



Designation: F3378/F3378M – 22

Standard Specification for Crosslinkable Polyethylene (CX-PE) Pipe¹

This standard is issued under the fixed designation F3378/F3378M; 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 outside diameter controlled crosslinkable polyethylene (CX-PE) pipe produced in sizes DN 25 to 630 and NPS 1 to 24 in various dimension ratios. Included in this specification are requirements and test methods for the determination of the long-term hydrostatic strength, hydrostatic burst pressure, hydrostatic sustained pressure, UV weathering resistance, initial and ultimate degree of crosslinking, workmanship, and marking.

1.2 This specification shall not be applied to crosslinked products, specifically PEX pipe or tubing.

NOTE 1—CX-PE is a different designation separate from conventional PEX materials, specifically with regard to the crosslinking rate, installation, and commissioning processes.

1.3 The pipe covered by this specification is intended for pressure and non-pressure applications. Fluids such as non-potable water, multi-phase mixed fluids, crude oils, gases, and chemical solutions containing some water are allowed to be transported in pipe made in accordance with this standard. Permissible operating temperatures for commissioned piping systems constructed from CX-PE pipe manufactured in accordance with this specification are ≤ 200 °F [93 °C].

1.4 Pipe produced in accordance with this specification is intended to be crosslinked during or after installation. The procedures and practices to be used for the installation and crosslinking of the CX-PE pipe are outside the scope of this specification. Manufacturer's recommendations for the commissioning of CX-PE pipe are used to ensure that the performance of the completed piping system meets design expectations.

NOTE 2—The difference between pipes made in accordance with this specification and PEX pipes made in accordance with Specification F2905 is that the final crosslinking process is completed as part of installation and commissioning as opposed to crosslinking taking place in the manufacturing facility.

1.5 This specification includes requirements to demonstrate a minimum level of performance in service.

1.6 Joining of CX-PE pipes made in accordance with this specification is outside the scope of this specification. For guidance on the joining of CX-PE pipe consult Practice F3507 and manufacturer's recommendations.

1.7 This specification references notes, footnotes, and appendixes, which provide non-mandatory explanatory material. Excluding table footnotes which are mandatory, notes, footnotes and information in parentheses shall not be considered as requirements of this specification.

1.8 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.

1.9 *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.*

1.10 *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

- D638 Test Method for Tensile Properties of Plastics
- D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- D1505 Test Method for Density of Plastics by the Density-Gradient Technique
- D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
- D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings

¹ This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.68 on Energy Piping Systems.

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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.

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

D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe

D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications

D2765 Test Methods for Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics

D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products

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

D4329 Practice for Fluorescent Ultraviolet (UV) Lamp Apparatus Exposure of Plastics

D4364 Practice for Performing Outdoor Accelerated Weathering Tests of Plastics Using Concentrated Sunlight

F412 Terminology Relating to Plastic Piping Systems

F876 Specification for Crosslinked Polyethylene (PEX) Tubing

F2023 Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Pipe, Tubing and Systems to Hot Chlorinated Water

F2657 Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing

F2905 Specification for Crosslinked Polyethylene (PEX) Line Pipe For Oil and Gas Producing Applications

F3203 Test Method for Determination of Gel Content of Crosslinked Polyethylene (PEX) Pipes and Tubing

F3507 Practice for Butt-Fusion Joining of Crosslinkable Polyethylene (CX-PE) Pipe and Tubing

2.2 *ANSI Standard*.³

B36.10 Standard for Welded and Seamless Wrought Steel Pipe

2.3 *ISO Standards*.⁴

ISO 14531-1 Plastics pipes and fittings — Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels — Metric series — Specifications — Part 1: Pipes

ISO 161-1 Thermoplastics pipes for the conveyance of fluids - Nominal outside diameters and nominal pressures - Part 1: Metric series

ISO 9080 Plastics Piping and Ducting Systems - Determination of The Long-Term Hydrostatic Strength of Thermoplastics Materials in Pipe Form by Extrapolation

2.4 *PPI Standard*.⁵

TR-3 2021 – HDB/HDS/PDB/SDB/MRS/CRS Policies

2.5 *Military and Federal Standards*.⁶

FED-STD 123G Marking for Shipment (Civil Agencies)

MIL-STD 129P Military Marking for Shipment and Storage

3. Terminology

3.1 *Definitions*—Unless otherwise specified, definitions are in accordance with Terminology **F412**, and abbreviations are in accordance with Terminology **F412** and Terminology **D1600**.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *commission*, *v*—a series of actions taken after installation to bring a new system into working condition.

