# Standard Specification for Coextruded Poly(Vinyl Chloride) (PVC) Non-Pressure Plastic Pipe Having Reprocessed-Recycled Content[1]

This standard is issued under the fixed designation F 1760; 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 has been published in response to the special circumstance of regulatory requirements regarding federal procurement guidelines for plastic pipe having recycled content.

1.2 This specification covers coextruded Poly(Vinyl Chloride) (PVC) plastic pipe with a center layer and concentric inner and outer solid layers. The pipe is produced using a multi-layer coextrusion die. The inner and outer layers are made of virgin PVC compound and the center layer has reprocessed-recycled PVC content. The pipe is for non-pressure use in three series:

1.2.1 Sewer-Drain series with a sewer-pipe outside diameter and a pipe stiffness of 46 psi (320 kPa),

1.2.2 IPS Schedule 40 series, and

1.2.3 IPS Pipe Stiffness (PS) series with pipe stiffnesses of 100 psi (690 kPa) and 120 psi (830 kPa).

1.3 Pipe that is outside-diameter controlled does not necessarily have an inside diameter suitable for use as a fitting socket.

1.4 All series may be perforated.

1.5 The values stated in inch-pound units are to be regarded as the standard. The SI values are provided for information only.

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:*

D 883 Terminology Relating to Plastics[2]

D 1243 Test Method for Dilute Solution Viscosity of Vinyl Chloride Polymers[2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1784 Specification for Rigid Poly(Vinyl Chloride) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading[3]

D 2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)[3]

D 2466 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40[3]

D 2665 Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings[3]

D 2855 Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings[3]

D 3034 Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings[3]

D 3212 Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals[3]

D 4396 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (PVC) Compounds for Plastic Pipe and Fittings Used in Nonpressure Applications[4]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe[3]

F 512 Specification for Smooth-Wall Poly(Vinyl Chloride) (PVC) Conduit and Fittings for Underground Installation[3]

F 1336 Specification for Poly(Vinyl Chloride) (PVC) Gasketed Sewer Fittings[3]

F 1365 Test Method for Water Infiltration Resistance of Plastic Underground Conduit Joints Which Use Flexible Elastomeric Seals[3]

2.2 *Plastic Pipe Institute Technical Report:*[5]

PPI-TR-7 Recommended Method for Calculation of Nominal Weight of Plastic Pipe

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.25 on Vinyl Based Pipe.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] *Annual Book of ASTM Standards*, Vol 08.03.

[5] Available from Plastic Pipe Institute, 1275 K Street NW, Suite 400, Washington, DC 20005.

## 3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D 883, D 1600, and F 412, unless otherwise indicated.

3.1.1 *coextrusion*—a process whereby two or more plastic material streams are forced through one or more shaping orifices and become one continuously formed piece.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *center-layer compound*—general description for "internal recycled material" (3.2.5), "external recycled material" (3.2.4), and "post-consumer recycled material" (3.2.6). These materials can be used straight or blended with virgin materials to make a compound, in accordance with this specification.

3.2.2 *certificate of composition*—a certificate describing certain properties of an external recycled material or a post-consumer recycled material.

3.2.2.1 *Discussion*—Examples include polymer, molecular weight, percentage of inorganic material, contamination type and level, tensile strength, modulus of elasticity, and izod impact.

3.2.3 *composition disclosure*—a document describing the formulation of an external recycled material.

3.2.4 *external recycled material*—industrial rework generated by a different company from the company manufacturing to this specification. Composition is known by the industrial source of the material.

3.2.5 *internal recycled material*—rework generated by the same company's production that is manufacturing to this specification. Composition of the material is known by the company manufacturing to this specification.

3.2.6 *post-consumer recycled material*—finished goods that have been purchased by the public, then returned to industry and reprocessed into raw materials. Identity of finished goods is known by the reprocessing company.

3.2.7 *thermoplastic coextruded pipe*—pipe consisting of two or more concentric thermoplastic layers formed through the process of coextrusion.

## 4. Classification

4.1 The pipes are produced in two diameter families: sewer-drain and IPS.

4.1.1 *Sewer-Drain Series*—Produced with a sewer pipe OD and a pipe stiffness of 46 psi (320 kPa). Sewer-drain pipe is intended for use outside of buildings as sewer, sewer connections, underground drain, and storm drain. Wall thicknesses shall be produced so that minimum pipe stiffnesses are met, but shall not be thinner than the minimum wall thickness requirements in Table 1 and Table 2.

**TABLE 1 Requirements for Sewer-Drain Pipe**

| Nominal Size, in. | Average, OD, in. | Tolerance on Average, in. | Minimum Wall Thickness, in.$^A$ | Impact Resistance, ft-lb |
|---|---|---|---|---|
| 4 | 4.215 | ±0.009 | 0.120 | 150 |
| 6 | 6.275 | ±0.011 | 0.180 | 210 |
| 8 | 8.400 | ±0.012 | 0.240 | 210 |
| 10 | 10.500 | ±0.015 | 0.300 | 220 |
| 12 | 12.500 | ±0.018 | 0.360 | 220 |
| 15 | 15.300 | ±0.023 | 0.437 | 220 |

$^A$ The maximum wall thickness shall not be greater than 1.25 times the minimum wall thickness.

**TABLE 2 SI Requirements for Sewer-Drain Pipe**

| Nominal Size, in. | Average OD, mm | Tolerance on Average, mm | Minimum Wall Thickness, mm$^A$ | Impact Resistance, J |
|---|---|---|---|---|
| 4 | 107.06 | ±0.23 | 3.05 | 203 |
| 6 | 159.39 | ±0.28 | 4.57 | 284 |
| 8 | 213.36 | ±0.30 | 6.10 | 284 |
| 10 | 266.70 | ±0.38 | 7.62 | 299 |
| 12 | 317.50 | ±0.46 | 9.14 | 299 |
| 15 | 388.62 | ±0.58 | 11.10 | 299 |

$^A$ The maximum wall thickness shall not be greater than 1.25 times the minimum wall thickness.

NOTE 1—Base inside diameters will be slightly smaller than those calculated for SDR 35 sewer-drain series pipe when wall thicknesses are increased to ensure minimum 46 pipe stiffness.

4.1.2 *IPS Diameter Family*—Produced in a Schedule 40 series and a Pipe Stiffness (PS) series.

4.1.2.1 *IPS Schedule 40 Series*—Produced to Schedule 40 wall thicknesses in accordance with Table 3 and Table 4. Schedule 40 pipe is intended for use as underground drain, DWV (drain, waste, and vent), sewer connections, and other non-pressure uses.

4.1.2.2 *IPS Pipe Stiffness Series*—Produced to pipe stiffness of 100 psi (690 kPa) or 120 psi (830 kPa). Intended uses include underground communications and electrical distribution. Wall thicknesses shall be produced so that minimum pipe stiffnesses are met, but shall not be thinner than the minimum wall thickness requirements in Table 5 and Table 6.

NOTE 2—The IPS Pipe Stiffness (PS) series having pipe stiffnesses of 100 psi (690 kPa) and 120 psi (830 kPa) is designed for direct burial (DB). Encasement in concrete is not necessary.

4.1.3 Before installing pipe for industrial waste disposal use, the approval of the code official having jurisdiction should be obtained, as conditions not commonly found in normal use may be encountered.

## 5. Material

5.1 *Center-layer Compounds*—Center-layer compounds (internal recycled, external recycled, and post-consumer recycled materials) shall be characterized as being PVC-polymer-based. Other PVC-compatible additives (such as lubricants, stabilizers, non-polyvinyl-chloride resin modifiers, pigments, and inorganic fillers) may be present in these materials. The three plastic material types may be used in the

**TABLE 3 Requirements for IPS Schedule 40 Pipe**

| Nominal Size, in. | Average OD, in. | Tolerance on Average, in. | Out of Round, in.$^A$ | Minimum Wall Thickness, in.$^B$ | Pipe Stiffness, psi | Impact Resistance, ft-lb |
|---|---|---|---|---|---|---|
| 1¼ | 1.660 | ±0.005 | 0.060 | 0.140 | 1100 | 60 |
| 1½ | 1.900 | ±0.006 | 0.060 | 0.145 | 800 | 60 |
| 2 | 2.375 | ±0.006 | 0.060 | 0.154 | 450 | 60 |
| 3 | 3.500 | ±0.008 | 0.060 | 0.216 | 400 | 80 |
| 4 | 4.500 | ±0.009 | 0.100 | 0.237 | 250 | 100 |
| 6 | 6.625 | ±0.011 | 0.100 | 0.280 | 120 | 120 |
| 8 | 8.625 | ±0.015 | 0.150 | 0.322 | 80 | 140 |
| 10 | 10.750 | ±0.015 | 0.150 | 0.365 | 60 | 160 |
| 12 | 12.750 | ±0.015 | 0.150 | 0.406 | 50 | 180 |

$^A$ "Out of Round" is defined as maximum diameter minus minimum diameter.
$^B$ The maximum wall thickness shall not be greater than 1.25 times the minimum wall thickness.

**TABLE 4 SI Requirements for IPS Schedule 40 Pipe**

| Nominal Size, in. | Average OD, mm | Tolerance on Average, mm | Out of Round, mm$^A$ | Minimum Wall, mm$^B$ | Pipe Stiffness, kPa | Impact Resistance, J |
|---|---|---|---|---|---|---|
| 1¼ | 42.16 | ±0.13 | 1.52 | 3.56 | 7600 | 80 |
| 1½ | 48.26 | ±0.15 | 1.52 | 3.68 | 5500 | 80 |
| 2 | 60.32 | ±0.15 | 1.52 | 3.91 | 3100 | 80 |
| 3 | 88.90 | ±0.20 | 1.52 | 5.49 | 2750 | 110 |
| 4 | 114.30 | ±0.23 | 2.54 | 6.02 | 1700 | 135 |
| 6 | 168.28 | ±0.28 | 2.54 | 7.11 | 830 | 160 |
| 8 | 219.08 | ±0.38 | 3.81 | 8.18 | 550 | 190 |
| 10 | 273.05 | ±0.38 | 3.81 | 9.27 | 415 | 220 |
| 12 | 323.85 | ±0.38 | 3.81 | 10.31 | 340 | 240 |

$^A$ "Out of Round" is defined as maximum diameter minus minimum diameter.
$^B$ The maximum wall thickness shall not be greater than 1.25 times the minimum wall thickness.

**TABLE 5 Requirements for IPS Pipe-Stiffness Pipe**

| Nominal Size, in. | Average OD, in. | Tolerance on Average, in. | Out of Round, in.$^A$ | Minimum Wall Thickness, in.$^{BC}$ | | Impact Resistance, ft-lb |
|---|---|---|---|---|---|---|
| | | | | DB 100 | DB 120 | |
| 4C | 4.350$^D$ | ±0.009 | 0.100 | 0.141 | 0.149 | 100 |
| 4 | 4.500 | ±0.009 | 0.100 | 0.145 | 0.154 | 100 |
| 5 | 5.563 | ±0.010 | 0.100 | 0.179 | 0.191 | 120 |
| 6 | 6.625 | ±0.011 | 0.100 | 0.213 | 0.227 | 150 |

$^A$ "Out of Round" is defined as maximum diameter minus minimum diameter.
$^B$ The maximum wall thickness shall not be greater than 1.25 times the minimum wall thickness.
$^C$ Minimum wall-thickness values are based on skin modulus of 400 000 psi combined with center-layer modulus of 500 000 psi.
$^D$ This is not an IPS OD, but is a standard-OD pipe-stiffness pipe used by communications utilities.

**TABLE 6 SI Requirements for IPS Pipe-Stiffness Pipe**

| Nominal Size, in. | Average OD, mm | Tolerance on Average, mm | Out of Round, mm$^A$ | Minimum Wall Thickness, mm$^{B,C}$ | | Impact Resistance, J |
|---|---|---|---|---|---|---|
| | | | | DB 100 | DB 120 | |
| 4C | 110.49$^D$ | ±0.23 | 2.54 | 3.58 | 3.78 | 135 |
| 4 | 114.30 | ±0.23 | 2.54 | 3.68 | 3.91 | 135 |
| 5 | 141.30 | ±0.25 | 2.54 | 4.55 | 4.85 | 165 |
| 6 | 168.28 | ±0.28 | 2.54 | 5.41 | 5.77 | 205 |

$^A$ "Out of Round" is defined as maximum diameter minus minimum diameter.
$^B$ The maximum wall thickness shall not be greater than 1.25 times the minimum wall thickness.
$^C$ Minimum wall-thickness values are based on skin modulus of 400 000 psi combined with center-layer modulus of 500 000 psi.
$^D$ This is not an IPS OD, but is a standard-OD pipe-stiffness pipe used by communications utilities.

percentages specified in 5.1.1, 5.1.2, and 5.1.3, provided that the pipe produced meets all of the requirements of this specification.

5.1.1 *Internal Recycled Material*—May comprise up to 100 % of the center layer. This material shall not be used in the inner or outer layers.

5.1.2 *External Recycled Material*—May comprise up to 100 % of the center layer. This material shall not be used in the inner or outer layers.

5.1.3 *Post-Consumer Recycled Material*—May comprise up to a maximum of 60 % by weight of center layer. This material shall not be used in the inner or outer layers.

NOTE 3—Post-consumer recycled material is limited to 60 % by weight of the center layer due to current technology. As more experience is gained with process and materials, this standard may be amended to increase the percentage.

5.1.4 When requested by the pipe manufacturer, the supplier shall provide with the external recycled and post-consumer recycled materials a certificate of composition, a composition disclosure, or both.

5.1.5 Virgin PVC homopolymer having an inherent viscosity greater than 0.68 (*K*-value 57) may be blended with center-layer compounds and compounding ingredients (lubricants, stabilizers, non-polyvinyl-chloride resin modifiers, pigments, and inorganic fillers) for use in the center layer. Inherent viscosity shall be determined in accordance with Test Method D 1243.

5.2 Inner and outer layers shall be made of virgin homopolymer PVC. Rework materials are not allowed.

5.3 *Cell Classification*—Properties of the compounds used to manufacture pipe in accordance with this standard shall be categorized using the cell classification method. The required cell values are considered minimums; compounds having higher values than those listed are considered acceptable.

5.3.1 Material for the Sewer-Drain series shall be categorized using Specification D 1784. Compound for the inner and outer layers shall have a minimum cell class of 12454B, and for the center layer 12223C.

5.3.2 Material for the IPS Schedule 40 series shall be categorized using Specification D 4396. Compound for the inside and outside layers shall have a minimum cell class of 11432, and for the center layer 11211. Compound for all layers shall meet the chemical-resistance requirement of Specification D 4396 with a 130°F (55°C), 14-day immersion.

5.3.3 Material for the IPS Pipe Stiffness (PS) series shall be categorized using Specification D 1784. Compound for the inner and outer layers shall have a minimum cell class of 12234C, and for the center layer 12223C.

5.4 *Color*—The center layer for all series shall contrast in color with the inner and outer layers such that wall measurements may be taken.

## 6. Joining Systems

6.1 *Solvent-Cement Joints*—In the solvent cement joint, the pipe spigot wedges into the tapered socket and the surfaces fuse together. The tapered socket may be a portion of a molded fitting or it may be a belled end of the pipe section.

6.1.1 The assembly of joints shall be in accordance with the recommendations of pipe, solvent cement, and fitting manufacturers pertaining to the particular system being employed or, in their absence, the methods described in Practice D 2855.

6.2 *Elastomeric-Gasket Joints*—In this system an elastomeric seal is situated in the bell or molded fitting, lubrication is applied to the spigot/gasket, and the pipe spigot is pushed past the gasket and into the bell forming a watertight joint. The design and control of the dimensions of gasketed bells, fittings, and elastomeric seals are not controlled by this specification, but are the responsibility of the manufacturers of the pipe, fittings, and gaskets.

6.2.1 The assembly of the joints shall be in accordance with the pipe manufacturer's recommendation. The lubricant shall be that recommended by the pipe manufacturer. Elastomeric seals shall meet the requirements of Specification F 477.

