be clearly marked with the following information: this designation "ASTM F2648"; the nominal pipe size in inches [mm]; the Specification D3350 cell classification per 5.1.1, the manufacturer's name, trade name or trademark, plant location, and date of manufacture. The marking shall be applied to the pipe in such a manner that it remains legible after installation and inspection. It shall be placed, at least, at each end of each length of pipe or spaced at intervals of not more than 10 ft [3.0 m].

11.2 *Recycled Resin Pipe*—Each length of pipe in compliance with this specification shall be clearly marked with the following information: this designation "ASTM F2648/F2648M"; the nominal pipe size in inches [mm]; the Specification D3350 cell classification per 5.2.1 followed by the statement "contains recycled resin", the manufacturer's name, trade name or trademark, plant location, and date of manufacture. The marking shall be applied to the pipe in such a manner that it remains legible after installation and inspection. It shall be placed, at least, at each end of each length of pipe or spaced at intervals of not more than 10 ft [3.0 m].

11.3 *Fittings*—Each fitting in compliance with this specification shall be clearly marked with the following information: this designation "ASTM F2648"; the nominal size in inches; the PE; the manufacturer's name, trade name or trademark; plant location, and date of manufacture.

## 12. Packaging and Package Marking

12.1 All pipe, fittings and accessories shall, unless otherwise specified, be packaged for standard commercial shipment.

## 13. Quality Assurance

13.1 When the product is marked with this designation (ASTM F2648), the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

## 14. Keywords

14.1 Profile wall; interior liner; pipe; fittings; PE; subdrainage; land drainage; polyethylene

## SUPPLEMENTARY REQUIREMENTS

## GOVERNMENT/MILITARY PROCUREMENT

These requirements apply only to Federal/Military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified herein. The manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the owner disapproves. The owner shall have the right to perform any of the inspections and tests set forth in this specification, where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the manufacturer's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

## APPENDIXES

**(Nonmandatory Information)**

## X1. AUTHORITIES

X1.1 Since this product has a wide variety of uses in underdrain and subsurface drainage systems, approval for its use rests with various agencies. The installer should contact the relevant authority to obtain local installation guidelines. A partial list of authorities, according to product usage is as follows:

X1.1.1 *Roadway underdrain and subsurface drainage*—Federal, state, county or local highway authority.

X1.1.2 *Farm subsurface drainage*—U.S. Department of Agriculture Natural Resource Conservation Service, local office. Reference, Engineering Standard 606.

X1.2 The pipe manufacturer(s) should be able to provide proof of product acceptance by specific agencies, when appropriate.

## X2. STRUCTURAL DESIGN

X2.1 After the design engineer satisfies project requirements, such as deflection, local and global buckling, and bending stress, it is advisable to review conditions with particular respect to long-term strain of 5%.

X2.2 When the pipe is buried deeply, where hydrostatic conditions exist or when excessive pipe deformations or deflections, or both, might develop, it is advisable to evaluate the strain and environmental conditions as indicated in the following sections.

X2.3 The following discussion is about tensile and compressive strains. It is presented in general form. The user is responsible for qualifying the pipe after reviewing the proposed conditions and the qualities of the manufacturer's product.

X2.3.1 *Tensile Strain:*

$$\varepsilon_T = \varepsilon_B - (\varepsilon_S + \varepsilon_H) \quad \text{(X2.1)}$$

where:

$\varepsilon_T$ = total tensile strain,

$\varepsilon_B$ = tensile strain from pipe bending in either diametric, axial, or combined situations,

$\varepsilon_S$ = compressive strain induced into the pipe walls by the soil weight above the pipe.

$\varepsilon_H$ = external hydrostatic compressive strain.

X2.3.2 *Compressive Strain:*

$$\varepsilon_C = \varepsilon_B + \varepsilon_S + \varepsilon_H \quad \text{(X2.2)}$$

where:

$\varepsilon_C$ = total compressive strain

NOTE X2.1—AASHTO LRFD Bridge Design Specifications, Section 12 is typically used for evaluation of structural design of corrugated polyethylene pipe. Reference LRFD Section 12 for additional information for an analytical method for evaluating the structural integrity of the pipe for the specific long-term material tensile and modulus limits of either the ESCR or recycled NCLS materials.

X2.4 A modulus of elasticity and tensile strength for the material rated at 50 years is often used in the calculations leading to the determination of strain. This value will vary directly in proportion to the stress level and should be provided by the manufacturer for design purposes.

## SUMMARY OF CHANGES

Committee F17 has identified the location of selected changes to this standard since the last issue (F2648/F2648M–11) that may impact the use of this standard.

*(1)* The 20 % continuous flattening requirement was changed to a strained based value in accordance with the AASHTO design limits. This value now varies depending on the diameter of pipe.