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Standard Specification for 150 to 1500 mm [6 to 60 in.] Annular Corrugated Profile-Wall Polyethylene (PE) Pipe and Fittings for Sanitary Sewer Applications[1]

This standard is issued under the fixed designation F2947/F2947M; 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 nominal inside diameters covered are 150 to 1500 mm [6 to 60 in.].

1.2 The requirements of this specification are intended to provide pipe and fittings suitable for underground use for non-pressure sanitary sewer systems. Pipe and fittings produced in accordance with this specification shall be installed in compliance with Practice D2321.

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

1.4 The products manufactured under this specification use either virgin or recycled (post-industrial or post-consumer) materials in accordance with the requirements specified for each.

1.5 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.6 The following precautionary caveat pertains only to the test method portion, Section 7, of this specification. *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.*

1.7 *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]

A666 Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar

D638 Test Method for Tensile Properties of Plastics

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.62 on Sewer.

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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.

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

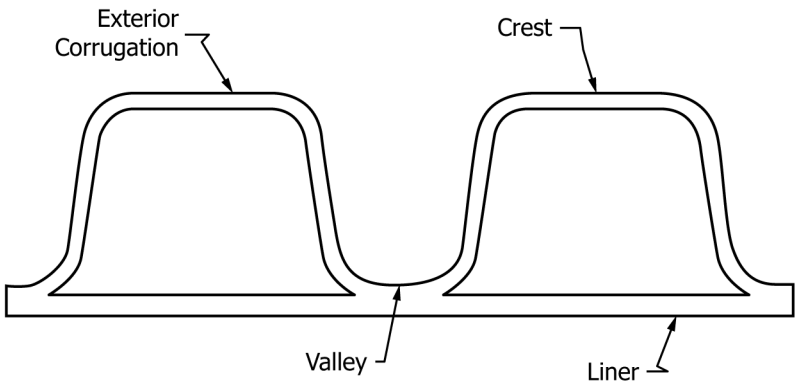

FIG. 1 Typical Annular Corrugated Pipe Profile

D618 Practice for Conditioning Plastics for Testing
D1600 Terminology for Abbreviated Terms Relating to Plastics
D1603 Test Method for Carbon Black Content in Olefin 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 Practice for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
D2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
D3212 Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
D3895 Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry
D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D4389 Specification for Finished Glass Fabrics Woven From Rovings
D4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets
D4883 Test Method for Density of Polyethylene by the Ultrasound Technique
D5630 Test Method for Ash Content in Plastics
D6992 Test Method for Accelerated Tensile Creep and Creep-Rupture of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method
D7399 Test Method for Determination of the Amount of Polypropylene in Polypropylene/Low Density Polyethylene Mixtures Using Infrared Spectrophotometry
F412 Terminology Relating to Plastic Piping Systems
F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
F2136 Test Method for Notched, Constant Ligament-Stress (NCLS) Test to Determine Slow-Crack-Growth Resistance of HDPE Resins or HDPE Corrugated Pipe
F3181 Test Method for The Un-notched, Constant Ligament Stress Crack Test (UCLS) for HDPE Materials Containing Post-Consumer Recycled HDPE
F3308 Practice for Sampling and Testing Frequency for Recycled Materials in Polyethylene (PE) Pipe for Non-Pressure Applications
G154 Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials
G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

2.2 *AASHTO Standard:*[3]

LRFD, Section 12 AASHTO LRFD Bridge Design Specifications Section 12–Buried Structures and Tunnel Liners

2.3 *NCHRP (National Cooperative Highway Research Program) Reports*[4]

NCHRP Report 631 – Updated Test and Design Methods for Thermoplastic Drainage Pipe
NCHRP Report 870 – Performance of Corrugated Pipe Manufactured with Recycled Content

2.4 *ISO Standard:*[5]

ISO 15270 Guidelines for the Recovery and Recycling of Plastic Waste

[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.
[4] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.
[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.

3. Terminology

3.1 *Definitions*—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 *profile wall, n*—in this case, the profile pipe wall construction provides an interior liner in the waterway and includes ribs, corrugations, or other shapes, which can be either solid or hollow, that helps brace the pipe against diametrical deformation.

3.2.2 *service temperature, n*—the average ambient temperature of the in situ conditions at which the pipe will be operating for the life of the project.

4. Ordering Information

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

4.1.1 This ASTM designation and year of issue,

4.1.2 Diameters,

4.1.3 Total footage of each pipe diameter involved,

4.1.4 Pipe laying length,

4.1.5 Virgin or recycled materials,

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.