NOTE 4—Straight alignment is essential when assembling gasketed pipe joints. Bar and block assembly is recommended. (The major advantage of this method is that the worker can feel the amount of force being used and whether the joint goes together smoothly. This helps ensure that gaskets remain properly seated.)

6.3 *Fittings*:

6.3.1 *Sewer-Drain Series Pipe*—May be joined using molded or fabricated fittings meeting the requirements of Specification D 3034 or F 1336.

6.3.2 *IPS Schedule 40 Series Pipe*—May be joined using molded fittings meeting the requirements of Specification D 2466 or D 2665.

6.3.3 *IPS Pipe Stiffness (PS) Series Pipe*—May be joined using molded or fabricated fittings meeting the requirements of Specification F 512.

## 7. General Requirements

7.1 *Conditioning*—Routine testing as part of the manufacturer's formal quality program may be conducted at the ambient temperature and humidity of the manufacturer's test area. Referee testing shall be conducted after conditioning the samples for a minimum of 40 h at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity. Testing shall be conducted under the same conditions.

7.2 *Test Methods*—Only specified ASTM test methods shall be used.

## 8. Quality Control Test Requirements: Nondestructive Testing

8.1 *Workmanship*—The pipe layers shall be homogeneous throughout, and free from visible cracks, holes, foreign inclusions, and other injurious defects. The pipe layers shall be as uniform as is commercially practical in color, opacity, density, and other physical properties.

8.2 *Outside Diameter*—The outside diameters and tolerances for Sewer-Drain series shall meet the requirements of Table 1 and Table 2. The outside diameter and tolerances for pipe having IPS outside diameters shall meet the requirements of Table 3 and Table 4 for IPS Schedule 40 series and of Table 5 and Table 6 for IPS Pipe Stiffness (PS) series. Dimensions shall be determined in accordance with Test Method D 2122. Tolerances for out-of-round shall apply only at the time of manufacture (prior to packaging and shipment).

8.3 *Wall Thickness*—The wall thickness for Sewer-Drain series shall meet the requirements of Table 1 and Table 2. The wall thickness for pipe having IPS outside diameters shall meet the requirements of Table 3 and Table 4 for Schedule 40 pipe and shall meet the requirements of Table 5 and Table 6 for Pipe Stiffness (PS) pipe. Dimensions shall be determined in accordance with Test Method D 2122.

8.4 *Layer Thickness*—The minimum thicknesses of the individual inner and outer layers shall be 10 % of the wall thicknesses specified in 8.3, rounded upward to the nearest 0.005 in. To measure the inner and outer layers, use a pocket optical comparator with a reticle scale graduated to 0.005 in. Make eight readings equally spaced around the pipe circumference. Report the layer thickness to the nearest 0.005 in.

## 9. Quality Assurance Test Requirements: Destructive Testing

9.1 *Impact Resistance*—The impact resistance of the pipe shall be determined at the time of manufacture. Energy test levels for Sewer-Drain series shall comply with Table 1 and Table 2. Energy test levels for IPS Schedule 40 series shall comply with Table 3 and Table 4. Energy test levels for IPS Pipe Stiffness (PS) series shall comply with Table 5 and Table 6. Failure in the test specimen shall be shattering or cracking of the specimen that is visible to the unaided eye.

9.1.1 *Impact Testing*—Test in accordance with Test Method D 2444. A20 lb (9.07 kg) "A" Tup and "B" Holder shall be employed for the Sewer-Drain series. A20 lb (9.07 kg) "B" Tup and" B" Holder shall be employed for pipe having IPS outside diameter.

9.1.1.1 Test 10 specimens. When 9 or 10 pass, accept the lot. When 4 or more specimens fail, reject the lot. When 2 or 3 of 10 specimens fail, test 10 additional specimens. When 17 or more of 20 specimens tested pass, accept the lot. When 7 or more of 20 fail, reject the lot. When 4, 5, or 6 of 20 fail, test 20 additional specimens. When 32 of 40 specimens pass, accept the lot. When 9 or more of 40 specimens fail, reject the lot.

9.2 *Bond Integrity*—The bonding of the three layers shall be strong and uniform.

9.2.1 *Bond Testing*—A sharp point or blade shall be used to test the bond between layers. It shall not be possible to separate any two layers so that the layers separate cleanly. Separation of the layers shall not occur during any other testing performed under the requirements of this specification.

9.3 *Flattening Integrity*—There shall be no evidence of splitting, cracking, breaking, or separation of layers when pipe specimen is subjected to flattening test.

9.3.1 *Flattening Test*—Flatten three specimens of pipe, having a minimum length of 6 in. (150 mm), between parallel plates in a suitable press until the distance between the plates is 40 % of the outside diameter of the pipe. The rate of loading shall be uniform and such that the flattening is completed within 2 to 5 min.

9.4 *Pipe Stiffness*—Sewer-Drain series shall have a minimum pipe stiffness value of 46 psi (320 kPa). IPS Schedule 40 series shall comply with the minimum pipe stiffness requirements in Table 3 and Table 4. IPS Pipe Stiffness (PS) series shall have minimum pipe stiffness values of either 100 psi (690 kPa) or 120 psi (830 kPa).

NOTE 5—Pipe stiffness is a function of the pipe dimensions and the physical properties of the pipe materials. Pipe stiffness is used for engineering design when considering load-deflection characteristics of a pipe. Appendix X1 provides methods by which to estimate pipe stiffnesses of three-layer pipe constructions.

9.4.1 *Pipe Stiffness Testing*—Determine the pipe stiffness at 5 % deflection of inside diameter as described in Test Method D 2412. Test three specimens. All three specimens shall meet the requirement.

## 10. Qualification Test Requirements: Performance Testing

10.1 *Joint Integrity, Solvent-Cement Joints*—Two systems of fit for integral bells are in common use: interference-fit (D 2665 for DWV pipe, D 2466 for electrical duct, and D 3034 for sewer pipe) and clearance fit (F 512 for electrical duct). Both systems shall be watertight when solvent cemented together in accordance with the manufacturer's recommendations.

10.1.1 *Joint-Tightness Testing*—Cement a section of pipe to a bell, using the manufacturer's recommendations or, in their absence, the methods described in Practice D 2855. Unless otherwise specified, allow the assembly to stand for a minimum of 6 h. Then subject the assembly to an internal pressure of at least 25 psi (170 kPa), using water as the test medium. Maintain the pressure for at least 1 h. There shall be no leakage.

10.2 *Joint Integrity, Elastomeric-Gasket Joints*—Piping intended for use in sewer or drainage applications shall have watertight joints against both infiltration of ground water and exfiltration of sewerage or storm water. Piping intended for electrical and communications cable shall have watertight joints against infiltration of ground water.

10.2.1 *Joint-Tightness Testing*—Piping intended for use in sewer or drainage applications shall meet the requirements of Specification D 3212. Piping intended for electrical and communications cable shall meet the requirements of Test Method F 1365.

## 11. Sampling, Inspection, Retest, and Rejection

11.1 *Sampling*—The manufacturer shall maintain a documented quality program detailing sampling procedures and test frequencies that have been established to ensure conformance to this specification.

11.2 *Inspection*—When required, inspection of the material shall be made as agreed upon by the purchaser and the seller as part of the purchase contract.

11.3 *Retest and Rejection*—If the results of any test(s) do not meet the requirements of this specification, the test(s) may be conducted again. 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 shall be followed. If, upon retest, failure occurs, the quantity of product represented by the test(s) shall be considered as not meeting this specification.

NOTE 6—Sampling and any retesting are normally done at the time of manufacture.

## 12. Marking

12.1 *General*—Marking shall be legible. The marking shall be applied in such a manner that it remains legible after installation and inspection. The pipe shall be marked at least every 5 ft (1.5 m) in letters not less than 3⁄16in. (5 mm) high.

12.2 *Content of Marking*—The following marking requirements are minimum requirements. Other information may be added as deemed necessary by the manufacturer.

12.2.1 The designation "ASTM F1760 – 96." This designation 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. Words modifying an ASTM designation to limit product characteristics to portions or sections of the said specification (for example "ASTM F1760 – 96 PERFORMANCE") are not permissible.

