Designation: F3372 – 20

An American National Standard

Standard Practice for Butt Fusion Joining of PA12 Pipe and Fittings[1]

This standard is issued under the fixed designation F3372; 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 Polyamide 12 (PA12) pipe and fittings by means of heat fusion joining in, but not limited to, a field environment. Procedure A is for environmental temperatures of 40 °F (4 °C) and higher. Procedure B is for site temperatures below 40 °F (4 °C). Other suitable heat fusion joining procedures are available from various sources including pipe and fitting manufacturers. This standard does not purport to address all possible heat fusion joining procedures, or to preclude the use of qualified procedures developed by other parties that have been proved to produce reliable heat fusion joints.

1.2 The parameters and procedures are applicable only to joining PA12 pipe and fittings and are not applicable to other polyamide types. They are intended only for PA12 fuel gas pipe per Specification F2785 and PA12 butt heat fusion fittings in accordance with Specification F1733. Fusion to other polyamide types (that is, cross-fusion) is not permitted under this practice, and this practice does not not apply to other polyamide types. Consult with the pipe and fittings manufacturers to make sure they recommend this procedure for the pipe and fittings to be joined (also see Appendix X1).

1.3 The procedures in this practice apply to the butt fusion of PA12 pipe and butt fusion fittings in accordance with 1.2 having like diameter and wall thickness.

NOTE 1—Refer to X1.5 for guidance regarding dissimilar wall thicknesses.

1.4 Other suitable heat joining procedures are available from various sources including pipe and fitting manufacturers. Melt characteristics, average molecular weight and molecular weight distribution of PA12 compounds are influential factors in establishing suitable fusion parameters; therefore, consider the manufacturer's recommendations in the use or development of a specific fusion procedure.

1.5 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.

1.6 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.

1.6.1 Non-conformance with this specification 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 non-mandatory informational purposes.

1.7 *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.*

1.8 *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]

F412 Terminology Relating to Plastic Piping Systems

F1733 Specification for Butt Heat Fusion Polyamide(PA) Plastic Fitting for Polyamide(PA) Plastic Pipe and Tubing

F2785 Specification for Polyamide 12 Gas Pressure Pipe, Tubing, and Fittings

3. Terminology

3.1 *General*—Definitions and abbreviations are in accordance with Terminology F412, unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *drag force, n*—the force required to overcome the static and dynamic resistance to motion of the movable carriage.

3.2.2 *fusion force, n*—the force applied between the melted polymer pipe ends.

[1] This test method 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] 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.

3.2.3 *total effective piston area, n*—the surface area of the piston face that drives the hydraulic fusion machine moveable carriage.

3.2.4 *fusion machine gauge pressure, n*—the pressure indicated on the hydraulic system pressure gauge on a hydraulic butt fusion machine.

3.2.5 *facer*—a rotating cutting device used to square-off the pipe or fitting ends to obtain properly mating fusion surfaces.

4. Summary of Practice

4.1 The principle of heat fusion joining of PA12 pipe is to heat two prepared surfaces to a designated temperature, then fuse them together by application of a sufficient force. This force causes the melted materials to flow and mix, thereby resulting in fusion.

4.2 Only butt heat-fusion procedures are covered in this practice.

4.3 The butt-fusion procedure in its simplest form consists of heating the squared ends of two pipes, a pipe and a fitting, or two fittings, 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.

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

4.5 This practice describes procedures for making butt fusion joints with Polyamide 12 (PA12) pipe and fittings by means of heat fusion joining in, but not limited to, a field environment using suitable equipment and appropriate environmental control procedures. When properly implemented, strong, pressure/leak-tight joints are produced.

4.6 For fuel gas applications, regulated oil and gas applications, and some industrial applications, qualification of the procedure by testing joints made using the procedure in accordance with regulations from the authority having jurisdiction is required.

4.7 The party responsible for the joining of PA12 pipe and fittings shall ensure that detailed procedures developed in conjunction with applicable codes and regulations and the manufacturers of the pipe, fittings, and joining equipment involved, including the safety precautions to be followed, are issued before actual joining operations begin.

5. Operator Experience

5.1 Skill, and knowledge, and proficiency on the part of the operator are required to obtain a good quality joint. This skill and knowledge is obtained by making joints in accordance with proven procedures under the guidance of skilled operators. Evaluate operator proficiency by testing sample joints.

