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An American National Standard

Standard Specification
Fabricated Fittings of Crosslinkable Polyethylene (CX-PE)[1]

This standard is issued under the fixed designation F3525/F3525M; 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 establishes requirements for fabricated fittings intended for use with outside-diameter controlled CX-PE pipe and tubing. These fittings are manufactured by heat-fusion joining shape-modified CX-PE components prepared from pipe, molded fittings, sheet, billet, or block. Included are requirements for materials, design, workmanship, minimum dimensions, marking, test methods, and quality control.

1.2 Pressure rating of the fabricated-fitting design is beyond the scope of this standard and shall be established by the fitting manufacturer.

1.3 Fittings manufactured in accordance with this specification are primarily intended to be joined to CX-PE pipes and used in CX-PE piping systems that are commissioned in accordance with a pipe manufacturer recommended commissioning practice. In addition, fittings manufactured in accordance with this specification that are ≥65 % crosslinked prior to installation can meet the additional requirements of Specification F2829.

1.4 The pressure rating determined for a fitting will result in the fittings' equivalent dimension ratio (EDR). The EDR specified by the fitting manufacturer is the DR of the piping system for which the fabricated fitting is intended to be joined. This standard specifies that fittings be fabricated from pipe sections of a lower DR than pipe that the fabricated fitting is intended to be joined to. This standard follows the pattern of Specification F2206 which specifies that the wall thickness of fabricated multiple segment elbow fittings shall be a minimum of 22 % more than the pipe to be joined to for example.

NOTE 1—Increased wall thickness alone is not necessarily sufficient to produce fittings adequate for use. Increased wall thickness without consideration of proper material placement can be detrimental to performance. Finite element analysis studies have shown that abrupt changes in fitting wall sections, such as between a heavy socket hub and body wall, concentrates stress at the transition point. Normal stresses from flex, pressure, expansion, and contraction in a plastic piping system can break a fitting at this point. Short transitions from 22 % thicker fittings to pipe or tubing create a similar condition.

1.5 Design of fabricated fittings is outside of the scope of this standard. Requirements related to thicknesses and taper angles are intended to differentiate potentially good, fabricated fittings from fittings with a high risk of failure. Users of the standard are advised that for large or made-to-order fittings, minimal testing is required by this standard, and it may be insufficient itself to identify improperly designed and produced fittings made in accordance with this standard. The design and production of fittings made in accordance with this standard shall be performed by a fabricator with appropriate training, equipment and knowledge of fitting design and production.

1.6 Pipe used to fabricate fittings in accordance with this specification shall be produced in accordance with pipe manufacturer specifications.

1.7 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

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 may not be exact equivalents; therefore, each system shall be used independently of the other. Nonconformance with this practice is possible if values from the two systems are combined. Values in parentheses are conversions that are appropriately rounded for accuracy and precision; that are not exact equivalents, and that are for nonmandatory informational purposes.

1.9 The following safety hazards caveat pertains only to the pressure test requirements 6.3 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.*

1.10 *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.*

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.10 on Fittings.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

D638 Test Method for Tensile Properties of Plastics

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

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

F412 Terminology Relating to Plastic Piping Systems

F2206 Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE)

F2829 Specification for Metric- and Inch-Sized Fittings for Crosslinked Polyethylene (PEX) Pipe

F2880 Specification for Lap-Joint Type Flange Adapters for Polyethylene Pressure Pipe in Nominal Pipe Sizes ¾ in. to 65 in.

F2928 Practice for Specimens and Testing Conditions for Testing Polyethylene (PE) Pipe Butt Fusions Using Tensile and Hydrostatic Test Methods

F3183 Practice for Guided Side Bend Evaluation of Polyethylene Pipe Butt Fusion Joint

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 *Other Standards:*

AWWA C906-15 Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 65 in. (100 mm Through 1650 mm), for Waterworks[3]

FED-STD 123G Marking for Shipment (Civil Agencies)[4]

Military Standard 129P Military Marking for Shipment and Storage[4]

3. Terminology

3.1 Definitions and abbreviations used are in accordance with Terminology F412 and with Terminology D1600, unless otherwise specified.

3.2 *Definitions:*

3.2.1 *crosslinkable polyethylene, (CX-PE), n*—polyethylene compound that has been chemically modified so that crosslinks will form when the compound is exposed to heat and moisture at the same time, with the possibility of the final crosslinking taking place after installation of pipe made from CX-PE compound.

3.2.1.1 *Discussion*—CX-PE pipe is minimally crosslinked and is best butt fused before the level of crosslinking reaches 30 %. When pipe made from CX-PE reaches a level of crosslinking ≥ 65 % it is considered crosslinked pipe. The pipe manufacturer measures the crosslinking level of CX-PE by performing a gel content test.

3.2.2 *equivalent dimension ratio (EDR), n*—the DR of the pipe to which the fabricated fitting is permitted to be joined.

3.2.2.1 *Discussion*—A fabricated fitting made in accordance with this standard will have a thicker wall than the pipe to which it is intended to be joined. Fitting ends are to be machined so that the fitting end matches the dimensional specifications of the pipe to which it is to be joined. Greater fitting body thickness is necessary to assure that the fittings have adequate strength in service.

3.2.3 *fitting end(s), n*—the end(s) of the fabricated fitting intended for field joining by the installer.

3.2.4 *fabricated fitting, n*—a fitting constructed from manufactured CX-PE components or materials.

4. Ordering Information

4.1 When ordering fittings under this specification include the following information:

4.1.1 CX-PE compound (material designation or trade name). The material designation shall match the pipe that the fabricated fitting is intended to be joined to.

4.1.2 Style of fitting (for example: 3-piece tee, 5-segment 90° ell, etc.).

4.1.3 *Size:*

4.1.3.1 Nominal size of end connections.

4.1.3.2 End configurations (for example, metric or inch, socket, or flange).

4.1.3.3 System DR.

5. Material

5.1 CX-PE materials allowed for use in fittings produced in accordance with this specification shall be in accordance with the manufacturer's fabricated-fitting design specifications.

5.2 CX-PE pipe used in the production of fittings in accordance with this specification shall meet the requirements of the applicable CX-PE pipe specification.

5.3 Flange adaptors used in the production of fabricated fittings in accordance with this specification shall meet purchaser requirements.

NOTE 2—Dimensions of CX-PE flange adapters should be in accordance with Specification F2880. A CX-PE flange adaptor specification using dimensions and tolerances like those specified in Specification F2880 is expected to be developed later.

5.4 Sheet, block or plate stock used in the production of fabricated fittings shall be produced from the same material designation of CX-PE compound. (See 4.1.1.)

NOTE 3—Manufacturers should use appropriate quality assurance procedures to ensure that sheet, block, and plate are free from voids, laminations, foreign inclusions, cracks, and other injurious defects. Manufacturers should also store all CX-PE pipe, sheet, block, or plate stock in as cool and dry a location as possible before fabrication. Storage should be for a minimal amount of time and should avoid exposure to UV weathering.

5.5 CX-PE pipe, sheet, block, or plate stock used to fabricate fittings per this specification shall have been produced

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235, http://www.awwa.org.

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

within less than six months prior to the date they are used for fabrication. Alternatively, documented testing shall be performed to demonstrate that the pipe sheet, block, or plate stock used to fabricate fittings is crosslinked to <30 % when tested in accordance with Test Method F3203 prior to fabrication. Follow Annex A1 which provides additional requirements for suitable storage and testing of storage life.

6. Requirements

6.1 *Dimension and Tolerances*—Fitting ends shall be machined to meet the diameter and wall thickness requirements of the pipe to which joining is intended.

6.1.1 *Diameter*—The outside diameters and diameter tolerances for fitting ends made in accordance with this standard specification shall be the same as specified in approved specifications for CX-PE pipe in metric and inch sizes for the specified nominal pipe size and DR. In the absence of an applicable pipe specification the diameter tolerance shall be a minimum ± 0.5 % of the average diameter of the pipe intended to be joined to.

6.1.2 *Wall Thickness*—The minimum wall thickness of fitting ends made in accordance with this specification shall be the same as specified for the CX-PE pipe the fittings are intended to be used with. This is permitted to be achieved by beveling either the inside or outside or both edges to transition from the thicker wall thickness of the fitting specified in 7.2 to the wall thickness of the pipe that the fitting is intended to be joined to. Allowance shall be made for facing and bead roll-back when the fitting is butt-fused to pipe in the field.

6.1.3 *Eccentricity*—The wall thickness variability of the fitting end as measured and calculated in accordance with Test Method D2122, in any diametrical cross-section of the pipe shall not exceed 12 %.

6.1.4 *Laying Lengths*—Laying length dimensions shall be defined by the manufacturer.

6.2 Physical Requirements—Fabricated straight reducer couplings do not require thicker walls but shall be fabricated from sufficiently heavy wall stock to permit tapering in accordance with 6.2.2. Fabricated fittings using miter cut pipe stock shall be manufactured from pipe stock with a wall thickness that is at least 22 % greater than that of the pipe to which the fitting is to be joined. (For example: An EDR11 five gore elbow fitting shall be made using DR9 pipe stock.) Fabricated tee fittings shall be manufactured from pipe stock with a wall thickness that is at least 50 % greater than that of the pipe to which the fitting is to be joined. Fabricated wyes shall be manufactured from pipe stock with a wall thickness that is at least 150 % greater than that of the pipe to which the fitting is to be joined.

6.2.1 For the fabrication of fittings requiring a heavier wall thickness it is permissible to use pipe stock of a larger outside diameter than the pipe it is intended to be joined to for the fabrication of fittings.

6.2.2 Fabricated fitting ends shall be machined at a maximum 30° taper to match the dimensions of the pipe that the pipe is intended to be joined to. If tapering of the wall is required for both the inside and outside of the pipe, the end of the tapers shall be offset by at least the wall thickness of the pipe intended to be joined to.

NOTE 4—The counterboring and outside tapering of the fitting ends to match the specified diameter and wall thickness of the pipe the fitting is intended to be joined to should be carefully designed. Generous radius fillets should be used. The intent is to minimize stress concentration due to differential strain on different parts of the fitting circumference.

6.2.3 Fabrication of complex fittings or made-to-order fittings that are combinations of elbows, tees and wyes are permitted, but require engineering consideration of the stresses on the individual joints making up the fitting and the combination of the joints together. For example, a cross fitting will require wall thickness reinforcement beyond that required for a tee fitting to achieve the same pressure rating.

NOTE 5—Specification F2206 which is applicable to production of PE fabricated fittings has similar minimum thickness requirements. CX-PE fittings being substantially identical to PE fittings with the exception that they are expected to be crosslinked after installation are therefore designed similarly. The wall thickness requirement of this specification is a minimum only and does not prohibit fittings from being fabricated from thicker wall stock or from being otherwise reinforced to meet other requirements either of this specification or resulting from anticipated uses of fabricated fittings.

6.3 *Pressure Test Requirements*—Tests in accordance with 6.3.2 and 6.3.3 need only be conducted on representative test samples of each style of fitting for diameters up to and including 12 in. (300 mm) diameter. Alternatively, if made-to-order or larger than 12 in. (300 mm) diameter fittings are produced, testing shall be in accordance with 6.3.4 only.

6.3.1 A single EDR sample shall be considered as representative of all the wall thicknesses produced in that style grouping. The EDR and diameter of the test fittings shall be in the mid-range of the wall thicknesses and diameters typically produced for that fitting style. Fitting styles are characterized as elbows, tees, wyes, crosses, reducing tees, reducing laterals, branch saddles, mechanical joint adapters, and end caps.

6.3.2 *Elevated Temperature Sustained Pressure Test*—Test three specimens per fitting style in accordance with 8.4.2. Each specimen shall have a minimum distance of three pipe diameters between end closures and any miter joints in the fittings. This test need only be performed for the initial qualification of a fitting style using a particular CX-PE compound.

NOTE 6—The elevated temperature sustained pressure test is intended to simulate that process of crosslinking of the fitting, but with a higher pressure. During crosslinking fittings made from CX-PE are most vulnerable to failure as a result of any stress concentration points in the design of the fitting. This is not intended to be a test of fusion joint strength but a test of the suitability of the fitting design with the CX-PE compound used.

6.3.3 *Short-term Pressure Testing*—Test five specimens per fitting style in accordance with 8.4.3. Each specimen shall have a minimum distance of three pipe diameters between end closures and any miter joints in the fittings.

6.3.4 *Five-Second Pressure Test*—The manufacturer shall conduct a Five-Second Pressure Test, as defined in AWWA C906-15, at a pressure equal to 3.2 times the intended pressure rating of the fitting, on the first fitting of a particular outside diameter and style and every fiftieth fitting thereafter for fabricated fittings.

NOTE 7—Fittings manufactured in accordance with this specification are intended to be installed into CX-PE piping systems and crosslinked in accordance with an approved commissioning practice. Leak testing requirements are expected to be part of a CX-PE system commissioning practice providing additional assurance that fabricated CX-PE fittings will perform as expected.

6.4 *Storage Life Requirements*—Fabricated fittings intended to be butt fused to CX-PE pipe shall be capable of tolerating a minimum of six months of storage before the fittings crosslink to >30 %. If a fabricated fitting is not intended to be butt fused, storage time before crosslinking exceeds 30 % is not a consideration.

6.4.1 Storage tests shall be conducted by the manufacturer to assure that the fittings are not crosslinked to >30 % after six months of storage. Storage tests shall be conducted by measuring the gel content per Test Method F3203, of representative sample fittings or the raw stock used to produce a fitting after a minimum of six months of storage. Storage times longer than six months are permitted to be established by testing. Follow Annex A1 which provides additional requirements for suitable storage and testing of storage life.

6.4.2 The fitting fabricator shall inform the fitting user of recommended storage conditions for fabricated fittings. The fabricator shall also inform the user of the latest date that the fabricated fitting used is permitted to be butt fused before degree of crosslinking becomes a concern.

6.4.3 The fitting manufacturer is permitted to store fabricated fittings in climate-controlled warehousing to slow the rate of crosslinking.

NOTE 8—CX-PE crosslinking rate is affected by temperature, humidity, and wall thickness. Warehousing that prevents fabricated fittings from being exposed to high temperature and humidity will significantly extend the allowable storage time for fabricated fittings. Representative samples to be used for crosslinking rate tests are usually of similar wall thickness. Thinner wall material crosslinks more quickly.

6.5 *Fusion Joining Requirements:*

6.5.1 The fitting fabricator shall determine the suitability of a CX-PE stock material and the joining procedure by tensile test of test fusion joints when joints of sufficient size and configuration are being fabricated to produce test specimens. Miter fusion joints shall be made between sufficiently large sections of pipe to be able to produce tensile specimens for testing per Test Method D638. Consult Practice F2928 for additional instructions on the preparation and testing of tensile test specimens for checking butt fusion joints.

6.5.2 The fitting fabricator shall determine the suitability of a CX-PE stock material and the joining procedure when joints of sufficient size and configuration are being fabricated to produce test specimens in accordance with Test Method F3183. Produced specimens shall be tested and shall have ductile test results when tested in accordance with Test Method F3183.

7. Workmanship, Finish, and Appearance

7.1 Fittings shall be produced to meet the requirements of this specification. Fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other injurious defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

7.2 The procedure used for the heat fusion in the fabrication process shall be written and qualified in accordance with the written joining procedure. The standard fusion joining procedures shall include procedures described in Practice F3507 as well as a cleaning of the ends of the pipe prior to fusion with a 95 % isopropyl alcohol wipe and alignment of the cut angles so they end up flat when completed. Any additional procedure determined by the fitting fabricator to be needed, such as procedures for cutting, milling, drilling and counterboring operations shall be included in their written fitting fabrication procedures.

7.3 All personnel engaged in the fitting fabrication process shall be qualified in accordance with the requirements set by the fitting manufacturer. Technicians making fusion joints shall be trained by the fitting fabricator in all necessary procedures specific to making fusion joints. They shall complete butt fusion training where they learn not only how to fuse, but the theory and concept of how it works. If possible, they shall attend external training and obtain that certification as well.

7.4 All fusion machinery shall have appropriate charts showing what the fusion pressure, soak time, cool time, and temperature needed be for fabrication of any given fitting. All machines shall have count down timers.

7.5 Data Loggers shall be used to record data for the production of each fusion joint. This data shall be reviewed by the fabricator's quality department.

7.6 All fusions shall be inspected by the technician making the joint and are permitted to be rejected at this point for any reason.

7.7 All fusion joints shall be reviewed and checked by quality control (QC) personnel. A QC technician shall sign off on a fitting on the work ticket and on a stamp on the fitting. This inspection shall include joint appearance and high / low.

7.8 Prior to shipping, the shipper who shall be trained appropriately, shall perform a final check on joint and fitting appearance.

8. Test Methods

8.1 *Conditioning*—Unless otherwise specified, condition the specimens prior to test at 73 °F ± 4 °F [23 °C ± 2 °C] for not less than 6 h in air or if pressure testing in accordance with 8.4, 1 h in water immediately prior to the test. Fitting specimens to be tested shall not be crosslinked after fabrication and prior to testing.

NOTE 9—Testing of CX-PE fittings prior to crosslinking is the most pertinent approach as the fitting will be most vulnerable to hydrostatic pressure failure prior to crosslinking. Fittings could change dimensionally after crosslinking; however, the fittings are intended to be joined to un-crosslinked pipe which may also change dimensions in a similar way after crosslinking.

8.2 *Test Conditions*—Conduct the tests at the standard laboratory temperature unless otherwise specified.

8.3 *Dimensions and Tolerances:*

8.3.1 *Outside Diameter*—Measure the outside diameter of the fittings at the butt-fusion end in accordance with the Wall