5. Materials and Manufacture

5.1 *Vigin Resin Pipe and Fabricated Fittings*—The pipe and fabricated fittings shall be made from virgin PE compound meeting the requirements of Specification D3350 with a minimum cell classification of 435400C or 435400E. Black compound shall have a carbon black content equal to or greater than 2.0 wt % and shall not exceed 3.0 wt % per 6.1.2. Colored compounds shall contain sufficient UV stabilizers to protect against UV degradation. For quality assurance purposes, the cell classification shall be performed on compression molded plaque, made according to Test Method D4703 and cooled at 15 °C/min [27 °F/min]. The pipe density shall be corrected for percentage carbon black according to Specification D3350. Compounds that have a higher cell classification in one or more performance properties shall be permitted provided all other product requirements are met.

5.1.1 For slow crack growth resistance, extruded pipe shall be evaluated using the notched constant ligament stress (NCLS) test according to the requirements and procedures described in 6.7.

NOTE 1—Pipe users should consult with the pipe manufacturer about the outdoor exposure life of the product under consideration. Evaluation of UV stabilizer in Code E color PE compound using Practice D2565, Practice G154 or Practice G155 may be useful for this purpose. Exposure to sunlight during normal construction periods is not harmful. It is good practice to store pipe and fittings under suitable cover prior to installation.

5.2 *Rework*—Clean rework generated from the manufacturer's own pipe and fittings production of this product shall be permitted to be used by the same manufacturer. Rework shall be the same cell classification as new PE compound with which it is blended and the pipe produced shall meet all the requirements of this specification.

5.3 *Recycled Material Pipe:*

5.3.1 *Recycled Material Pipe*—The pipe containing any post-consumer or post-industrial (pre-consumer) recycled materials shall

be made of PE plastic compound recovered and recycled in accordance with Guide ISO 15270 such that the compound is a blend of virgin compound and post-consumer/post-industrial compound that meets the following additional requirements in accordance with Specification D3350:

5.3.1.1 Cell classification 435400C or 435400E in accordance with Specification D3350.

5.3.1.2 The carbon black content in compounds meeting cell classification 435400C 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 the density of the compound shall not exceed 0.955 g/cm^3 as tested in accordance with Test Method D4883 and all other product requirements are met.

5.3.1.3 For slow crack growth resistance, extruded pipe shall be evaluated using the notched constant ligament stress (NCLS) test according to the requirements and procedures described in 6.7.

5.3.1.4 Crack initiation shall be tested in accordance with the procedures in 7.10. The average failure time of five test specimens shall exceed the minimum required for the applied tensile stress, service temperature and required service life required for the application.

5.3.1.5 Maximum level of polypropylene present by volume shall not be greater than 5 percent when tested in accordance with the procedures in 7.8.

5.3.1.6 Maximum ash content shall not be more than 2% in accordance with the procedures in 7.9.

5.3.1.7 Samples taken from the extruded pipe supplied to the project shall have a minimum Oxidative-Induction-Time of 25 minutes when tested in accordance with Test Method D3895 and break strain of 150% when tested in accordance with Test Method D638.

5.3.1.8 Service prediction shall be done in accordance with 7.10.

5.3.1.9 All sampling and testing requirements and frequencies for recycled material pipe shall be conducted in accordance with Practice F3308.

5.3.2 *Recycled Material Fittings*—Fittings made from recycled materials are not permitted under this standard.

NOTE 2—Post-consumer recycled materials contain a wide assortment of polyethylene compounds, which may have a combination of high and low environmental stress crack resistance. Post-industrial recycled materials will have much more consistent quality of compounds, but they will be of the same stress-crack resistance. They may, therefore, have higher or lower environmental stress crack resistance than postconsumer materials. The ASTM F3181 test method will, however, provide predictable and reproducible results for either material.

6. General Requirements

6.1 *Workmanship*—The pipe and fittings shall be black or color; shall be homogeneous throughout; and shall 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. The ends shall be cut cleanly and squarely through valleys.

6.1.1 Visible defects, cracks, creases, splits, and delaminations in pipe are not permissible.

6.1.2 Carbon black content in this pipe or fitting shall be tested in accordance with Test Method D1603 or Test Method D4218.

6.2 *Dimensions and Tolerance:*

6.2.1 *Nominal Size*—The nominal size for the pipe and fittings shall be the inside diameter shown in Table 1.

NOTE 3—The actual inside diameter of a pipe depends on the material distribution, construction and stiffness. It may be considerably higher than the minimums specified in this table. For more information, see the manufacturer's documentation.