12.2.2 Manufacturer's name or trademark.

12.2.3 The wording "CONTAINS RECYCLED PVC".

12.2.4 Nominal pipe size and pipe series identification (for example, "6" Sewer PS 46" or "6" IPS Sch 40" or "6" IPS DB 120").

12.2.5 Manufacturer's code for identifying date of manufacture, plant location, and production line.

NOTE 7—Code bodies may require that pipe be marked on two opposite sides. For example, "DWV pipe" may be required to be marked on the side opposite from the rest of the marking.

## 13. Keywords

13.1 coextruded pipe; PVC plastic pipe; recycled plastic material; reprocessable plastic material

# APPENDIX

**(Nonmandatory Information)**

## X1. PIPE STIFFNESS CALCULATIONS

X1.1 This appendix contains the information necessary for calculating pipe stiffness by two methods. The methods differ in their determination of the pipe's modulus of elasticity:

X1.1.1 The modulus is determined experimentally by testing of pipe samples. (See X1.3 and X1.5.1.)

X1.1.2 The modulus is calculated using the minimum published properties of the pipe's layers. (See X1.4 and X1.5.2)

X1.2 *Background*—The products covered by this specification are modeled after PVC pipe products in Specifications D 2665 (DWV pipe), D 3034 (sewer pipe), F 512 (electrical utility duct), and several communications-company standards (communications duct). The methods for calculating pipe stiffness are not uniform throughout these specifications.

X1.2.1 *DWV Pipe*—D 2665 DWV pipe is Schedule 40 pipe, which is dimension-based. Pipe stiffness is calculated using minimum wall and minimum modulus values.

X1.2.2 *Sewer Pipe*—Specification D 3034 recognizes that average wall thickness is greater than minimum wall. Pipe stiffness is calculated using average wall (106 % of minimum wall) and minimum modulus values.

X1.2.3 *Electrical Utility Duct*—Specification F 512 made pipe stiffness the defining property. The specification allows thinner walls when higher-modulus compounds are used, as long as specified pipe stiffness is met. Pipe stiffness is calculated using the minimum wall values with the maximum modulus and the maximum wall values with the minimum modulus.

X1.2.4 *Communications Duct*—The utility standards that specify communications duct have the same philosophy that was used in Specification F 512. (This is the reason for the inclusion of the "4C" product in Table 5 and Table 6 of this specification.)

X1.3 *Formula A*—The formula for pipe stiffness in a cylindrical specimen is as follows:

$$PS = 0.559E\left(\frac{t}{r_m}\right)^3 \quad (X1.1)$$

where:
$t$ = average wall thickness,
$r_m$ = mean radius, and
$E$ = flexural modulus of elasticity.

X1.3.1 This pipe stiffness formula applies to specimens with average wall thickness, uniform mean radius, and a uniform flexural modulus of elasticity.

X1.3.2 Individual plastic pipe specimens vary in wall thickness and in out-of-round, defined as "maximum OD minus minimum OD".

X1.4 *Formula B*—The formula for pipe stiffness for a three-layer pipe is as follows (See Fig. X1.1 for wall-section dimensions.):

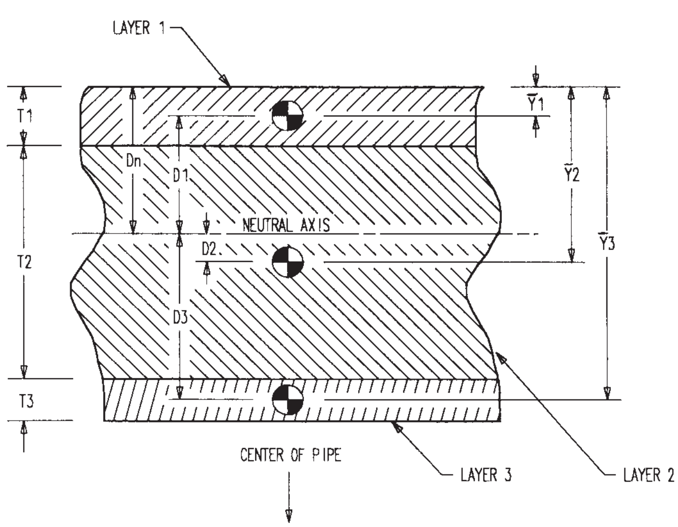


**FIG. X1.1 Three-Layer Pipe, Wall Section**

$$PS = \frac{\Sigma E_i I_i}{0.149\, r_m^3} \quad (X1.2)$$

for $i$ = 1 through 3 (for a three-layer pipe).

