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Standard Specification for 12 to 60 in. [300 to 1500 mm] Annular Corrugated Profile-Wall Polyethylene (PE) Pipe and Fittings for Gravity-Flow Storm Sewer and Subsurface Drainage Applications[1]

This standard is issued under the fixed designation F2306/F2306M; 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 12 to 60 in. [300 to 1500 mm].

1.2 The requirements of this specification are intended to provide pipe and fittings for underground use for gravity-flow storm sewer and subsurface drainage systems.

NOTE 1—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 standard 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 may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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]

D618 Practice for Conditioning Plastics for Testing

[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**

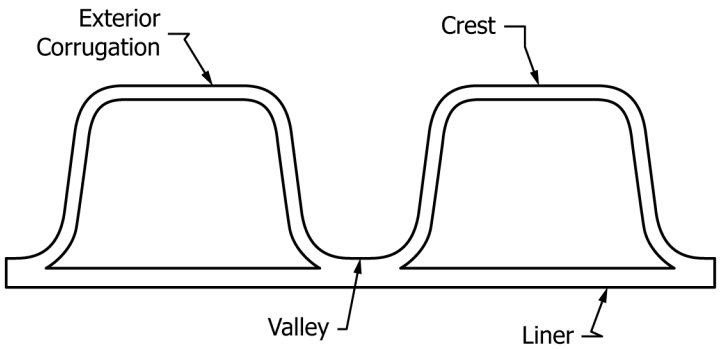

FIG. 1 Typical Annular Corrugated Pipe Profile

D638 Test Method for Tensile Properties of Plastics
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 Practice for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
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
D4883 Test Method for Density of Polyethylene by the Ultrasound Technique
D5630 Test Method for Ash Content in Plastics
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

2.2 *AASHTO Standard:*[3]
AASHTO LRFD Bridge Design Specifications
LRFD, Section 12 Bridge Design Specifications Section 12 – Buried Structures and Tunnel Liners
AASHTO M 145 : Classification of Soils and Aggregate Mixtures

2.3 *Department of Agriculture Standard:*
Standard 606 Soil Conservation Service Engineering[4]

2.4 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[5]

2.5 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage[5]

2.6 *NCHRP (National Cooperative Highway Research Program) Report:*[6]
NCHRP Report 631 Updated Test and Design Methods for Thermoplastic Drainage Pipe
NCHRP Report 870 Performance of Corrugated Pipe Manufactured with Recycled Content

2.7 *ISO Standard:*[7]
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, Mail Stop: SDE, Washington, DC 20401. http://www.gpo.gov/about/bookstore.htm
[5] DLA Document Services Building 4/D 700 Robbins Avenue Philadelphia, PA 19111-5094 http://quicksearch.dla.mil/
[6] Transportation Research Board, The National Academies 500 Fifth Street, NW Washington, DC 20001. http://www.TRB.org
[7] 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 *design diameter, n*—the manufacturer's stated inside diameter.

3.2.2 *mold line, n*—a line formed on the product as a result of the mold blocks coming together during manufacturing.

3.2.3 *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.

3.2.4 *service temperature, n*—the average ambient temperature of the insitu 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 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 laying length, and

4.1.6 Virgin or recycled resins.

4.1.7 Fitting type(s):

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

4.1.7.2 Number of fittings per diameter.

5. Materials and Manufacture

5.1 *Virgin Resin Products:*

5.1.1 *Pipe and Blow-Molded Fittings*—The pipe and fittings shall be made of virgin PE plastic compound meeting the requirements of Specification D3350 cell classification 435400C or 435400E, except that carbon black content in compounds meeting cell classification 435400C shall be greater than 2% but not exceed 4 %. Compounds that have a higher cell classification in one or more properties shall be permitted provided the density of the base resin compound without pigment shall not exceed 0.955 g/cm^3 and all other product requirements are met. For slow crack-growth resistance, the plastic compound shall be evaluated using the notched constant ligament stress (NCLS) test according to the procedure described in 7.8. The average failure time of the five test specimens shall exceed 24 h with no single test specimen's failure time less than 18 h.

5.1.2 *Rotationally Molded Fittings and Couplings*—Compounds used in the manufacture of rotationally molded fittings and couplings shall be virgin PE meeting the requirements of Specification D3350 and cell classification 213320C or 213320E, except

that the carbon black content in compounds meeting cell classification 213320C shall be greater than 2% but not exceed 4%. Compounds that have a higher cell classification in one or more properties shall be permitted provided the density of the base resin shall not exceed 0.940 g/cm^3 and all other product requirements are met.

5.1.3 *Injection-Molded Fittings and Couplings*—Compounds used in the manufacture of injection molded fittings and couplings shall be made of virgin PE meeting the requirements of Specification D3350 and cell classification 414420C or 414420E, except that the carbon black content in compounds meeting cell classification 213320C shall be greater than 2% but not exceed 4%. 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 requirements of 5.1.1 or 5.1.2 as applicable for the intended part and pipe or fittings produced meet all the requirements of this specification.

5.2 *Recycled Resin Products:*

5.2.1 *Recycled Resin Pipe*—The pipe containing any post-consumer or post-industrial recycled materials shall be made of PE plastic compound recovered and recycled in accordance with Guide ISO 15270 such that the final blended compound meets the following requirements in accordance with Specification D3350:

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

5.2.1.2 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.

5.2.1.3 For slow crack growth resistance, extruded pipe shall be evaluated using the notched constant ligament stress (NCLS) test according to the procedure described in 7.8. The average failure time of the five test specimens shall exceed 24 h with no single test specimen's failure time less than 18 h.

5.2.1.4 Crack initiation shall be tested in accordance with the procedures in 7.11. 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.

5.2.1.5 Maximum level of polypropylene present by volume shall not be greater than 5 percent when tested in accordance with the procedures in 7.9.

5.2.1.6 Maximum ash content shall not be more than 2 % in accordance with the procedures in 7.10.

5.2.1.7 Samples taken from the extruded pipe supplied to the project shall have a minimum Oxidative-Induction-Time of 20 min when tested in accordance with Test Method D3895 and break strain of 150 % when tested in accordance with Test Method D638.

5.2.1.8 Service life prediction shall be done in accordance with 7.11. The predicted service life shall meet or exceed 100 years.

5.2.1.9 All sampling and testing frequency for recycled resin pipe shall be in accordance with Practice F3308.

5.2.2 *Recycled Resin Fittings*—Fittings made from recycled resins 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 post-consumer materials. The 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 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. The ends shall be cut cleanly and squarely. Holes intentionally placed in perforated pipe are acceptable.

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

6.2.2 *Inside Diameter*—The average inside diameter for pipe and fittings shall not vary more than ± 1 % from the design 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.

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

6.2.4 *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.

6.2.5 *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.

NOTE 4—For perforated pipe applications, the size of the embedment zone and permeability of the embedment material provide the desired level of infiltration or exfiltration. The pipe or embedment zone shall be wrapped with a geotextile designed to prevent migration of fine soils into the pipe or embedment zone. Where a geotextile is not used, the gradation of the embedment material shall be compatible with the perforation size to avoid backfill migration into the pipe.

6.3 *Pipe Stiffness*—Minimum pipe stiffness at 5 % deflection shall meet the requirements given in Table 1 when tested in accordance with 7.5.

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 seams, separation of the outer and

TABLE 1 Pipe Stiffness and Pipe Dimensions

Pipe Inside Diameter		Minimum Pipe Stiffness at 5 % Deflection		Minimum Inner Liner Thickness	
in.	[mm]	lb/in./in.	[kPa]	in.	[mm]
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	[95]	0.079	[2.0]

[†] Editorially corrected in March 2015.

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]
12	[300]	⅜	[10]	1.5	[30]
15	[375]	⅜	[10]	1.5	[30]
18	[450]	⅜	[10]	1.5	[30]
21	[525]	⅜	[10]	2.0	[40]
24	[600]	⅜	[10]	2.0	[40]
27	[675]	⅜	[10]	2.0	[40]
30	[750]	⅜	[10]	2.0	[40]
36	[900]	⅜	[10]	2.0	[40]
42	[1050]	⅜	[10]	2.0	[40]
48	[1200]	⅜	[10]	2.0	[40]
54	[1350]	⅜	[10]	2.0	[40]
60	[1500]	⅜	[10]	2.0	[40]

inner wall, or combinations thereof, when tested in accordance with 7.6. 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:

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

where:

Δb = 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 6—Field deflection limits are typically taken at 5 % (see Annex A1). 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.

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 should 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.

6.6.3 Fittings shall be supplied with joints compatible with the overall system. All joints for gravity-flow Sewer systems shall meet the requirements of 6.6.3.3. All other joints shall meet the requirements of a soil-tight joint unless otherwise specified by the owner/designer.

6.6.3.1 Soil-tight joints are specified as a function of opening size, channel length, and backfill particle size. If the size of the opening exceeds 3 mm, the length of the channel shall be at least four times the size of the opening. A backfill material containing a high percentage of fine-graded soils requires investigation for the specific type of joint to be used to guard against soil infiltration.

NOTE 7—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 permitted to be wrapped with a geotextile designed to prevent migration of these fine soils into the pipe.

6.6.3.2 Silt-tight joints shall be used where the backfill material has a high percentage of fines. Silt tight joints shall meet laboratory test in accordance with Test Method D3212 except that the joint be tested using 2.0 psi (14 kPa) and utilize a bell and spigot joint with a gasket meeting Specification F477.

6.6.3.3 Watertight joints shall meet a 10.8 psi (74 kPa) laboratory test in accordance with Test Method D3212 and utilize a bell and spigot design with a gasket meeting Specification F477.

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~~3.6 °F [23 ± ~~2°C~~]2 °C] for not less than 40 h prior to test. Conduct tests under the same conditions of temperature.

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 73.4 ± ~~3.6°F~~3.6 °F [23 ± ~~2°C~~]2 °C] 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 73.4 ± ~~3.6°F~~3.6 °F [23 ± ~~2°C~~],2 °C], 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 sample selected by the testing laboratory shall be deemed 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. These measurements may be taken 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° around the circumference in order to obtain a minimum of eight measurements in accordance with Test Method D2122.

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 at least one diameter or 24 in. in length, which ever is less. However, the test specimen shall not be less than three full corrugations in length.

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

7.5.3 Locate the first specimen in the loading machine with the minimum inner wall thickness located at 9:00 and 3:00 when viewing the specimen from the end. The specimen shall 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 two specimens. Rotate subsequent specimens 45° and 90°, respectively, from the original orientation. Test each specimen in only one position.

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].~~between 0.50 ± 0.02 in./min [12.5 ± 0.5 mm/min] and 2.00 ± 0.02 in./min [50.0 ± 0.5 mm/min]. It is acceptable to use pipe specimens that have been used to determine pipe stiffness in accordance with