Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe

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FOREWORD

GENERIC BUTT FUSION JOINING PROCEDURE FOR FIELD JOINING OF POLYETHYLENE PIPE

This report was developed and published with the technical help and financial support 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 without any warranty, expressed or implied, 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.

www.plasticpipe.org

This Technical Report, TR-33, was first issued in October 1999, and was revised in 2006, and in June 2012.

SECTION I – GENERIC BUTT FUSION PROCEDURE TESTING FOR FIELD JOINING OF ASTM D2513 GAS PIPING MATERIALS[1]

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 examine the differences among the varying joining procedures, to identify similarities in those procedures, and to determine whether there were a sufficient number of common elements to provide a basis for a more uniform, or "generic" joining procedure that could be qualified by pipeline operators for most applications. A more uniform joining procedure would bring 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 generic set of conditions was designed to reflect the fusion conditions and parameters specified in most joining procedures recommended by pipe producers and qualified by pipeline operators. It was intended to provide a technical basis for the development of a generic butt fusion procedure (see Appendix A) that can be offered to the industry for use with selected PE (polyethylene) piping products. The procedure would be available for use by pipeline operators who would determine whether the procedure is appropriate for use with the PE piping products it employs. Pipeline operators could consider the recommendations and testing performed by others in their effort to comply with the 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 by the PPI Task Group 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 with a broad range of polyethylene piping products. The testing was not intended to qualify the

[1] Dupont Aldyl A MDPE, Uponor Aldyl A MDPE and Phillips Driscopipe 7000 and 8000 HDPE are not included in this procedure.

procedure for use with any particular pipe product, and PPI offers no opinion on whether the procedure is properly qualified for use with any particular PE pipe product. PE pipe producers remain solely responsible for any representations that they may make about the use of this generic procedure or any other joining procedure with their proprietary PE 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 generic procedure for joining their product to itself and to other commercially available pipe materials. Pipe producer compliance letters are in Appendix B for gas pipe applications and Appendix D for all other applications. A typical illustration of a properly made butt fusion joint is in Appendix D.

PPI hopes that the inherent value of greater uniformity will provide all the incentive necessary for companies to evaluate the generic procedure in Appendix A as a first option for butt fusion joining of its PE piping products. Use of this procedure is obviously not mandatory, and every PE 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 generic 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 PE pipe.

3.0 TESTING PROGRAM TO EVALUATE USE OF GENERIC JOINING PROCEDURE WITH POLYETHYLENE GAS PIPING PRODUCTS

The Task Group collected and examined a large number of diverse procedures now in use by gas pipeline operators or recommended by pipe producers for specific PE piping products. It then identified those conditions and fusion parameters that were common to the majority of those procedures. The Task Group proposed the following fusion parameters as representative of the conditions in the individual procedures that they reviewed:

Heater Surface temperature	**400 - 450° F (204-232°C)**
Interfacial Pressure	**60-90 psi (4.14-6.21 bar)**

From its review of the different procedures collected from PE gas pipe producers, the Task Group further developed the generic joining procedure set out in Appendix A, based on its assessment of the common elements in the individual procedures. It was agreed that proprietary products such as Uponor Aldyl A MDPE products and Phillips Driscopipe® 8000 HDPE piping products were sufficiently different from the remainder of the materials being discussed that they were not included in the test program.[2] The manufacturers should be contacted for more information on particular joining procedures for those

[2] Uponor Aldyl-A and Phillips Driscopipe 8000 are no longer manufactured.

products. Only current commercially available products from PPI member companies were included in this test program. For information on older or other products, please contact the manufacturer of those products.
Using these parameter ranges and procedures, the Task Group initiated a 3-part test program to evaluate whether a representative cross-section of marketed PE gas piping products would qualify under the qualification requirements of Part 192 when joined in accordance with this generic joining procedure. The evaluation was conducted using pipe from MDPE and HDPE materials deemed suitable for fuel gas applications per ASTM D2513. These materials have a grade designation, in accordance with ASTM D3350, of PE24 and PE34, respectively.

Grade	Density (Grams/cc)	Melt Index (Grams/10min.)	Pipe Marking
PE 24	.926 - .940	.15 to .40	PE 2406
PE 34	.941 - .955	.05 to .15	PE 3408

After fusion of the samples, tensile and quick-burst tests were conducted in accordance with the requirements of 49 C.F.R. § 192.283 (Plastic pipe, qualifying joining procedures). Non-destructive ultrasonic inspections and high speed tensile impact testing were also conducted on each fusion combination. Additional testing conducted only on 8” pipe samples, included 176° F (80°C), 1,000-hour long-term hydrostatic testing at 580 psi (40 bar) hoop stress. The results of the test program are described in the following sections. PPI’s Conclusions and Recommendations, based on the Task Group’s work, are found at the end of this section. Test data are maintained at PPI headquarters.