TABLE 1 Pipe Stiffness and Pipe Dimensions

Nominal Diameter		Minimum Inside Diameter		Minimum Pipe Stiffness Stiffness at 5% Deflection		Minimum Liner Thickness	
mm	[in.]	mm	[in.]	kPa	[lb/in./in.]	mm	[in.]
150	6	145	5.91	441	64	1.0	0.039
200	8	195	7.87	414	60	1.1	0.043
225	9	220	8.86	407	59	1.2	0.047
250	10	245	9.84	400	58	1.3	0.051
300	12	294	11.57	372	54	1.4	0.055
375	15	369	14.51	310	45	1.7	0.067
400	16	392	15.43	303	44	1.8	0.071
450	18	450	17.72	297	43	1.9	0.074
500	20	490	19.29	276	40	2.0	0.079
600	24	588	23.15	262	38	2.2	0.087
750	30	751	29.56	228	33	2.4	0.094
800	32	785	30.91	200	29	2.6	0.102
900	36	902	35.49	179	26	2.7	0.106
1000	40	985	38.79	179	26	2.9	0.114
1050	42	1051	41.39	172	25	3.2	0.126
1200	48	1185	46.65	152	22	3.5	0.138
1500	60	1501	59.10	138	20	4.0	0.157

6.2.2 *Minimum Inside Diameter*—The manufacturer's stated minimum inside diameter shall be as shown in Table 1, when measured in accordance with 7.3.1.

NOTE 4—The outside diameters and the corrugation pitch of products manufactured to this specification are not specified; therefore, compatibility between pipe and fittings made to this specification from different manufacturers must be verified.

6.2.3 *Laying Length*—The pipe shall be supplied in any laying length agreeable to both the owner and the manufacturer. Laying length shall not be less than 99 % of stated quantity when measured in accordance with 7.3.2.

6.2.4 *Liner Thickness*—The minimum liner thickness of the pipe shall meet the requirements given in Table 1 when measured in accordance with 7.3.3.

6.3 *Pipe Stiffness*—Minimum pipe stiffness at 5 % deflection shall meet the requirements given in Table 1 when tested in accordance with 7.4.

NOTE 5—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 corrugation seams, separation of the valley and liner, or combinations thereof, when tested in accordance with 7.5.

6.5 *Pipe Impact Strength*—There shall be no evidence of splitting, cracking, breaking, separation of corrugation seams, separation of the valley and liner, or combinations thereof, on any specimen when tested in accordance with 7.6.

6.6 *Fittings and Joining Systems:*

6.6.1 Only fittings fabricated from pipe meeting this specification and supplied or recommended by the pipe manufacturer shall be used. Fabricated 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.

6.6.3 Pipe and fittings shall have a watertight bell/spigot joint that complies with the laboratory tests defined and described in Test Method D3212 and utilizes a gasket that complies with the requirements of Specification F477. All joints shall show no signs of leakage when tested in accordance with Specification D3212. Note that special provisions must be taken in order that joints made to field cut pipe meet the requirements of Specification D3212. Any component used in the joining material shall be resistant to effluents being carried in the pipe.

6.6.4 *Optional Bell Restraining Bands*—Bell restraining bands, when used, shall be made of corrosion resistant materials such as fiberglass (Specification D4389) or stainless steel (Specification A666).

6.6.5 *Joint Proof-of-Design*—To assess the effects of longterm properties of the pipe and gasket material under a joint assembly, a joint proof-of-design test shall be conducted on the pipe joints using the test method outlined in 7.11. Each joint proof of design pressure test shall be conducted by an independent third party, which provides written certification for each test. This test is a one-time validation test for the specific pipe diameter, profile geometry, gasket and joint configuration supplied by the manufacturer. This proof-of-design test shall be conducted on at least one pipe diameter within the prescribed diameter range and shall be conducted on each diameter that differs in joint design. If the joint design does not change within the prescribed range, the largest diameter shall be tested. If the diameter range includes more than 5 different pipe diameters, then two sizes shall be tested; the largest and smallest diameters.

6.7 *Slow Crack Growth Resistance–Pipe*—For slow crack-growth resistance, the pipe shall be evaluated using the notched constant ligament stress (NCLS) test according to the procedure described in 7.7. The NCLS test shall be conducted on molded plaques, and the average failure time of the five test specimens shall exceed 41 h with no single test specimen's failure time less than 29 h.

6.8 *Structural Design:*

6.8.1 The manufacturer shall supply appropriate data necessary to satisfy the requirements of deflection, thrust, buckling, bending stress and long-term strain in accordance with the design criteria of the AASHTO LRFD Bridge Design Specification (LRFD, Section 12). The design engineer shall verify that the data provided by the manufacturer satisfy the product requirements.

6.8.2 The minimum long-term (50-year) design values for modulus of elasticity and tensile strength for the PE compounds shall be 152 MPa ~~(22~~[22 000 ~~psi)~~psi] and 6.2 MPa ~~(900 psi),~~[900 psi], respectively. The maximum allowable long-term (50-year) tensile strain limit for design shall be 5 %.