where:
$E_i$ = flexural modulus of elasticity for layer $i$, and
$I_i$ = moment of inertia for layer $i$.

$$= \frac{wT_i^3}{12} + A_i D_i^2 \quad (X1.3)$$

where:
$w$ = unit width of section (for example, 1 in.),
$T_i$ = thickness of layer $i$,
$A_i$ = area of layer $i$ section,
= $wT_i$,
$D_i$ = distance from the center of area of $A_i$ to composite wall neutral axis,

$$= D_n - \bar{Y}_i \quad (X1.4)$$

$D_n$ = distance from pipe outside wall to composite wall neutral axis

$$= \frac{\Sigma E_i \bar{Y}_i A_i}{\Sigma E_i A_i} \quad (X1.5)$$

for $i$ = 1 through 3,
$\bar{Y}_i$ = distance from pipe outside wall to center of area of $A_i$

$$\bar{Y}_1 = \frac{T_1}{2} \quad (X1.6)$$

$$\bar{Y}_2 = T_1 + \frac{T_2}{2} \quad (X1.7)$$

$$\bar{Y}_3 = T_1 + T_2 + \frac{T_3}{2} \quad (X1.8)$$

$r_m$ = composite wall mean radius (distance from pipe central axis to composite wall neutral axis).

$$= \frac{OD}{2} - D_n \quad (X1.9)$$

where:
$OD$ = average pipe outside diameter.

X1.4.1 Individual plastic pipe specimens vary in wall thickness and in out-of-round, defined as "maximum OD minus minimum OD." A coextruded pipe will also vary in thickness of each layer and may vary in the material modulus of each layer.

X1.5 There are several methods for treating the variables which exist. In ASTM standards for plastic pipe, there are two methods for determining pipe stiffness:

X1.5.1 *Method 1—Formula A*:

X1.5.1.1 *Calculate the Modulus of Elasticity*—Determine $E$ experimentally for a specific three-layer pipe construction by making pipe specimens, performing pipe stiffness tests at 5 % deflection, determining average total wall thickness, and then computing flexural modulus using Formula A. The flexural modulus is the mean of the several test values less two standard deviations.

X1.5.1.2 Calculate the nominal wall thickness.

X1.5.1.3 Calculate the nominal mean radius.

X1.5.1.4 Calculate pipe stiffness using Formula A. Use the nominal wall thickness, the nominal mean radius, and the flexural modulus calculated in Step 1 above.

NOTE X1.1—*Nominal Weight*—The Plastic Pipe Institute's Technical Report PPI-TR-7, defines nominal weight as the weight which is calculated by using the nominal or stated diameter (without consideration of tolerance) and the nominal wall thickness of the pipe. The diameter and wall thickness values are obtained from the applicable standard specification which must be reported. The nominal wall thickness is the minimum plus 6 % rounded to the nearest 0.001 in.

X1.5.2 *Method 2—Formula B*:

X1.5.2.1 *Determine the Values for Modulus of Elasticity*—Use published minimum flexural modulus values for the materials comprising each layer. If there are no published flexural modulus values, use published minimum tensile modulus values.

X1.5.2.2 Calculate minimum layer thicknesses as specified in the standard, using minimum total wall thickness.

X1.5.2.3 Calculate the nominal mean radius.

X1.5.2.4 Calculate pipe stiffness using Formula B. Use the minimum layer thicknesses, the nominal mean radius, and the flexural modulus values determined in Step 1 above.

NOTE X1.2—Method 2 introduces a conservative bias by using the minimum wall and minimum moduli. Actual pipe production will result in total wall and inner and outer layer thickness that average greater than the absolute minimums used in the Method 2 calculation. Any increase in layer thicknesses or in material modulus will increase pipe stiffness. Actual measured pipe stiffness values may vary from values calculated by Method 2.