3.2.2 *crosslinked pipe*, *n*—pipe that is crosslinked to a measured gel content level of $\geq 65\%$.

3.2.3 *crosslinkable polyethylene*, *CX-PE*, *n*—a polyethylene compound that has been chemically modified so that crosslinks will form when the compound is exposed to heat and moisture.

3.2.3.1 *Discussion*—When pipe made from CX-PE reaches a level of crosslinking $\geq 65\%$ it is considered fully crosslinked and is referred to as crosslinked pipe in accordance with this standard.

3.2.4 *design factor*, *DF*, *n*—a number between 0 and 1, that the HDB is multiplied by to determine the HDS. This value is intended to contribute to the certainty that pipe will not fail in the service it is designed for.

3.2.5 *nominal diameter*, *DN*, *adj*—a designation for SI unit of outside diameter-controlled pipe sizes that generally comply with outside diameters specified in ISO 161-1.

3.2.6 *nominal pipe size*, *NPS*, *adj*—a designation for inch-pound unit outside diameter-controlled pipe sizes that generally comply with outside diameters specified in ANSI B36.10.

3.2.7 *maximum allowable operating pressure*, *MAOP*, *n*—the estimated maximum continuous pressure a pipe is capable of withstanding at the maximum operating temperature of a piping system with a high degree of certainty that failure of the pipe will not occur.

4. Materials

4.1 *Basic Materials*—CX-PE compound used for production of pipe in accordance with this specification, and for optional co-extruded stripes and layers shall be made from polyethylene compounds which have been made crosslinkable during polyethylene compound manufacture by chemically grafting reactive molecules (for example, vinyl trimethoxy silane) onto polyethylene molecules, or by copolymerization of reactive molecules with ethylene to create a modified polyethylene compound. Compounds and pipes that are produced by other means such as peroxide crosslinking and radiation crosslinking, do not meet the requirements of this specification. CX-PE compounds are crosslinked by added heat and water (see manufacturer's recommendations).

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁴ Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

⁵ Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, <http://www.plasticpipe.org>.

⁶ Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, <http://quicksearch.dla.mil>.

4.2 Density—When tested in accordance with **7.4**, CX-PE compound shall have a minimum density of 0.033 lb/in³ or [0.926 g/cm³].

4.3 Degree of Crosslinking—When CX-PE compound is fully crosslinked and tested in accordance with **7.6**, it shall have minimum degree of crosslinking (gel content) of 65 %.

4.4 Hydrostatic Design Basis (HDB) of Crosslinked Compound—CX-PE compound in pipe form and fully crosslinked, having a degree of crosslinking (gel content) ≥65 %, shall have an HDB value determined and categorized in accordance with the requirements of Test Method **D2837**.

4.5 Thermal Stability—When CX-PE compound is tested in accordance with **D3895** at 392 °F [200 °C], it shall have an oxidative induction time of greater than 20 minutes.

4.6 UV Resistance and Color:

4.6.1 The CX-PE materials and any compounds used for striping or outer layer co-extrusion shall contain sufficient stabilizers or carbon black to protect the pipe from UV degradation for a period of not less than six months

5. Product Qualification

5.1 Product qualification testing shall be performed to demonstrate the suitability of a CX-PE compound in pipe form in accordance with this specification. Unless otherwise specified, product qualification tests are conducted on any representative size of pipe.

5.2 Tensile Elongation—When crosslinked CX-PE pipe is tested in accordance with **7.8**, it shall have a tensile elongation at break exceeding 350 %.