6.8.2.1 *Creep Rupture Strength*—Specimens fabricated in the same manner and composed of the same materials as the finished pipe shall have a 50-year creep rupture tensile strength at 23 °C ~~(73 °F)~~[73 °F] not less than 6.2 MPa ~~(900 psi),~~[900 psi], when determined in accordance with 7.12.

6.8.2.2 *Creep Modulus*—Specimens fabricated in the same manner and composed of the same materials as the finished pipe shall have a 50-year tensile creep modulus at 23 °C ~~(73 °F)~~[73 °F] at the stress level of 3.5 MPa ~~(500 psi)~~[500 psi] not less than 152 MPa ~~(22,000 psi).~~[22 000 psi]. The creep modulus shall be determined in accordance with 7.13.

NOTE 6—The 50-year creep rupture strength and 50-year creep modulus values, determined by the test methods in 7.12 and 7.13, are used to define the slope of the logarithmic regression curves to describe the required material properties sampled from the product. They are not to be interpreted as service life limits.

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 ~~23~~23 °C ± 2 °C ~~[73.4~~[73.4 °F ± 4 °F] for not less than 40 h prior to test. Conduct tests under the same conditions of temperature. The random 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 sample selected by the testing laboratory shall be permitted.

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

7.2 *Test Conditions*—Conduct tests other than those for routine quality control purposes in the standard laboratory atmosphere of ~~23~~23 °C ± 2 °C ~~[73.4~~[73.4 °F ± ~~3.6 °F],~~4 °F], in the referenced test method or in this specification.

7.3 *Dimensions:*

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

7.3.2 *Laying Length*—Measure pipe laying length in accordance with Test Method D2122. These measurements may be taken at ambient temperature.

7.3.3 *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° around the circumference in order to obtain a minimum of eight measurements in accordance with Test Method D2122.

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

7.4.1 The test specimens shall be at least one diameter or 600 mm [24 in.] in length, whichever is less. However, the test specimen shall not be less than three full corrugations in length.

7.4.2 Each specimen shall be cut mid-valley to mid-valley (see Fig. 1) while still meeting or exceeding the minimum length requirement.

7.4.3 Determine the minimum inner wall thickness and locate the first specimen in the loading machine with the minimum inner wall thickness located at 9:00 or 3:00 when viewing the specimen from the end. The specimen shall lie flat on the plate within 3 mm [0.117 in.]. Use the first location as a reference point for rotation and testing the other two specimens. Rotate the other specimens 60° and 120°, respectively, from the original orientation. Test each specimen in only one position.

7.5 *Flattening*—Flatten the three test specimens from 7.4 between parallel plates until the pipe inside diameter is reduced by 40 %. The rate of loading shall be 12.5 mm/min [0.5 in./min], and may be increased after 5 % deflection is obtained for pipe stiffness so the remainder of the test is completed within 2 to 5 minutes. Additionally, at or below the deflection limit defined in Eq 1, the specimen shall be considered as failing this test when the load does not increase continuously with increasing deflection.
Buckling Deflection Limit:

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

where:

Δ_b = Minimum buckling deflection limit (%)
D = Mean diameter (centroid) of the 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—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 in accordance with this specification.

7.6 *Impact Resistance*—Test pipe specimens in accordance with Test Method D2444 except six specimens shall be tested once each at random orientations or six impacts shall be made on one specimen. In the latter case, as a referee test, successive impacts shall be separated by 60 ± 10° for impacts made on one circle, or at least 300 mm [12 in.] longitudinally for impacts made on one element. Impact points shall be at least 150 mm [6 in.] from the end of the specimen. Impact strength shall not be less than the requirements in Table 2. Tests shall be conducted using either a 9 kg [20 lb] Tup B or 14 kg [30 lb] Tup B and a flat-plate specimen Holder B. Condition the specimens for 24 h at a temperature of ~~23~~23 °C ± 2 °C ~~[73.4~~[73.4 °F ± 4 °F], and conduct all tests within 60 s of removal from this atmosphere. The center of the falling tup shall strike on a corrugation crown for all impacts.

7.6.1 All the impact specimens shall be cut valley to valley. In sizes 300 to 450 mm [12 to 18 in.], the minimum length of the test specimens shall be the nominal diameter. In sizes greater than 450 mm [18 in.], the minimum length shall be 450 mm in. [18 in.].

7.7 *Slow-Crack Growth Resistance–PE Pipe*—Pipe test specimens shall be molded into test specimens from the pipe. Test 5 pipe specimens using the same protocol for molded bars in Test Method F2136 test, except for the following modifications: