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An American National Standard

Standard Practice for Butt-Fusion Joining of Crosslinkable Polyethylene (CX-PE) Pipe and Tubing[1]

This standard is issued under the fixed designation F3507; 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 practice describes procedures for making butt fusion joints with crosslinkable polyethylene (CX-PE) pipe and tubing[2] which is less than 30 % crosslinked at the time of joining. This practice shall **not** be applied to crosslinked products, that is PEX pipe or tubing or to CX-PE after commissioning[3] (commissioning transitions CX-PE pipe into crosslinked pipe).

NOTE 1—For avoidance of doubt, CX-PE is a completely different product than PEX, especially for the purposes of butt-fusion joining and the fabrication of fittings. The two must not be confused by the reader of this standard.

1.2 The main difference between this practice and Practice F2620 is that the production date of pipe must be checked prior to butt fusion. Field experiments have indicated that it is best to make heat fused joints before the pipe has aged six months to ensure it has not crosslinked more than 30 % at ambient conditions. (See 7.2.)

1.3 Joints are made by means of butt-fusion joining in, but not limited to, a field environment. Other suitable butt-fusion joining procedures may be available from various sources including pipe and fitting manufacturers. This practice does not claim to address all possible butt-fusion joining procedures and does not prevent the use of qualified procedures developed by other parties that have been proven to produce reliable butt fusion joints.

1.4 The parameters and procedures set forth in this practice are applicable to the butt-fusion joining of CX-PE pipe and tubing. Consult with the manufacturers of CX-PE pipe or tubing to ensure that they approve of the use of this practice for butt-fusion joining of their products. This practice applies to butt fusion of both CX-PE pipe and tubing even when tubing is not explicitly referred to.

1.5 CX-PE pipe or tubing is required to produce sound joints when using the joining procedures described in this practice. Component ends joined in accordance with this practice shall be of the same nominal diameter and wall thickness.

1.6 The ability to join pipe using this practice does not imply that the pipe joined is suitable for any intended use.

1.7 This practice does not purport to address any issues related to the commissioning of a CX-PE system prior to its use. The intention of this standard practice is to set forth requirements for the butt fusion of CX-PE pipe and tubing which when followed are expected to yield durable joints in the said pipe and tubing.

1.8 Only procedures related to butt-fusion joining are covered in this practice. Saddle fusion and socket fusion are not included in this practice.

1.9 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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

1.11 *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.*

1.12 *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 practice is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.20 on Joining.

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[2] A standard specification for CX-PE pipe is being developed by Subcommittee F17.68.

[3] A practice for commissioning of CX-PE piping systems is being developed by Subcommittee F17.68.

2. Referenced Documents

2.1 *ASTM Standards:*[4]

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
F412 Terminology Relating to Plastic Piping Systems
F876 Specification for Crosslinked Polyethylene (PEX) Tubing
F2620 Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings
F2634 Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints using Tensile-Impact Method
F3124 Practice for Data Recording the Procedure used to Produce Heat Butt Fusion Joints in Plastic Piping Systems or Fittings
F3183 Practice for Guided Side Bend Evaluation of Polyethylene Pipe Butt Fusion Joint
F3190 Practice for Heat Fusion Equipment (HFE) Operator Qualification on Polyethylene (PE) and Polyamide (PA) Pipe and Fittings

2.2 *MIL/FED Standard:*[5]

US DOT Codes 49 CFR Part 192 Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards

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.

3.2.1.1 *Discussion*—As it relates to CX-PE piping, this includes crosslinking and leak testing of an installed system (see manufacturers recommendations). For a CX-PE piping system the ultimate completion of commissioning results in a system composed of crosslinked pipe (see 3.2.2). A system that has been subjected to a commissioning process is considered commissioned.

3.2.2 *crosslinked pipe, n*—pipe that is crosslinked to a measured level of ≥65 %.

3.2.2.1 *Discussion*—At this point the pipe material is no longer CX-PE because it is crosslinked to a degree where it cannot be butt fused or melt processed.

3.2.3 *crosslinkable polyethylene, (CX-PE), n*—polyethylene compound that has been chemically modified so that crosslinks will form when the pipe 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.

3.2.3.1 *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 referred to as crosslinked pipe in accordance with this standard. The pipe manufacturer measures the crosslinking level of CX-PE by performing a gel content test.

3.2.4 *drag pressure, fusion machine (P_D), n*—the amount of pressure that needs to be applied during a butt fusion process to overcome the frictional resistance in the butt fusion machine carriage components.

3.2.5 *gauge pressure, fusion machine (P_G), n*—the pressure reading displayed on a hydraulic fusion machines pressure gauge.

3.2.5.1 *Discussion*—To make a durable butt fusion this pressure is equal to the theoretical fusion pressure plus the drag pressure for the fusion machine.

3.2.6 *interfacial pressure, (IFP), n*—the pressure required between the heated surfaces of two pieces of pipe necessary to create a durable joint during butt fusion. This pressure is normally 60 to 90 psi (0.41 to 0.62 MPa).

3.2.7 *theoretical fusion pressure, (TFP), n*—the theoretical hydraulic pressure required for a hydraulic fusion machine to make a durable joint.

3.2.7.1 *Discussion*—This is equivalent to the calculated total force required to press the ends together divided by the total effective piston areas (TEPA). The total force required is equal to the interfacial pressure (IFP) multiplied by the area of the end of the pipe.

3.2.8 *total effective piston area, (TEPA), n*—a value provided by the fusion machine manufacturer to quantify the area of the hydraulic piston or pistons used to drive the pipe ends toward each other.

4. Summary of Practice

4.1 The principle of butt-fusion joining of CX-PE pipe is to heat two prepared surfaces to a designated temperature, and then fuse them together by application of a sufficient force. This force causes the melted materials to flow and undergo intermolecular diffusion and entanglement, thereby resulting in fusion.

4.2 *Butt Fusion*—The butt fusion procedure consists of heating the squared ends of two pipes by holding them against a heated plate, removing the heater plate when the proper melt is obtained, promptly bringing the ends together, and allowing the joint to cool while maintaining the appropriate applied force.

4.2.1 An appropriately sized butt fusion machine is used to clamp, align, and face the pipe ends and to apply the specified fusion force. See Fig. 1.

NOTE 2—*Research Report*—A research report has been prepared in connection with this practice. Samples of CX-PE pipe were joined using butt fusion procedures at various conditions consistent with this practice and were subsequently tested for joint strength. The research report is

[4] 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.

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

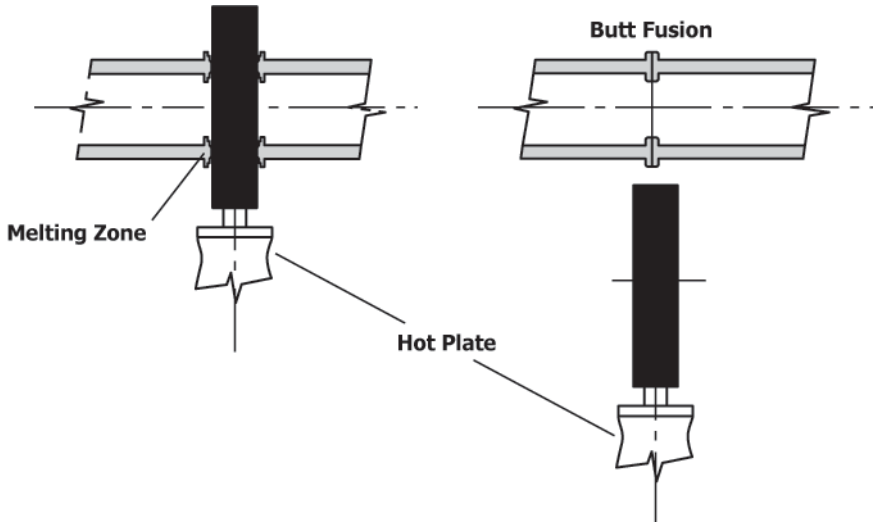


FIG. 1 Butt Fusion

available from ASTM International Headquarters and is designated RR:F17-2000.[6]

5. Significance and Use

5.1 The procedures described in Section 8 are intended for butt-fusion joining of CX-PE pipe and tubing, using suitable equipment and appropriate environmental control procedures. Appropriate controls are established on the butt-fusion joining process to ensure that the pipe is suitable for joining, that the operator is properly trained, that adequate apparatus and procedures are used, and that the process is protected from environmental extremes. The controls are established by testing butt-fusion joints, operator skills, the apparatus and the procedures used. When this practice is properly implemented, strong pressure and leak-tight joints are produced. When joints made in accordance with this practice are destructively tested, failures are expected to occur outside the fusion-joined area.

5.1.1 This practice shall **not** be used to join PEX pipe or tubing made in accordance with Specification F876 or any other PEX pipe or system specification. This practice is not intended to be used for pipe or tubing to be crosslinked by radiation or by using peroxides. This practice shall **not** be used to join CX-PE pipe that has been commissioned. CX-PE pipe that has been commissioned is crosslinked pipe.

5.2 Melt characteristics, average molecular weight and molecular weight distribution are influential factors in establishing suitable fusion parameters, therefore, consider the manufacturers instructions in the use or development of a specific fusion procedure.

5.3 The butt fusion procedures in this practice are suitable for joining CX-PE pipe and tubing that is used in pressure, low pressure, and non-pressure applications. For some applications, qualification of the procedure by testing joints made using the procedure in accordance with regulations from the authority having jurisdiction are required.

5.4 This butt-fusion joining practice shall only be used to join pipe or tubing made from compatible CX-PE compounds and meeting the same specification dimensions for outside diameter and wall.

6. Operator Training or Qualification

6.1 Skill and knowledge on the part of the operator are required to obtain a good quality joint. Skill and knowledge are obtained by making butt fusion joints in accordance with proven procedures under the guidance of trained or qualified operators.

6.2 Evaluate operator proficiency by testing sample joints. (See Appendix X3 for guidance on testing of sample joints).

6.3 The party responsible for the butt-fusion joining of CX-PE pipe or tubing shall ensure that detailed procedures are issued before actual joining operations begin. These procedures shall be developed in conjunction with the manufacturers of the pipe and the joining equipment used, shall take into consideration applicable codes and regulations, and shall include safety precautions to be followed.

6.4 When operator qualification procedures are not defined by the applicable owner or authority having jurisdiction, the use of operator qualification and testing procedures in accordance with Practice F3190 shall be considered acceptable.

7. Pipe Qualification and Preparation

7.1 *General*—Only CX-PE pipe marked with CX-PE and the date of extrusion in the print string shall be butt fused in accordance with this practice.

NOTE 3—CX-PE pipe should have a comprehendible date printed on the pipe. If the butt-fusion operator requires additional information about the pipe they should consult with the seller of the pipe, and if the pipe seller does not provide appropriate assistance, then they should contact the pipe manufacturer directly. Information resources pertaining to the product or the pipe manufacturer may also be available on the internet.

7.2 *Allowable Pipe Storage Time:*

7.2.1 CX-PE pipe is intended to be butt fused using this practice. Pipe to be fused in accordance with this practice shall

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F17-2000. Contact ASTM Customer Service at service@astm.org.

tolerate a minimum of six months outdoor storage under conditions like those used for the pipe manufacturers ambient crosslinking testing. Consult the pipe manufacturer for the maximum storage time allowed for the pipe prior to it being butt fused. If available, the certificate of analysis for the pipe to be butt fused shall be consulted prior to butt fusing CX-PE pipe of a particular lot to confirm the date of manufacture and expected length of time the pipe is permitted to be stored before butt-fusion. Do not butt fuse CX-PE pipe if the pipe has been in storage for over six months in accordance with the date on the print line on the pipe without consulting the pipe manufacturer or the pipe certificate of analysis.

NOTE 4—The CX-PE pipe specification[7] will have requirements that the pipe producer establish CX-PE pipe storage life so that crosslinking tests will not be required. The manufacturer of CX-PE joined using this standard is required to establish that pipe they produce has a high probability of not crosslinking to >30 % in six months under reasonably severe conditions. Longer duration storage may be approved by the manufacturer. CX-PE pipe that has been commissioned should have crosslinking >30 % and may not be joined by butt fusion but may be joined by mechanical fittings or electrofusion.

7.2.2 If the crosslinking level of CX-PE pipe determined by the pipe manufacturer prior to shipment is acceptable and the pipe manufacturer advises the installer that the pipe is permitted to be butt fused for a longer time than six months from the date of extrusion, the installer is permitted in accordance with this standard to butt fuse the pipe at any time within the manufacturer permitted maximum storage time.

NOTE 5—The CX-PE pipe manufacturer should be contacted by the installer to coordinate delivery of the pipe to permit adequate time for the CX-PE piping system to be installed by butt fusion after delivery. Preferably the installer will have up to five months after delivery to install pipe before ambient crosslinking becomes a concern.

7.3 *Cutting pipe*—When cutting a CX-PE pipe to length before fusing, the CX-PE pipe shall be cut using cutting tools which do not introduce contamination to the pipe surfaces or the fusion equipment. Cutting shall be performed using tools such as hand saws, reciprocating saws, run-around pipe cutters, guillotine cutters, and pipe shears. No lubricants are permitted to be used when cutting pipe to be butt fused. In the event contamination is transferred to the pipe or pipe ends during cutting, it shall be removed in accordance with the cleaning procedure in X1.5.1. Additionally, care shall be taken so that contamination does not transfer to fusion equipment and contaminate subsequent joints.

NOTE 6—Use of chainsaws for cutting pipe should be avoided because it is difficult to completely remove all oil and grease from a chainsaw, which will cause contamination of the joint surface

7.4 *Sample Joints*—Each week, the first fusion of the day shall be a sample joint that is visually inspected and subjected to a least one destructive mechanical test. Acceptable destructive mechanical tests include Test Method D638 using Type III or Type IV tensile specimens, or Test Method D1599, or Practice F3183, or Test Method F2634, or bent strap testing (see Appendix X3). Acceptable destructive mechanical test results shall be non-failure or failure outside of the joint interface. A sample butt fusion joint shall be produced and tested at least once every week in accordance with butt-fusion operator actively producing butt-fusion joints.

8. Butt Fusion

8.1 *Apparatus—General Requirements:*

8.1.1 *Heating Tool*—Electric heating tools used shall be of sufficient size to adequately cover the ends of the pipe being joined and shall match the fusion machines capabilities. They shall be designed with enough wattage and electronic control to maintain the specified heater face temperature required in this procedure. The range of the heater control shall be larger than the heating temperature specification (the typical control range is 50 °F or 28 °C above and below the maximum and minimum required heating tool surface temperatures). Electric heating plates shall maintain consistent fusion temperatures when provided with an adequate power source.

8.1.2 *Heating Tool Faces*—Heating tools are made from materials such as aluminum, stainless steel, copper, or copper alloys. CX-PE material is known to stick to hot metal heating surfaces. This sticking may be minimized by applying a non-stick coating to the heating surfaces or by fitting a high-temperature, non-stick fabric over the heating surfaces. The heating plate surfaces, coated or uncoated, shall be kept clean and free of contaminants such as dirt, grease and plastic build-up, which may cause excessive sticking and create unsatisfactory joints. Most of these contaminants are removed from the hot tool surfaces using a clean, dry, lint-free, non-synthetic cloth such as cotton. Do not use synthetic fabrics which may char and stick to the fusion surface. Some pigments, such as carbon black, may stain a heating surface and cannot be easily removed; such stains will not contaminate the joint interface.

8.1.3 After a period in service, non-stick coatings or fabrics will deteriorate and become less effective. Deteriorated fabrics shall be replaced, and worn, scratched, or gouged non-stick coatings shall be re-coated when they lose effectiveness. Heat fusion quality may be adversely affected by deteriorated non-stick surfaces. Spray-on chemicals, such as non-stick lubricants or oils shall not be applied to heating iron surfaces as they will contaminate the joint.

8.1.4 *Temperature Indicator*—Heating tools shall be equipped with a thermometer or other built-in temperature indicating device. This device indicates the internal temperature of the heating iron, which is usually higher than the temperature of the heating tool surfaces. Use a pyrometer, or other temperature measuring device, on the first joint of the day and periodically during the day to verify the temperature of the tool face surfaces within the pipe contact area. Select multiple checkpoints on each side to ensure uniform surface temperature. An infrared pyrometer is calibrated by comparison to a calibrated surface pyrometer and adjusted to agree on each heating tool.

NOTE 7—A significant temperature variation, that is, cold spots, on the heating tool surfaces may indicate a faulty heating iron which may need to be serviced before it can be used.

8.2 *Butt Fusion Machine:*

[7] A standard specification for CX-PE pipe is being developed by subcommittee F17.68.

8.2.1 A Butt Fusion Machine has three basic parts: *(1)* a stationary clamping fixture and a movable clamping fixture for aligning and holding each of the two pipes to be fused; *(2)* a facer for simultaneously preparing the ends of the parts to be joined (Note 7); and *(3)* appropriate inserts for clamping different pipe sizes. Butt Fusion Machines are operated manually or hydraulically. Some have their own power supply commonly attached to the clamping fixture, and some require a separate generator. They are available in a variety of sizes to fuse pipe and tubing produced to ASTM and other industry specifications.

NOTE 8—A facer is a rotating cutting device used to square-off the pipe ends to obtain properly mating fusion surfaces. If so equipped, facing should continue until a positive mechanical stop on the butt fusion machine is reached.

8.2.2 *Pipe Support Stands*—Optional pipe support stands or racks are used to support the pipe at both ends of the butt fusion machine to assist with pipe loading and alignment.

8.3 *Setup:*

8.3.1 The butt fusion machinery shall be setup in accordance with the parameters prescribed in Table 1.

8.3.2 An interfacial pressure (IFP) of 60 psi to 90 psi (0.41 MPa to 0.62 MPa) (see Note 1 regarding research report) is used to determine the force required to butt fuse the pipe components. For manually operated fusion machines, enough force shall be applied to roll the bead back to the pipe surface. A torque wrench is permitted to be used to apply the proper force.

8.3.3 For hydraulically operated fusion machines, the IFP is multiplied by the pipe area (A_p) to obtain the fusion force required in pounds. The fusion force required is then divided by the total effective piston area (TEPA) of the fusion machine carriage to obtain the theoretical fusion pressure (TFP) (see Eq 2). The drag pressure (P_D) is then added to the TFP to obtain the fusion machine gauge pressure (P_G) in psig required by the machine (see Eq 1). TFP and IFP are **not** the same value. P_D is found by bringing the faced pipe ends within 2 in. (50 mm) of each other and increase the pressure on the carriage until it starts moving. Back off the pressure until the carriage is barely moving and record the drag pressure in psig. The equations used to calculate for the fusion machine gauge pressure is shown below. These equations only apply when using a hydraulic fusion machine.

$$P_G = TFP + P_D \quad (1)$$

$$TFP = \frac{(A_p \times IFP)}{TEPA} \quad (2)$$

$$A_p = (OD - T)T3.14 \quad (3)$$

where:

P_G = Fusion Machine Gauge Pressure, psig
TFP = Theoretical Fusion Pressure, psig
IFP = Interfacial Pressure, 60 psig – 90 psig
$TEPA$ = Total Effective Piston Area, in.^{2} Supplied by fusion machine manufacturer
P_D = Fusion Machine Drag Pressure, psig
A_p = Pipe Area, in.^{2}
OD = Pipe Outside Diameter, in.
T = Pipe Wall Thickness, in.

NOTE 9—Interfacial pressure is used to determine butt-fusion-joining pressure settings for hydraulic butt fusion machines when joining specific pipe diameters and DR's. Interfacial pressure is **not** the gauge pressure. A slide rule or a gauge pressure calculator obtained from the machines manufacturer can be used as a tool for the calculation.

8.4 *Procedure:*

8.4.1 Clean the inside and outside of the pipe to be joined with a clean, dry, lint-free, non-synthetic cloth such as cotton. Remove all foreign matter from the piping component surfaces where they will be clamped in the butt fusion machine. If this does not remove the contamination, refer to X1.5.1.

8.4.2 If applicable, place pipe support stands at both ends of the butt fusion machine and adjust the support stands to align the pipe with the fusion machine centerline. Install the pipes being joined in the stationary and movable clamps of the butt

TABLE 1 Butt Fusion Machine Setup Parameters

Setup Parameter		Required Condition
Manual Butt Fusion Machine	Hydraulic Butt Fusion Machine	
Set heating tool temperature and heat to specified temperature	Set heating tool temperature and heat to specified temperature	The surface temperature of heating tool faces must be 400 °F to 450 °F (204 °C to 232 °C). in accordance with 8.4.5 (make sure equipment is in working order, see X1.1.) (see Note 1 regarding research report)
Install clamp inserts	Install clamp inserts	Install clamping inserts to match the pipe OD being fused.
Electric power supply	Electric power supply	Check field generator for adequate power supply and fuel sufficient to complete the fusion joint.
Manual pressure	Set facing pressure	As required. Observe butt fusion machine manufacturer's instructions for setting facing pressure.
Manual pressure	Set heating pressure	Observe the pipe and butt fusion machine manufacturer's instructions for setting heating pressures.
Manual pressure	Set fusion joining pressure	Determine fusion joining pressure for the pipe OD and dimension ratio (DR) using 60 psi to 90 psi (414 kPa to 621 kPa) interface pressure. Observe pipe and butt fusion machine manufacturer's instructions to determine the theoretical fusion joining pressure (TFP). (see Note 1 regarding research report)
	Determine drag pressure (P_D)	Drag pressure is the amount of pressure required to get the carriage to move. Add this pressure to the theoretical fusion joining pressure to get the actual machine gauge pressure (PG) to set.

fusion machine. Leave enough pipe protruding through the clamps to allow for facing and clamp the pipe in the machine.

8.4.2.1 Take care when placing pipe in the butt fusion machine. Pipe shall be aligned before the alignment clamp is closed. Do not force the pipe into alignment by pushing it against the side of an open butt fusion machine clamp. Pipes that are freshly cut generally do not have toe-in, and when mated to old-cut pipe removing toe-in can ease adjustment for high-low alignment.

8.4.3 Face the pipe ends until the facer bottoms out on the stops to establish clean, parallel mating surfaces between the pipe ends. Move the carriage to separate the pipe ends from the facer after it comes to a complete stop, remove the facer and all shavings and debris from the facing operation by brushing away with a clean, dry, lint-free, non-synthetic cloth such as cotton. Bring the pipe ends together at facing pressure. A visual inspection of this operation should verify a square face, perpendicular to the pipe centerline on each pipe end and with no detectable gap.

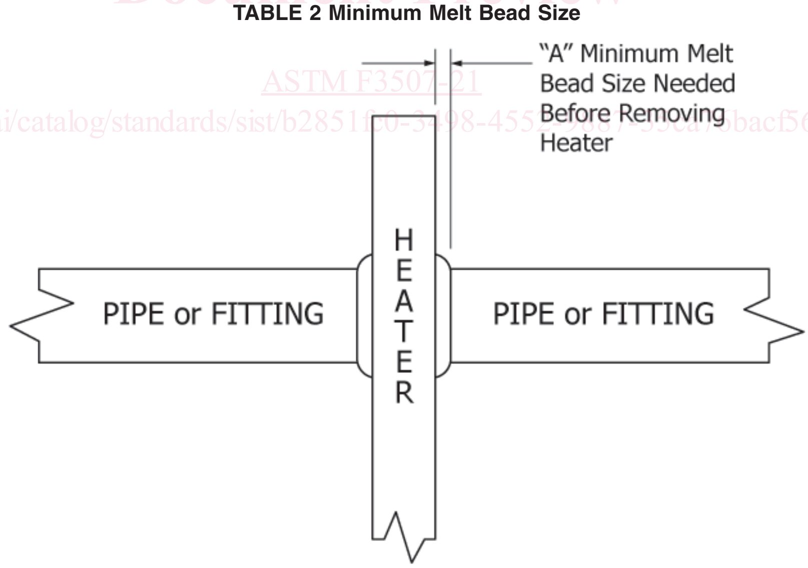
8.4.4 Check the pipe ends for high-low alignment and out-of-roundness. If adjustment is needed, adjust the high side down by tightening the high side clamp. Do not loosen the low side clamp or slippage may occur during fusion. Re-face the pipe ends if excessive adjustment is required (more than 180 rotation of the clamp knob) and remove any shavings from the re-facing operation with a clean, dry, lint-free, non-synthetic cloth such as cotton. The maximum OD high-low misalignment allowed in the butt fusion procedure is to be less than 10% of the pipe minimum wall thickness.

8.4.5 Verify that the heater surface temperatures are in the specified temperature range 400 °F to 450 °F (204 °C to 232 °C) (make sure equipment is in working order, see Appendix X1). A pyrometer or other surface temperature measuring device shall be used before the first joint of the day and periodically throughout the day to ensure proper temperature of the heating tool face. All pyrometers are sensitive to usage techniques. Carefully follow the pyrometer manufacturers instructions for best results. Check the surface temperature of the heater surface in several locations on both sides when checking the heater temperature.

8.4.5.1 Clean the contact surfaces of the heating tool with a clean, dry, lint-free, non-synthetic cloth such as cotton. Place the heating tool in the butt fusion machine between the piping component ends and bring the pipe ends into full contact with the heating tool at fusion pressure. Briefly ensure full contact between piping component ends and the heating tool and then reduce the pressure to drag pressure but without breaking contact between the piping component ends and the heating tool.

8.4.5.2 Once the indication of melt is observed around the circumference of the pipe and pressure has been reduced from fusion pressure to drag pressure a bead of molten CX-PE will develop between the heater and the pipe ends, beginning the heat soak time. Continue heat soak time until the melt bead size has developed against both heater faces in accordance with Table 2.

TABLE 2 Minimum Melt Bead Size



Pipe (OD) [Outside Diameter, in. (mm)]	A Minimum Bead Size, in. (mm)
< 2.37 (60)	1⁄32 (1)
2.37 (60) 3.5 (89)	1⁄16 (1.5)
3.5 (89) 8.62 (219)	3⁄16 (5)
> 8.62 (219) 12.75 (324)	1⁄4 (6)
> 12.75 (324) 24 (610)	3⁄8 (10)
> 24 (610) 36 (900)	7⁄16 (11)

8.4.6 When the proper bead size is observed, quickly move the piping component ends away from the heating tool, remove the heating tool and quickly inspect the pipe ends.

8.4.6.1 Acceptable melt appears flat and smooth with no un-melted areas. Unacceptable melt appearance is any combination of a concave surface, un-melted areas, a bubbly pock-marked sandpaper-like surface or melted material sticking to heating tool surfaces (see Appendix X2 for examples). Low-strength joints result from attempting to join components with unacceptable melt appearance. If the melt appearance is determined to be unacceptable, discontinue the joining procedure, allow the pipe ends to cool completely and restart from 8.4.1. (See Appendix X2.)

NOTE 10—A concave melt surface is caused by unacceptable pressure during heating.

8.4.6.2 Table 3 presents the maximum time allowed for opening the machine, removing the heater, inspecting the melt, and if the melt is acceptable bringing the pipe ends together. For sizes that are generally butt fused with mechanical fusion machines which are not hydraulically controlled and typically are for pipe and tubing not larger than NPS 1½, the maximum heater plate removal time is 4 s. The quicker this process can be done safely, the better. Do not slam the pipe ends together. See Practice F2620 Annexes for guidance on butt fusion in cold temperatures.

NOTE 11—Fusion joints made in an enclosed and controlled factory fabrication environment will tolerate and may use longer maximum heater removal times.

8.4.6.3 The correct fusion pressure rolls a portion of both melt beads over so that they touch the piping component outside surfaces (see Fig. 2). Do not use excessive or insufficient force (more than or less than the fusion interfacial pressure range). If the components are brought together with excessive force, molten material will be pushed out of the joint and cold material brought into contact forming a “cold” joint. If too little force is used or fusion pressure is not maintained, voids and weak bonded areas can develop in the joint as molten material cools and contracts

TABLE 3 Maximum Time to Open, Remove Heater, Inspect Melt, and Close

Field Applications	
Pipe Wall Thickness, in. (mm)	Maximum Heater Plate Removal Time (s)
0.17 to 0.36 (5 to 9)	8
>0.36 to 0.55 (9 to 14)	10
>0.55 to 1.18 (14 to 30)	15
>1.18 to 2.5 (30 to 64)	20
>2.5 to 4.5 (64 to 114)	25

8.4.7 Hold the molten joint immobile under fusion pressure until sufficiently cooled. Cooling under pressure before removal from the butt fusion machine is important in achieving joint integrity. Maintain fusion pressure against the piping component ends for a minimum of 11 min/in. (25.4 mm) of pipe wall thickness. For ambient temperatures above 100 °F (38 °C) additional cooling time may be required. Avoid stressing the joint by pulling, installation or rough handling for 30 min or more after removal from the fusion machine, with the exception that only 10 min additional cooling time is required for IPS or NPS 1 and smaller pipe sizes. Do not apply internal pressure until the joint and surrounding material have reached ambient air temperature. (See Appendix X1)

NOTE 12—Pouring water on or applying wet cloths to the joint to reduce cooling time is not acceptable. The use of a controlled cooling cycle to reduce the cooling time, (for example applying conditioned air) is acceptable only where testing demonstrates that acceptable joints are produced using the controlled cooling cycle procedure.

8.4.7.1 Strict adherence by a trained or qualified operator to the butt fusion procedures and adequate butt fusion process controls are the primary means to ensure quality fusion joints are produced.

8.4.8 Visually inspect and compare the joint against the butt fusion bead visual inspection acceptance guideline in Fig. 2. This figure is intended to give general guidance for the appearance of CX-PE butt-fusion joints. There will be variation in the beadcross-section profile depending on the degree of crosslinking, environmental conditions, the wall thickness of the pipe and the flow properties of the individual CX-PE compound, most of which will be allowable. If the bead shape indicates excessive crosslinking (minimal or no roll back of the beads), confirm acceptable crosslinking level for final determination if a joint shall be rejected. The bead profile must be of a consistent general shape around the joint circumference.

8.4.8.1 Deep V-grooves (see Fig. 2) indicate that either the fusion pressure was too high, or that the pipe ends were underheated before being pushed together. Deep V-groves are stress concentration points and indicate weak improperly made joints and shall be rejected due to high risk of failure of the joint in service.

8.4.9 *Commissioning Butt-Fused Joints*—Butt fused joints and piping system shall subsequently be commissioned in accordance with pipe manufacturers recommendations. Commissioning of the system including butt fusion joints is required to assure expected joint strength.

9. Keywords

9.1 butt fusion; crosslinkable; CX-PE; heat fusion; joining; PEX; pipe; polyethylene