6. Butt Fusion Apparatus

6.1 *Heating Tool*—The heating tool shall have sufficient area to adequately cover the ends of the size of pipe to be joined. This electrical tool shall have sufficient wattage and control to maintain the specified temperature of the tool faces within the required control range when used in cold weather conditions with the largest diameter and lowest DR specified for the butt fusion machine. See Section 8 for cold and adverse weather considerations. Heating tool faces shall be coated with a non-stick material to keep melted material from sticking to the surface.

6.1.1 *Heating Tool Faces*—PA12 material may stick to hot metal heating tool surfaces. Sticking is minimized by applying a non-stick coating to the heating tool surfaces. The heating

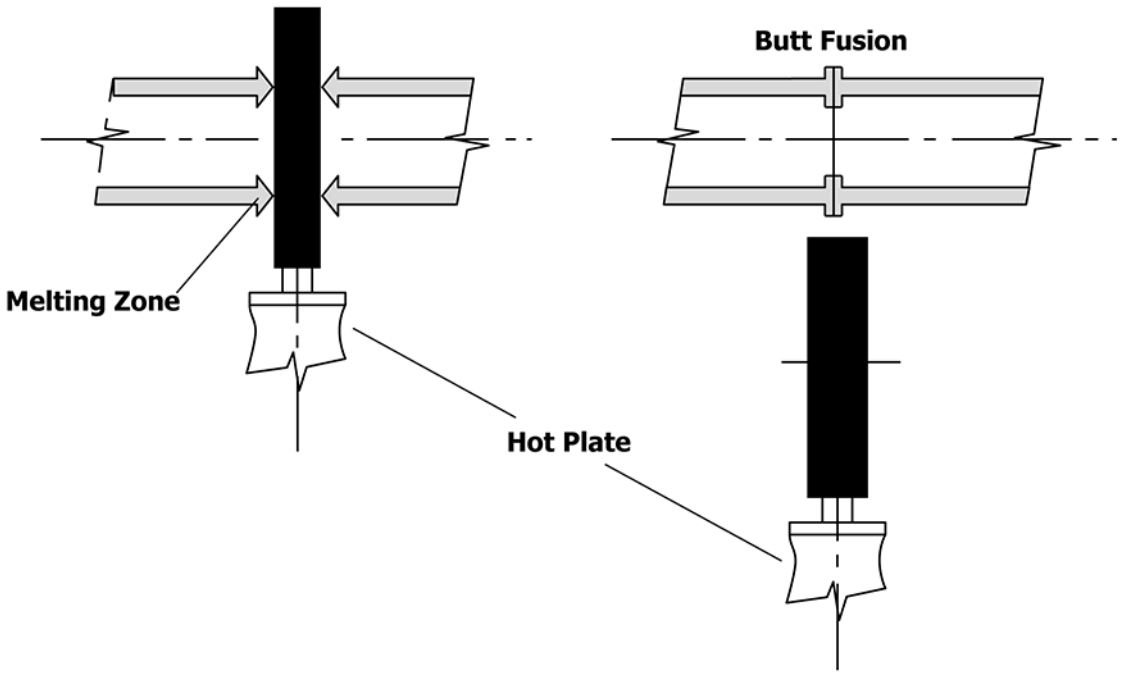


FIG. 1 Butt Fusion

tool surfaces 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 contaminants are removed from the hot or cold heating tool surfaces by using a clean, dry, lint-free, non-synthetic cloth such as cotton. Do not use synthetic fabrics that char and stick to the heating tool surface.

6.1.2 After a period of time in service, non-stick coatings will deteriorate and become less effective. Worn, scratched, or gouged non-stick coatings shall be re-coated when they lose effectiveness. Heat fusion quality is adversely affected by deteriorated non-stick surfaces. Spray-on chemicals, such as nonstick lubricants or oils shall never be applied to heating iron surfaces as they will contaminate the joint.

6.1.3 *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 not necessarily the temperature of the heating tool surfaces. Use a pyrometer, or other surface-temperature measuring device to measure the heating tool surface temperature, at the time of the first joint of the day and periodically during the day to verify the temperature of the tool face surfaces at the pipe or fitting contact area. Select multiple checkpoints around the diameter of the pipe contact area to ensure uniform surface temperature.

NOTE 2—An infrared pyrometer can be calibrated by comparison to a calibrated surface pyrometer and adjusted to match on each heating tool.

NOTE 3—A significant temperature variation, that is, cold spots, on the heating tool surfaces may indicate a faulty heating iron which should not be used.

6.2 *Butt Fusion Machine*—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 pipe or fitting ends to be fused, *(2)* a facer for simultaneously machining and squaring the ends of the pipe or fitting to be joined; and *(3)* appropriate inserts for clamping different pipe sizes or fitting shapes. Butt fusion machines are operated manually or hydraulically. Butt fusion machines are available for various pipe and tubing size ranges.

6.3 *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.

7. Procedure A-For Site Temperature of 40 °F (4 °C) and Higher

NOTE 4—For site temperatures lower than 40 ° F (4 °C) see Section 8.

7.1 *Setup:*

7.1.1 Butt fusion machine setup parameters for manual and hydraulic machines are prescribed in Table 1.

7.1.2 *Manual butt fusion machine*—An interfacial pressure (IFP) of 60 to 90 psi (0.41 to 0.62 MPa) is used to determine the fusion force required to butt fuse the pipe components. Fusion force is applied to achieve the required bead height and width. For a manually operated fusion machine the IFP is multiplied by the pipe area (A_P) to obtain the fusion force required in pounds. (See Eq 3.) A torque wrench may be used to apply the proper force. Consult the manual butt fusion machine manufacturer's operating manual for the correct conversion of torque to force. If a torque wrench is not used the visual guidelines in 7.2 shall apply.

NOTE 5—The drag force on manual machines should be considered when determining the torque necessary to achieve the correct IFP. See Note 6 regarding the components of drag force which for hydraulic machines is expressed as drag pressure. On manual machines a torque wrench may be used to measure the drag force. The torque value when the carriage starts moving is the drag force.

7.1.3 *Hydraulic butt fusion machine:*

TABLE 1 Butt Fusion Machine Setup Parameters Summary

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 470 to 500 °F ±10 °F (243 to 261 °C ±6 °C). A pyrometer or other surface temperature measuring device should be used periodically to ensure proper surface temperature of the heating tool faces.
Install Inserts	Install Inserts	Install inserts for the pipe OD or the fitting being fused.
Electric Power Supply	Electric Power Supply	Check that the field generator has adequate power for the equipment per the manufacturer's instructions, and that the generator's fuel supply is sufficient to complete the fusion joint.
Manual Pressure	Determine Drag Pressure	See Note 5 for manual machines. See 7.1.3.2 for hydraulic machines.
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	See 7.1.2 for manual machines See 7.1.3.1 for hydraulic machines

7.1.3.1 *Calculate the Fusion Force and Theoretical Fusion Pressure*—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.

7.1.3.2 *Determine the Drag Pressure, P_D*—P_D is found by bringing the faced pipe ends within 2 in. (50 mm) of each other and increasing the pressure on the carriage until it starts moving. Reduce the pressure until the carriage is barely moving. The hydraulic machine gauge pressure at this point is the drag pressure. Record the drag pressure P_D in psig.

NOTE 6—Drag pressure, P_D, will vary depending on the components being fused and site conditions. Long pipe strings, or pulling pipe lengths uphill or downhill, can have different movement resistance compared to fittings, or shorter pipe lengths, or fusion on level terrain. P_D should be determined for the specific conditions, and re-determined if conditions change.

7.1.3.3 *Determine the Fusion Machine Gauge Pressure, P_G*—An interfacial pressure (IFP) of 60 to 90 psi (0.41 to 0.62 MPa) is required for butt fusion. To determine the hydraulic butt fusion machine gauge pressure, P_G, the IFP is multiplied by the cross-section area of the pipe end (A_p) to obtain the required fusion force in pounds. The fusion force is then divided by the Total Effective Piston Area (TEPA) of the fusion machine's carriage hydraulic cylinders to obtain the Theoretical Fusion Pressure (TFP). The drag pressure (P_D) is then added to the TFP to obtain the fusion machine gauge pressure (P_G) in psig required for the hydraulic butt fusion machine, see (Eq 1). (TFP and IFP are not the same value.) The equations below are used for these calculations.

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

$$TFP = (A_p \times IFP)/TEPA \quad (2)$$

$$A_p = (OD - t) \times t \times 3.1416 \quad (3)$$

$$t = OD/DR \quad (4)$$

where:

P_G = Fusion Machine Gauge Pressure, psig
TFP = Theoretical Fusion Pressure, psig
IFP = Interfacial Pressure, 60 – 90 psi
$TEPA$ = 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.
DR = Dimension ratio
t = Pipe Wall Thickness, in.

NOTE 7—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 (sometimes in the form of a smartphone app) obtained from the machine's manufacturer can be used as a tool for the calculation.

7.2 *Procedure:*

7.2.1 Clean the inside and outside surfaces of the piping components being joined before starting the joining procedure. Use a clean, dry, lint-free, non-synthetic cloth such as cotton. Do not use solvents. Also clean the outside surfaces of piping components where they will be clamped in the butt fusion machine. (See X1.8.)

7.2.2 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 or fittings being joined in the stationary and movable clamps of the butt fusion machine. Leave enough pipe protruding through the clamps to allow for facing and clamp the pipe or fitting in the machine.

7.2.2.1 Take care when placing pipe or fittings in the butt fusion machine. Pipes 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.

7.2.2.2 Clamps shall be tightened securely. Security is checked by bringing the piping component ends together under pressure and assuring that the components do not slip in the clamps. When clamping pipes in a two-clamp carriage, tighten the rear clamp more than the front clamp. This will facilitate front clamp high-low alignment adjustment.

7.2.2.3 Pipes that are freshly cut, and molded fittings generally do not have toe-in, and when mated to old-cut pipe or fabricated fittings, adjustment for high-low alignment is eased by removing toe-in. Refer to X1.7.

7.2.3 Install the facer between the piping component ends. Face the piping component ends until the facer bottoms out against the stops. To assure complete facing, operate the facer for at least two additional revolutions and then stop facing. Move the carriage to separate the pipe component ends from the facer, remove the facer and clear all shavings and debris from the facing operation. Use a clean, dry, lint-free, non-synthetic cloth such as cotton to clean the component ends again after facing. Do not touch the faced surfaces with bare hands or use solvents. To check for complete facing, bring the pipe/fitting ends together at facing pressure. A visual inspection should verify a square face, perpendicular to the pipe centerline on each pipe component end with no detectable gap.

NOTE 8—See X1.8.2 for detailed guidance regarding cleaning pipe ends that cannot be cleaned with a dry, lint-free, non-synthetic cloth such as cotton.

7.2.4 Bring the faced component ends together and check for high-low alignment. Check that any step between the OD surfaces of the piping components is less than 10 % of the minimum wall thickness. 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 or fitting ends if adjustments were necessary, and remove any shavings from the re-facing operation with a clean, dry, lint-free, non-synthetic cloth such as cotton. Do not touch the faced surfaces with bare hands or use solvents. See 7.2.3.

7.2.5 Before the first use of the day, verify that the heater surface temperature on both sides is in the specified temperature range of 470 to 500 °F ±10 °F (243 to 261 °C ±6 °C) by using a pyrometer or other surface temperature measuring device.

7.2.5.1 When measuring heating tool surface temperature, also record the heating tool thermometer temperature, and before each fusion, verify that the heating tool thermometer reading is the same as the temperature record during the heating tool surface temperature verification.

7.2.5.2 Re-verify heating tool surface temperature periodically throughout the day. All pyrometers and surface temperature measurement devices are sensitive to usage techniques. Carefully follow the manufacturer's instructions for best results.

7.2.5.3 Clean the contact surfaces of the heating tool with a clean, dry, lint-free, non-synthetic cloth such as cotton. Do not touch the faced surfaces with bare hands or use solvents. Place the heating tool in the butt fusion machine between the piping component ends and bring the pipe or fitting ends into full contact with the heating tool at fusion pressure briefly to 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.

7.2.5.4 Once the indication of melt is observed around the circumference of the pipe, begin the heat soak by reducing the pressure to maintain contact, without force, while a bead of molten PA12 develops between the heater and the pipe or fitting ends. Continue heating the pipe ends until the melt bead size has developed against the heater face per Table 2.

NOTE 9—See X1.4 for guidance on heat soak time.

7.2.6 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.

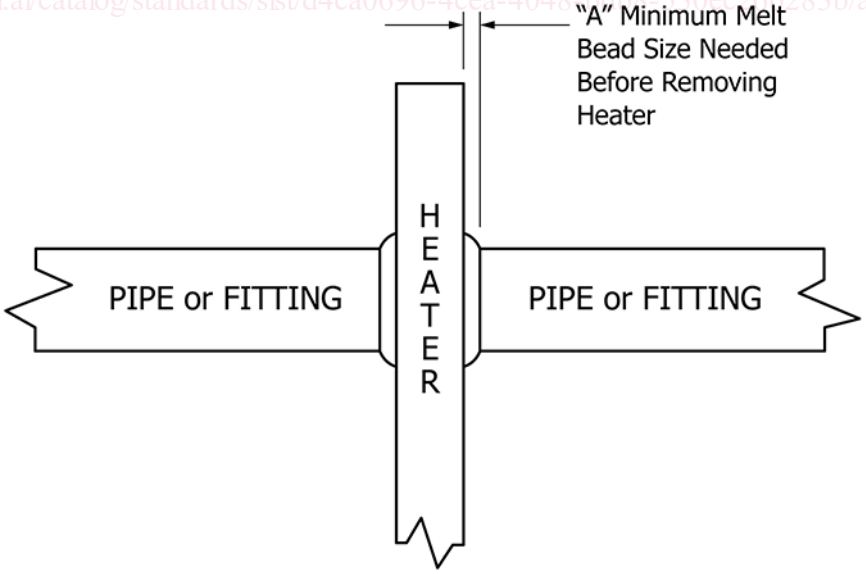
7.2.6.1 It is normal for PA12 melt to have small bubbles. Unacceptable melt appearance is any combination of a concave surface, unmelted areas, or melted material sticking to heating tool surfaces. Low strength joints result from unacceptable melt appearance. If unacceptable melt appearance is observed, discontinue the joining procedure, allow the component ends to cool completely and restart from 7.2.1.

7.2.6.2 The maximum time allowed for opening the machine, removing the heater and bringing the pipe ends together is shown in Table 3. For tubing sizes that are generally butt fused with mechanical fusion machines (not hydraulically controlled) (CTS ½ to IPS 1 ½), the maximum open/close time is 4 s. The quicker this can be done, the better. Do not slam the pipe ends together. See Section 8 for guidance on butt fusion in cold temperatures below 40 °F (4 °C).

7.2.6.3 Assuming the equipment set-up, temperatures, and procedures are followed to this point, the correct fusion pressure creates a single bead, usually with small bubbles or roughness evident on the surface. 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 may be pushed out of the joint and cold material brought into contact forming a "cold" joint. If too little force is used, voids and weak bonded areas can develop in the joint as molten material cools and contracts.

7.2.7 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 45 min per in. (25.4 mm) of

TABLE 2 Minimum Melt Bead Size



IPS Pipe Size	"A" Minimum Bead Size, in. (mm)
≤1¼	1/32 – 1/16 (0.8 – 1.6)
> 1¼ – 3	1/16 (1.6)
>3 – 8	1/8 – 3/16 (3 - 5)

TABLE 3 Maximum Heater Plate Removal Times

NOTE 1—Fusion joints made in an enclosed and controlled factory fabrication environment will tolerate and may use longer maximum heater removal times.

Field Applications Pipe Wall Thickness, in. (mm)	Max. Heater Plate Removal Time Seconds
0.17 to 0.36 (5 to 9)	4-6
>0.36 to 0.55 (>9 to 14)	6-8
>0.55 to 1.18 (>14 to 30)	8-14

pipe wall. But in no case shall the cooling time be less than 10 min. For ambient temperatures 100 °F (38 °C) and higher, additional cooling time may be needed. Avoid high stress such as pulling, installation or rough handling for an additional 30 min or more after removal from the fusion machine. Only 10 min additional cooling time is required for IPS 1 and smaller pipe sizes. Do not apply internal pressure until the joint and surrounding material have reached ambient air temperature. (See Appendix X1 for additional guidance.)

7.2.8 Pouring water or applying wet cloths to the joint to reduce cooling time is not acceptable. Applying conditioned air is acceptable only as part of a controlled cooling cycle procedure where testing demonstrates that acceptable joints are produced using the controlled cooling cycle procedure.

7.2.8.1 Visually inspect and compare the joint against the butt fusion bead visual inspection acceptance guideline in Fig. 2 and Fig. 3. The ratio of bead width to height (W/H) in Fig. 3 should be between 1.5 and 2.5, although other ratios may be shown to be acceptable through testing. An unacceptable bead appearance is shown in Fig. 4. When butt fusing to molded fittings, the bead appearance may appear unsymmetrical. The bead appearance closest to the fitting may display shape irregularities such as minor indentations, deflections and non-uniform bead size from molded part cooling and knit lines. See Fig. 2. In such cases, visual evaluation is based mainly on the shape of the bead closest to the pipe.

8. Procedure B-For Site Temperature Below 40 °F (4 °C) and Adverse Weather

8.1 *Cold Weather Handling:*

NOTE 10—This section provides guidance on adaptations and modifications to the procedures in Section 7 to account for cold site temperature and adverse weather conditions. The user should be completely familiar with the content of Section 7 prior to applying the adaptations of this section.

8.1.1 Pipe shall be inspected for damage. PA12 pipes have reduced impact resistance in sub-freezing conditions. Avoid dropping pipe in sub-freezing conditions. When handling coiled pipe at temperatures below 40 °F (4 °C), it is helpful to uncoil the pipe prior to installation and let it straighten out. Gradually uncoil the pipe and cover it with dirt or sand bags at intervals to keep it from recoiling. Always use caution when cutting the straps on coils of pipe because the outside end of a coil may spring out when the strapping is removed.

8.2 *Preparation for Butt Fusion Joining:*

8.2.1 *Wind and Precipitation*—The heating tool shall be shielded in an insulated container to prevent excessive heat loss. Shield the pipe fusion area and fusion tools from wind, snow, blowing dust, and rain by using an enclosed portable structure, canopy, tent or similar device. Exposure of the fusion heater plate and pipe to wind can result in unacceptable temperature variations during butt fusions and possible joint

Left: Outer Bead on Pressure Pipe. Center: Inner bead on Pressure Pipe. Right: Outer Bead on Black Fitting Made with Lower Viscosity Molding Grade Resin

FIG. 2 Normal Appearance of PA12 Fusion Beads

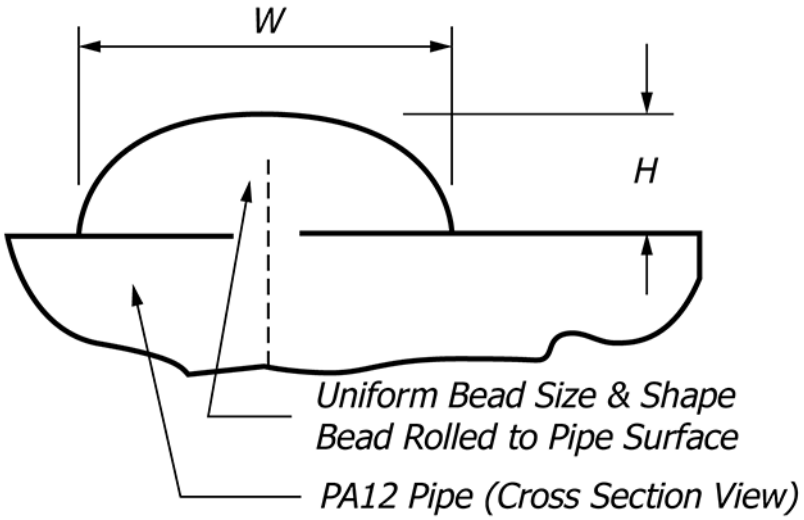


FIG. 3 Outside Diameter Butt Fusion Bead Dimensions

This double-roll-back appearance is often caused by insufficient fusion pressure or incorrect heater settings during soak time. Polyethylene bead appearances are not appropriate for PA12 fusion beads.

FIG. 4 Unacceptable Fusion Bead.

contamination. When extreme wind conditions exist, the provision of a suitable shelter is required to protect the pipe and fusion heater plate to ensure a more consistent environment is provided. Wind conditions can develop through the pipe bore and cause unacceptable temperature variations during the heating process. Therefore, open pipe ends may require plugs or covers to prevent this condition.

NOTE 11—Although wind conditions during cold weather butt fusion are the primary concern, wind conditions can affect butt fusion quality at all ambient temperatures by chilling the heated pipe surfaces during the heat soak. This increases the heat soak time to obtain the bead size against the heater surface. It may be necessary to increase the heater temperature within the recommended temperature range and/or provide a more controlled environment to achieve a heat soak time within the range shown in Table X1.1.