5.3 Hydrostatic Design Basis (HDB) of Crosslinked Pipe—CX-PE compound in pipe form and fully crosslinked, having a degree of crosslinking (gel content) ≥65 %, shall have an HDB value determined and categorized in accordance with the requirements of Test Method **D2837**.

5.3.1 The CX-PE crosslinked compound, when fully crosslinked, shall have a minimum HDB value of 1250 psi at 73 °F [8.62 MPa at 23 °C], 800 psi at 180 °F [5.52 MPa at 82 °C] and 630 psi at 200 °F [4.34 MPa at 93 °C].

NOTE 3—Where a Long-Term Hydrostatic Strength (LTHS) value is needed for an application at a temperature intermediate between the established lower HDB and established higher temperature HDB values, interpolation may be used. Refer to the calculations provided in The Plastics Pipe Institute's Technical Report TR-3, Part D2 -Policy for Determination of Long-Term Strength by Temperature Interpolation

5.4 Stabilizer Functionality—The functionality of a stabilizer in a specific CX-PE compound shall be verified by hydrostatic testing of pipe in accordance with **7.9**, or with an ISO 9080 data set for pipe made from the compound containing data at 110 °C that shows data points at a stress of greater than or equal to 3.24 MPa and time greater than 8000 h.

5.5 Chlorine-Thermal Oxidative Stabilization—Resistance to thermo-oxidation shall be determined for CX-PE pipe in accordance with Test Method **F2023**. Tubing made in accordance with the dimensional requirements of Specification **F876** for NTS ½ shall be tested.

5.6 UV Resistance and Color:

5.6.1 The CX-PE materials and any compounds used for striping or outer layer co-extrusion shall contain sufficient stabilizers to protect the pipe from UV degradation for a period of not less than six months.

5.6.2 CX-PE pipe containing between 2.0 wt. % and 3.0 wt. % well dispersed carbon black shall be considered to be stabilized against UV exposure for not less than ten years. The carbon black content in black CX-PE pipe shall be measured in accordance with the requirements of either Test Method **D1603** or Test Method **D4218**.

5.6.3 The maximum UV exposure time for CX-PE pipe not containing a minimum of 2.0 wt. % carbon black, shall be determined by exposing representative pipe samples to natural weathering in accordance with Test Method **F2657**, or ISO 14531-1 Annex C. Alternatively accelerated UV weathering in accordance with Practice **D2565**, or Practice **D4329**, or Practice **D4364** are permitted to be used. The minimum total UV exposure tested with shall be 218 MJ/m² which shall be considered equivalent to six months of outdoor weathering exposure as described in Test Method **F2657**. A total solar UV radiation value of 339 MJ/m² per year shall be considered the amount of natural UV weathering exposure per year when determining the maximum UV exposure time.

5.6.4 If natural weathering in accordance with Test Method **F2657** or ISO 14531-1 Annex C is used, and post exposure testing in accordance with Test Method **F2657** is excluded, post exposure testing per the requirements of this standard shall be used to determine maximum UV exposure time. Alternatively, for CX-PE pipes that have a maximum UV exposure time determined when tested in accordance with Test Method **F2657** post exposure requirements, no further post exposure testing is required

5.6.5 Following UV weathering exposure, CX-PE pipe shall meet the tensile elongation and OIT requirements of **5.2** and **4.5**.

6. Pipe Requirements

6.1 The requirements of **6.2** through **6.11** shall apply to CX-PE pipe.

6.2 Workmanship—The pipe shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties. Pipe made in accordance with this specification that is co-extruded with an external color layer or external color stripes shall be acceptable.

6.2.1 Preservation—Pipe produced in accordance with this specification shall be handled and stored in such a way as to preserve the quality and workmanship of the pipe. This shall include appropriate storage to manage weathering of the pipe (for example, use of tarps over pallets of pipe stored outdoors).

6.3 Pipe Diameter—The outside diameter of the pipe shall be in accordance with **Table 1** or **Table 2** when measured in accordance with Test Method **D2122**. The outside diameter measurement shall be taken at a distance at least 1.5 times the average outside diameter or 11.8 in. or 300 mm, whichever is less, from the cut end of the pipe. The pipe shall be measured