Part 1 - Pipe Fusion and Testing - 2" IPS DR 11 (Like Materials)

Part 1 of this project was to evaluate the generic procedure for use in fusing a PE pipe producer’s product to itself (e.g., Phillips MDPE to Phillips MDPE). The Task Group members supplied 2" SDR 11 pipe samples for fusion joining.

A total of 24 sample fusions, like material to like material, were made for each MDPE and HDPE pipe product. The total number of sample pieces was 72 and the total number of fusion joints made was 290. To evaluate the fusion parameters initially selected by the Task Group, all combinations of min/max heater surface temperatures 400 - 450°F (204 -232°C) and min/max interfacial pressures 60—90 psi (4.14-6.21 bar) were used in this testing. In addition, sample fusions at heater face temperatures (375°F and 475°F) (191°C and 246°C) and interfacial pressures (50 and 100 psi) (3.45 and 6.90 bar) were made and tested to examine conditions for fusion outside the initially generic parameters. The Task Group agreed to use these same fusion parameters for both the MDPE and HDPE.

The results of testing these fusion samples were 100% positive. All of the fusion joints (including those made under the extended parameters) passed every test conducted. As noted above, these tests included tensile testing, quick burst testing, high speed tensile impact testing and 100% ultrasonic inspection.

Part 2 - Pipe Fusion and Testing -2" IPS DR11 (Unlike Materials)

Part 2 of this project was to evaluate the generic procedure, the fusion temperature range, and the interfacial pressure range for cross fusions of unlike materials (e.g., Phillips MDPE to PLEXCO MDPE or Uponor MDPE to KWH Pipe HDPE).

Again 2" IPS SDR11 PE pipe was chosen. The Task Group members reviewed the information presented in *Table* 1. Overview of Polyethylene Plastic Gas Pipe Materials and decided that the cross fusion program could be simplified by selecting representative materials only. For MDPE materials it was decided that two materials could be selected to represent the two main families of MDPE materials (chromium oxide/slurry loop produced MDPE and Unipol Gas Phase MDPE). The two specific materials selected were Phillips Marlex TR-418 and Union Carbide DGDA 2400. The testing of these two materials would help to assess the appropriateness of the generic conditions for cross fusion of all MDPE plastic pipe gas compounds commonly being used today. The Task Group decided to use the same joining parameters as in Part 1 in these tests, based on the view that successful fusions under these conditions would cover all the other materials under the generic ranges. The chosen combinations of joining parameters were (1) 475°F/100 psi (246°C/6.90 bar) and (2) 375°F/50 psi (191°C/3.45 bar). The remainder of the fusion procedures remained the same as Part 1. Fusion joints between Phillips TR-418 and Union Carbide DGDA 2400 were prepared. There were nine (9) joints made at each joining parameter, for total of (18) joints.

For HDPE materials, the Task Group selected three (3) HDPE materials for evaluation: Chevron 9308, Novacor HD2007-H and Fina 3344. There were nine (9) joints made at each of the selected combinations of fusion parameters and combinations of materials, for total of (54) joints.

For MDPE to HDPE joints, the Task Group elected to fuse Union Carbide 2400 to Fina 3344 to establish the cross fusion procedure for the fusion of MDPE to HDPE. Nine (9) joints were made at each of the two extended parameter combinations, for total of (18) joints.

The results of testing these fusion samples were 100% positive. All of the fusion joints passed every test conducted. As noted above, these tests included tensile testing, quick burst testing, high speed tensile impact testing and 100% ultrasonic inspection.

Part 3 - Pipe Fusion and Testing - 8" IPS DR11 (Unlike Materials)

Part 3 of this project was to test 8" IPS SDR 11 PE pipe to establish a range of pipe sizes where the generic procedure could be used. For MDPE materials, the Task Group identified five different medium density polyethylene materials which can be classed into two main types based on catalyst family, production process and melt index:

A. Phillips Marlex TR-418, Chevron 9301, 9302, Solvay Fortiflex K38-20-160
B. Novacor Chemical HD-2100, Union Carbide 2400

The Task Group agreed to make (10) joints of each of the following combinations:

UCC2400 to Phillips Marlex TR-418
UCC2400 to Chevron 9301
UCC2400 to Solvay Fortiflex K38-20-160

The joints were made at the same parameters as before with five (5) made at 475°F/100 psi (246°C/6.90 bar) interface and five (5) made at 375°F/50 psi (191°C/3.45 bar) interface. In effect, this would provide representative results for all medium density polyethylene except Uponor Aldyl A MDPE. Thus, this portion of the testing program would require 30 joints in total. It was also decided that if there were any failures with joints made under these parameters, then the fusions should be duplicated under the generic parameters 400 - 450°F/60-90 psi (204-232°C/4.14
6.21 bar).

For HDPE materials, the Task Group identified seven different high density polyethylene materials which could be classed into three main categories based on catalyst family, production process and melt index:

A. Chevron 9308, Phillips TR 480 and Solvay Fortiflex K44-15-123.
B. Novacor Chemical HD-2007-H, Chevron 9346 and UCC2480
C. Fina 3344

The HDPE cross fusion testing covered 10 joints for each of the following combinations: A to A, B to B, C to C, A to B, B to C, and A to C, for a total of 60 fusion joints. The representative materials selected from each category were the Fina 3344, UCC2480 and Phillips TR480.

For MDPE to HDPE cross fusions, the Task Group decided to use the same materials as were used for the cross fusion of 2" pipe; i.e., Fina 3344 and Union Carbide 2400. This portion of the testing program would involve A to B fusions of the two materials, for a total of 10 joints.

In addition to the tensile testing, high speed tensile impact testing, quick burst testing and 100% ultrasonic inspection, each fusion combination described in

Part 3 was subjected to a long- term 176°F (80°C), 1000 hour test using 580 psi (40 bar) hoop stress. As with the 2" IPS testing, all joints passed every test conducted.

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, 400-450°F (204-232°C), and interfacial pressure, 60-90 psi (4.14-6.21 bar), for fusing most of the PE gas pipes on the market today. The PE pipes used in these tests were selected PE2406 and PE3408 materials, which were deemed suitable for fuel gas applications (per ASTM D2513) and which have a grade designation, in accordance with ASTM D3350, of PE24 and PE34, respectively, excluding Uponor Aldyl A MDPE and Phillips Driscopipe 8000 HDPE. The results further indicate that there is a strong likelihood that the generic 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 PE gas piping products. To the extent that this PPI generic procedure in Appendix A can be qualified for use with more and more of the PE pipe products in the marketplace, the closer the industry can move to meeting DOT's objective of greater uniformity, efficiency, and simplicity in the area of fusion procedures.

5.0 ACKNOWLEDGEMENTS

This document has been produced by an industry Task Group from equipment, fitting, pipe, and resin manufacturers from the following companies.

Performance Pipe (formerly Phillips Driscopipe and PLEXCO)
PolyPipe Central Plastics US Poly (formerly Uponor)
Charter Plastics
BP Solvay
Total Petrochemicals (formerly Fina)
KWH Pipe
McElroy Manufacturing
Connectra Fusion Technologies, LLC

Table 1. Overview of Polyethylene Plastic Gas Pipe Materials

Company	Resin	Melt Index (MI) Grams/10 min.	High Load MI Grams/10 min.
Phillips	TR480	.11	13
Solvay	K44-15-123	.12	13
Solvay	K44-08-123	.08	8.5
Chevron	9346	.08	10
Chevron	9308	.10	10
Novacor Chem.	HD-2007-H	.07	8.5
Union Carbide	2480	.10	12
Fina	3344	.10	8
Phillips	TR418	.12	
Chevron	9301	.20	
Solvay	K38-20-160	.20	
Novacor Chem.	2100	.15	
Union Carbide	2400	.20	

Note: Some resins may no longer be produced, or company names may have changes. This information is for historical purposes for the types of resin utilized in this report.

SECTION II – GENERIC BUTT FUSION PROCEDURE TESTING FOR FIELD JOINING OF ASTM F714, ASTM D3035, AWWA C-901, AWWA C-906 AND PE PIPING FOR OTHER APPLICATIONS.

1.0 SCOPE

This program, undertaken by a different PPI Task Group, than the Task Group that established the Generic Butt Fusion Procedures for Polyethylene Gas Pipe (TR33/2001) for the testing of representative materials under a generic set of conditions, was designed to reflect the fusion conditions and parameters currently specified in TR-33/2001, Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe. While it is recognized that these fusion conditions do not include some parameters currently specified by some pipe producers for their Municipal and Industrial products, it was selected in an attempt to bring uniformity of fusion parameters to the industry. Additionally, as part of the overall goal of the Task Force, it was intended to provide a technical basis for the development of a generic butt fusion procedure (see Appendix A) that can be offered to the industry for use with selected PE (polyethylene) piping products. The procedure would be available for use by pipeline operators who would determine whether the procedure is appropriate for use with the PE piping products it employs.

It is important to emphasize that the testing performed by the PPI Task Group 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 with a broad range of polyethylene piping products. The testing was not intended to qualify the procedure for use with any particular pipe product, and PPI offers no opinion on whether the procedure is properly qualified for use with any particular PE pipe product. PE pipe producers remain solely responsible for any representations that they may make about the use of this generic procedure or any other joining procedure with their proprietary PE piping products. PPI member pipe manufacturers have endorsed this generic procedure for joining their products to themselves and to other commercially available pipe materials. A generic endorsement for the range of resins that have been proven to be successfully joined by this method is detailed in Appendix C along with a list of many product standards that utilizes these resins. An illustration of a properly made butt fusion joint is in Appendix D.

PPI hopes that the inherent value of greater uniformity will provide all the incentive necessary for companies to evaluate the generic procedure in Appendix A as a first option for butt fusion joining of its PE piping products. Use of this procedure obviously is not mandatory, and every PE 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 generic 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 PE pipe.

2.0 TESTING PROGRAM TO EVALUATE USE OF GENERIC BUTT JOINING PROCEDURE FOR FIELD JOINING OF POLYETHYLENE PIPING PRODUCTS

The Task Group looked at the Generic Butt Fusion Procedure previously released in TR-33 (2001) and other procedures approved by pipe manufacturers for butt fusing PE pipe products that satisfy the ASTM F714, ASTM D3035, AWWA C-901, and AWWA C-906 Pipe Specifications. Since there was overlap in the main fusion parameter areas, the Task Group proposed the same butt fusion parameters previously released in TR-33 (2001) for PE gas piping products be utilized, recognizing that the selected interfacial pressure range does not include all of the interfacial pressures that are promoted on a global basis. Interfacial fusion pressure recommendations typically range from a low of 21.7 psi (1.5 bar) to a maximum of 150 psi (10.34 bar). In spite of this broad range, the fact still remains that properly conducted fusions, across this range of interfacial pressures result in quality fusions that cannot always be differentiated by the various available testing techniques.

Heater Surface temperature	**400-450ºF (204-232ºC)**
Interfacial Pressure	**60-90 psi (4.14-6.21 bar)**

From its review of the different procedures collected from the PE pipe producers, the Task Group further developed the Generic Butt Joining Procedure set out in Appendix A., based on its assessment of the common elements in the individual procedures. The only exception to this was that fusion pressure was used to seat the pipe against the heater plate and this pressure remained until an indication of melt around the circumference of the pipe was observed. Then the pressure was reduced to drag pressure and the carriage control valve shifted to the middle position to keep the carriage from moving. It was agreed that proprietary products such as Phillips Driscopipe 8000/8600 series HDPE piping products were sufficiently different from the remainder of the materials being discussed that they were not included in the test program[3]. The manufacturer should be contacted for more information on particular joining procedures for those products. Only current commercially available products from PPI member companies were included in this test program. For information on older or other products, please contact the manufacturer of those products.

Using these parameters and procedures, the Task Group initiated a 2-part test program to evaluate butt fused samples joined at the extremes of the parameters. After the samples were fused, they were cut into tensile test specimens where high speed tensile testing was conducted on each specimen. PPI's Conclusions and Recommendations, based on the task group's work, are found at the end of this section. Test data are maintained at PPI headquarters.

[3] Phillips Driscopipe 8000 and 8600 are no longer manufactured.

Part 1 – Pipe Fusion and Testing – (5) different pipe manufacturers pipe samples with various wall thickness.

The pipe samples we tested were:

KWH Pipe –12” IPS DR11
KWH Pipe – 12” IPS DR6
Phillips – 14”IPS DR 9
Plexco – 12”IPS DR 9
Plexco – 12” IPS DR 9 Yellowpipe

Like pipe to like pipe was fused in this evaluation. There were (4) joints made at the following parameters for each pipe size to be tested:

400º F and 60 psi interface
400º F and 90 psi interface
450º F and 60 psi interface
450º F and 90 psi interface

We recorded the following times and bead sizes in the fusion process:

- Time to get indication of melt
- