

Butt Fusion Joining Procedure for Field Joining of Polyamide-11 (PA-11) Pipe TR-45/2016



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Foreword

BUTT FUSION JOINING PROCEDURE FOR FIELD JOINING OF POLYAMIDE-11 (PA-11) PIPE

This report was developed and published with the technical help of the members of the PPI (Plastics Pipe Institute, Inc.). The members have shown their interest in quality products by assisting independent standards-making and user organizations in the development of standards, and also by developing reports on an industry-wide basis to help engineers, code officials, specifying groups, and users.

The purpose of this technical report is to provide important information available to PPI on a particular aspect of polyethylene pipe butt fusion to engineers, users, contractors, code officials, and other interested parties. More detailed information on its purpose and use is provided in the document itself.

This report has been prepared by PPI as a service of the industry.

The information in this report is offered in good faith and believed to be accurate at the time of its preparation, but is offered “as is” without any express or implied warranty, including WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Consult the manufacturer for more detailed information about the particular joining procedures to be used with its piping products. Any reference to or testing of a particular proprietary product should not be construed as an endorsement by PPI, which does not endorse the proprietary products or processes of any manufacturer. The information in this report is offered for consideration by industry members in fulfilling their own compliance responsibilities. PPI assumes no responsibility for compliance with applicable laws and regulations.

PPI intends to revise this report from time to time, in response to comments and suggestions from users of the report. Please send suggestions of improvements to the address below. Information on other publications can be obtained by contacting PPI directly or visiting the web site.

The Plastics Pipe Institute, Inc.

<http://www.plasticpipe.org>

This Technical Report, TR-45, was updated in January 2008 and March 2016.

1.0 Introduction

In 1994, representatives of the U.S. DOT (Department of Transportation), Office of Pipeline Safety requested that the Plastics Pipe Institute (PPI) assist in promoting greater uniformity in the joining procedures utilized by gas utilities in the butt fusion of polyethylene (PE) gas piping products. DOT reported that it had encountered a proliferation of similar but slightly varying joining procedures from individual PE pipe producers. The slight differences in the various procedures made it more difficult for pipeline operators to qualify persons with appropriate training and experience in the use of these procedures. It was even more difficult for DOT to enforce the joining requirements in § 192.283 (Plastic pipe, qualifying joining procedures) of the C.F.R. (Code of Federal Regulations) Title 49.

In response to DOT's request, PPI established a task group to develop a generic butt fusion procedure for the fusion joining of polyethylene piping in the form of the published PPI TR-33.

In the spirit of complying with the above request a second task group was formed to develop a butt fusion procedure for the joining of polyamide-11 (PA-11) piping. PA-11 piping is approved for use in piping systems under the jurisdiction of CFR Title 49 Part 192, incorporated by reference of ASTM D 2513-99 in 192.7. PA-11 gas piping requirements are detailed in Annex A5 of editions of ASTM D 2513-1999 through 2007. ASTM D2513 underwent revision in 2009 to remove all materials other than polyethylene and as part of that process a new standard specifically for PA-11 was released as ASTM F2945. ASTM F2945 Appendix X1 for butt fusion guidelines for polyamide (PA-11) references this PPI technical report. Thus this PPI technical report provides a uniform joining procedure bringing greater consistency to this aspect of gas pipeline installation, facilitate the pipeline operator's efforts to qualify the procedure, reduce costs, and simplify DOT's enforcement duties.

2.0 Scope

The program undertaken by the PPI Task Group for the testing of representative materials under a set of conditions was designed to reflect the fusion conditions recommended for the butt fusion of PA-11 piping. Butt fusion evaluation work was performed starting in the mid-1990s by the Gas Research Institute¹ and continued at McElroy Manufacturing, Inc. and in the Arkema (formerly Atofina) R&D laboratories in Pennsylvania. The results of these studies, as detailed below, resulted in the recommended fusion procedures contained in Appendix A of this report. It is the intention that this procedure would be available for use by pipeline operators who would determine whether the procedure is appropriate for use with the PA-11 piping products it employs. Pipeline operators could consider the recommendations and testing performed by others in their effort to comply with the

¹ H.V. Patadia, R.H. Doctor, "Final Report – Part I: Technical Reference on the Physical, Mechanical, and Chemical Properties of PA11 Pipe Materials for Use in Gas Distribution Systems Operating at Higher Pressures and Temperatures," GRI-99/0039, 55 (1998).

fusion procedure qualification requirements of 49 C.F.R. § 192.283 (Plastic pipe, qualifying joining procedures).

It is important to emphasize that the testing performed was intended only to establish a technical basis for developing and proposing a more generic fusion joining procedure that would offer the maximum opportunity to be qualified and used by pipeline operators. The testing was not intended to qualify the procedure for use with any PA-11 piping manufacturer's particular pipe product, and PPI offers no opinion on whether the procedure is properly qualified for use with any particular PA-11 piping. PA-11 pipe producers remain solely responsible for any representations that they may make about the use of this procedure or any other joining procedure with their proprietary PA-11 piping products, and pipeline operators remain solely responsible for compliance with the requirements of 49 C.F.R. § 192.283 (Plastic pipe, qualifying joining procedures) when qualifying any procedure for use with the products it selects for its pipelines. PPI member pipe manufacturers have endorsed this procedure for joining their product to itself and to other commercially available PA-11 pipe materials. Pipe producer compliance letters are in Appendix B for gas pipe applications. A typical illustration of a properly made PA-11 butt fusion joint is shown in Appendix C.

PPI believes that the inherent value of greater uniformity of this technical report will provide all the incentive necessary for companies to evaluate the procedure in Appendix A as a first option for butt fusion joining of its PA-11 piping products. Use of this procedure is obviously not mandatory, and every PA-11 pipe producer and pipeline operator retains the option of developing different procedures for its particular products and pipelines. However, PPI believes that its work in developing this procedure as a candidate for widespread acceptance throughout the industry will lead to greater efficiency, simplicity, and understanding in this area and promote the use of effective, qualified procedures for butt fusion joining of PA-11 pipe.

3.0 Testing Program²

3.1 Introduction

In order to validate an appropriate butt fusion procedure for polyamide 11 (PA-11) pipe, an in-depth fusion study was undertaken, with the underlying goal of establishing the optimum conditions for making a good fusion. An added objective of this study was to establish visual standards depicting the wide variety of bead appearances corresponding to a good fusion. The details of this testing program and the test data are contained in the below footnoted report by Dr. John Chen.

² Dr. John Chen; *Optimization of Parameters Influencing Butt Fusion Integrity in Polyamide 11 Pipe*; Presented at Natural Gas Technologies 2005: What's New & What's Next (2005)

3.2 Fusion Parameters

This study is supplemental to a previous testing program conducted by McElroy Manufacturing and the Gas Research Institute (now the Gas Technology Institute, or GTI) using McElroy's high-speed tensile impact test. Based on this previous study, the optimum butt fusion parameters for 2" SDR11 PA-11 pipe were determined to be:

Heater surface temperature: 495 – 505 °F

Interfacial pressure: 60 – 90 psi

Heating (soak) time: 60 – 75 seconds

The current study outlined in this report serves to independently revalidate and update the findings of the previous study using ASTM D1599 Quick Burst and ASTM D638 Tensile Testing, both required by the D.O.T. Code of Federal Regulations (CFR) 192.283 for qualifying joining procedures for plastic pipe. The end goal is to find if any or all of the parameter values used in this study qualify for use in the joining procedure, and if so, determine the optimum values for producing fusions with the best possible properties.

3.3 Testing Parameters

Testing performed in this study included:

- Quick Burst testing of joints in accordance with ASTM D1599 (192.283);
- Tensile Testing of joints in accordance with ASTM D638 at 0.2 ipm (192.283);
- Sustained Pressure Testing in accordance with ASTM D1598
 - 80°C, 1850 psi hoop stress (14% above the hoop stress requirement in ASTM F1733 *Standard Specification for Butt Heat Fusion Polyamide (PA) Fitting for Polyamide (PA) Plastic Pipe and Tubing* All ductile pipe failures outside of fusion joint (or non-failures exceeded 170 hours on test).

4.0 Conclusions and Recommendations

The results of this study indicate that there is a single fusion procedure with defined ranges of acceptable heater surface temperature, 495-505°F, and interfacial pressure, 60-90 psi (4.14-6.21 bar), for fusing PA-11 piping. The results further indicate that there is a strong likelihood that the fusion procedure used in this testing (see Appendix A) could be qualified by gas pipeline operators under DOT's regulations in Part 192 for use with most of these PA-11 gas piping products. To the extent that this PPI procedure in Appendix A can be qualified for use with PA-11 piping, the industry can move closer to meeting DOT's objective of greater uniformity, efficiency, and simplicity in the area of fusion procedures.

5.0 Other Acceptable Fusion Procedures

It must be recognized that there are many other different procedures and fusion parameters used throughout the world that have been proven to make effective, reliable joints. The pipeline operator and every pipe producer retain the option of developing and qualifying different fusion procedures for its particular products and pipelines. In certain cases, due to operating conditions, weather, or the characteristics of the joining equipment, it may be necessary or even advisable to use another procedure.

PPI believes that its work in developing this procedure as a candidate for widespread acceptance throughout the industry will lead to greater efficiency, simplicity, and understanding in this area and promote the use of effective qualified procedures for butt fusion joining of PA-11 piping.

APPENDIX A

BUTT FUSION JOINING PROCEDURE FOR FIELD JOINING PA-11

(POLYAMIDE-11) PIPE

This procedure has not been qualified for use with any particular piping product or combination of piping products and must be qualified for use in accordance with 49 CFR Part 192 prior to its use to join PA-11 pipe in a gas pipeline. Any copying or reproduction of this procedure without this paragraph and the accompanying TR-XX is a violation of the copyright.

This procedure is intended for butt fusion joining of PA-11 fuel gas pipe produced in accordance with ASTM D2513-99 and/or ASTM F2945.

Butt Fusion Parameters:

Fusion Interface Pressure Range ³	60-90 psi
Heater Surface Temperature Range	495 - 505°F

Butt Fusion Procedure:

The principle of heat fusion is to heat two 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. When fused according to the proper procedures, the joint area becomes as strong as or stronger than the pipe itself in both tensile and pressure properties.

Field-site butt fusions may be made readily by trained operators using butt fusion machines that secure and precisely align the pipe ends for the fusion process. The six steps involved in making a butt fusion joint are:

1. Securely fasten the components to be joined
2. Face the pipe ends
3. Align the pipe profile
4. Melt the pipe interfaces
5. Join the two profiles together
6. Hold under pressure

Secure

Clean the inside and outside of the pipe to be joined by wiping with a clean lint-free cloth. Remove all foreign matter.

Clamp the components in the machine. Check alignment of the ends and adjust as needed.

³ Interfacial pressure is used to determine fusion joining pressure settings for hydraulic butt fusion machines or torque measurements in combination with hand-operated machines when joining specific pipe diameters and DR's. Interfacial pressure is NOT the gauge pressure.

Face

The pipe ends must be faced to establish clean, parallel mating surfaces. Most, if not all, equipment manufacturers have incorporated the rotating planer block design in their facers to accomplish this goal. Facing is continued until a minimal distance exists between the fixed and movable jaws of the machine and the facer is locked firmly and squarely between the jaw bushings or mechanical stops. Open the jaws and remove the facer. Remove any pipe chips from the facing operation and any foreign matter with a clean, lint-free cotton cloth. Bring the pipe ends together with minimal force and inspect the face off. A visual inspection of this operation should verify square faces, perpendicular to the pipe centerline on each pipe end and with no detectable gap.

Align

The pipe profiles must be rounded and aligned with each other to minimize mismatch (high-low) of the pipe walls. This can be accomplished by tightening clamping jaws until the outside diameters of the pipe ends match. The jaws must not be loosened or the pipe may slip during fusion. If adjustments are made, re-face the pipe ends and remove any chips from re-facing operation with a clean, lint-free cotton cloth.

Melt

Heating tools that simultaneously heat both pipe ends are used to accomplish this operation. These heating tools are normally furnished with thermometers to measure internal heater temperature so the operator can monitor the temperature before each joint is made. However, the thermometer can be used only as a general indicator because there is some heat loss from internal to external surfaces, depending on factors such as ambient temperatures and wind conditions. A pyrometer or other surface temperature-measuring device should be used before the first joint of the day and periodically throughout the day to insure proper temperature of the heating tool face that contacts the pipe or fitting ends. Additionally, heating tools are usually equipped with suspension and alignment guides that center them on the pipe ends. The heater faces that come into contact with the pipe should be clean, oil-free and coated with a permanent nonstick coating as recommended by the manufacturer to prevent molten plastic from sticking to the heater surfaces. Remaining molten plastic can interfere with fusion quality and must be removed according to the tool manufacturer's instructions. Never use chemical cleaners or solvents to clean heating tool surfaces.

The surface temperatures must be in the temperature range 495-505°F. Install the heater in the butt fusion machine and bring the pipe ends into full contact with the heater. To ensure that full and proper contact is made between the pipe ends and the heater, the initial contact should be under moderate pressure. After holding the pressure very briefly, it should be released without breaking contact. On larger pipe sizes, initial pressure may be maintained until a slight melt is observed around the circumference of the pipe before releasing pressure. Continue to hold the components in contact with each other, without force, while a bead of molten polyamide-11 develops between the heater and the pipe ends. When the proper bead size is formed against the heater surfaces all around the pipe or fitting ends, remove the heater. Melt bead size is dependent on pipe size. See Table 1 for approximate bead sizes.

Table 1. Approximate Melt Bead Size

Pipe Size	Approximate Melt Bead Size
1 ¼" and smaller (40mm and smaller)	1/32" – 1/16" (1-2mm)
Above 1 ¼" through 3" (above 40mm-90mm)	About 1/16" (2mm)
Above 3" through 8" (above 90mm-225mm)	1/8"-3/16" (3-5mm)
Above 8" through 12" (above 225mm-315mm)	3/16"-1/4" (5-6mm)

Joining

After the heater tool is removed, quickly inspect the pipe ends (NOTE: If a concave melt surface is observed, unacceptable pressure during heating has occurred and the joint will be low quality. Do not continue. Allow the component ends to cool completely, and restart at the beginning. Except for a very brief time to seat the components fully against the heater tool, do not apply pressure during heating.), then immediately bring the molten pipe ends together with sufficient fusion force to form a bead against the pipe wall.

For larger manual and hydraulic butt fusion machines, fusion force is determined by multiplying the interfacial pressure, 60-90 psi, by the pipe area. For manually operated fusion machines, a torque wrench may be used to apply the proper force. For hydraulically operated fusion machines, the fusion force can be divided by the total effective piston area of the carriage cylinders to give a hydraulic gauge reading in psi. The gauge reading is theoretical; internal and external drags are added to this figure to obtain the actual fusion pressure required by the machine. The hydraulic gauge reading is dependent upon pipe diameter, DR and machine design. Interfacial pressure and gauge reading are not the same value.

Hold

Hold the molten joint immobile under fusion force until the joint has cooled adequately to develop strength. Allowing proper cooling time under fusion force prior to removal from the clamps of the machine is important in achieving joint integrity. The fusion force should be held between the pipe ends until the surface of the melt bead is cool to the touch.

Avoid pulling, installation or rough handling for an additional 30 minutes.

Visual Inspection

Visually inspect and compare the joint against the manufacturer's recommended appearance guidelines. Visually, the width of butt fusion beads should be approximately 1-1 ½ times the bead height above the pipe and the fusion bead should be rounded and uniformly sized all around the pipe circumference (see Appendix C). **Note in fusing PA-11 piping a single roll back bead is formed as opposed to the double roll back bead observed when fusing PE (polyethylene) piping.** Examples of acceptable fusions made to this procedure are shown in figures A3 and A4. The presence of bubbles in the fusion bead is normal and can vary for PA-11, which absorbs water up to about 2% by weight upon storage. Higher moisture content pipe and fittings will exhibit more bubbles

in the fusion bead. The bubbles do not adversely affect the fusion strength, and are present only in the bead, not in the fused pipe wall. When butt fusing to molded fittings, the fitting-side bead may display shape irregularities such as minor indentations, deflections and non-uniform bead rollover from molded part cooling and knit lines. In such cases, visual evaluation is based mainly on the size and shape of the pipe-side bead. Visually unacceptable joints should be cut out and re-fused using the correct procedure. (See manufacturer's visual inspection guidelines)

Coiled pipe is available in sizes through 4" IPS. Coiling may leave a set in some pipe sizes that must be addressed in the preparation of the butt fusion process. There are several ways to address this situation:

1. Straighten and re-round coiled pipe before the butt fusion process. (ASTM D2513 requires field re-rounding of coiled pipe before joining pipe sizes larger than 3" IPS.)
2. If there is still curvature present, install the pipe ends in the fusion machine in an "S" configuration with print lines approximately 180° apart in order to help gain proper alignment and help produce a straight joint. See Figure A1
3. Visually mitered (angled, off-set) joints should be cut out and re-fused.

Every effort should be made to make the joint perpendicular to the axis of the pipe.

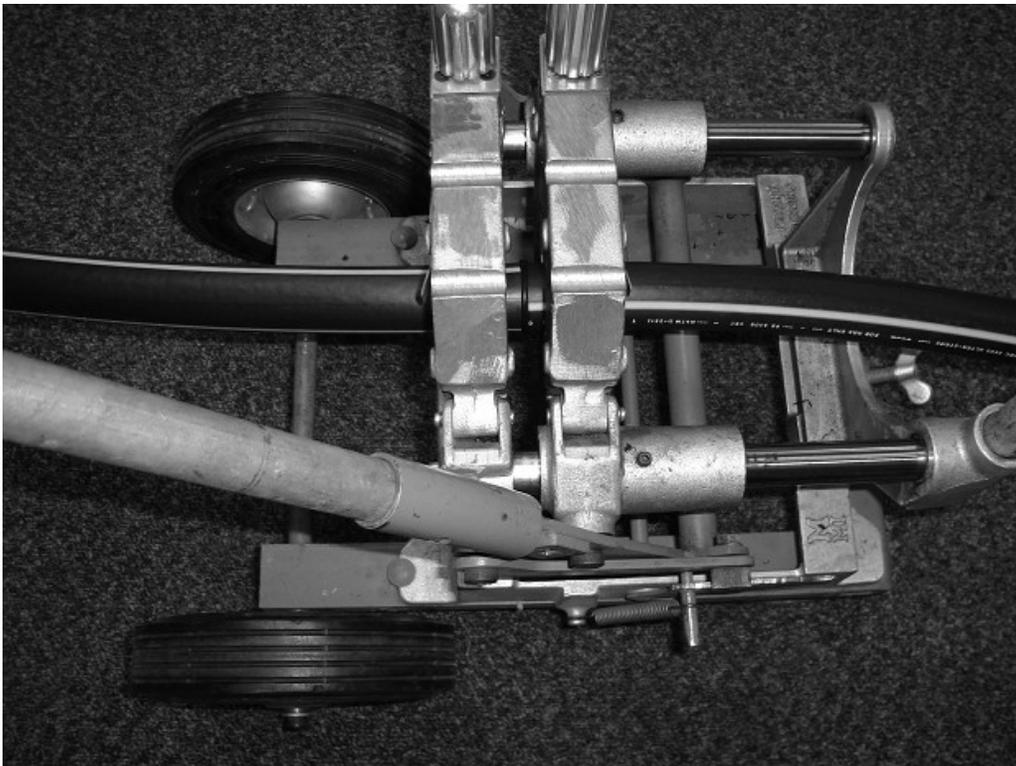


Figure A 1. Alignment of Coiled Pipe Ends Through a Butt Fusion Machine



Figure A 2. Visually unacceptable mitered joint

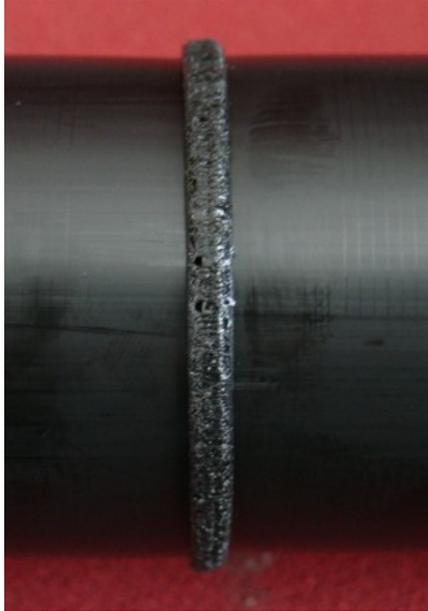


Figure A 3. Examples of Acceptable PA-11 Fusions

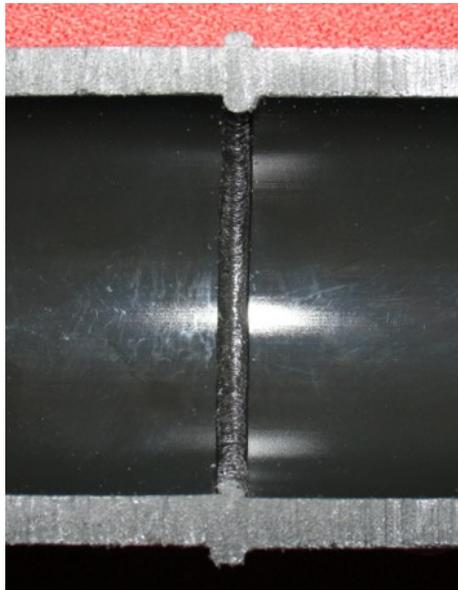
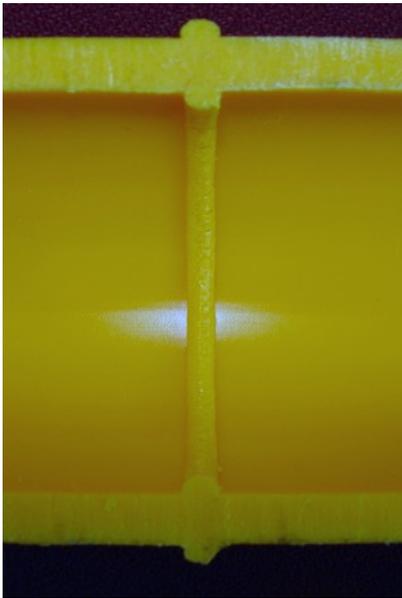


Figure A 4. Sectioned Acceptable PA-11 Fusions

APPENDIX B

LETTERS OF COMPLIANCE FROM PPI MEMBER COMPANIES FOR 49 CFR
§192.283 FOR PIPE INTENDED FOR GAS DISTRIBUTION APPLICATIONS

Please contact the pipe or fitting manufacturer for letters of compliance.

APPENDIX C

ILLUSTRATION OF A PROPERLY MADE PA-11 BUTT FUSION JOINT

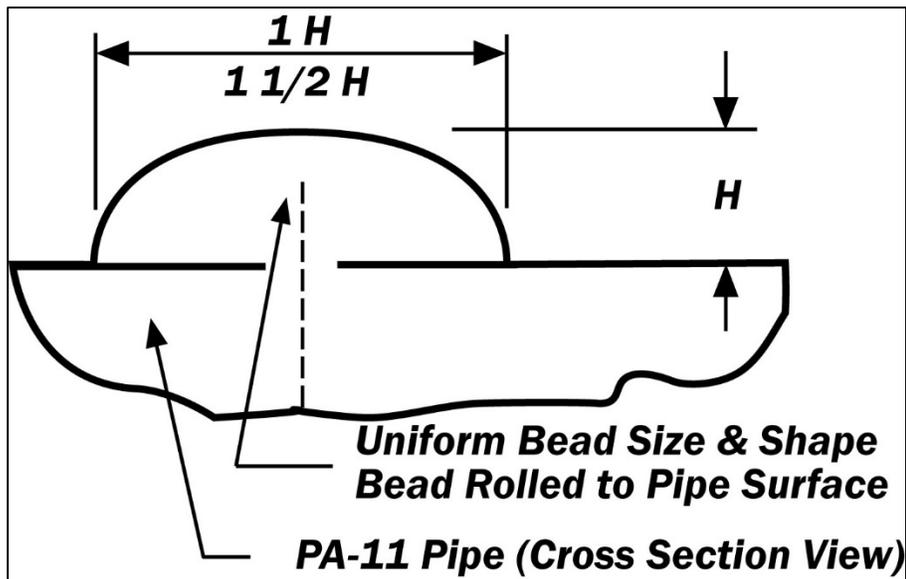


Figure C 1. Illustration of a Properly Made PA-11 Butt Fusion Joint

Note: The presence of bubbles in the bead is normal, and varies with the amount of absorbed water in the pipe and/or fitting. When butt fusing to molded fittings, the fitting side bead may have an irregular appearance.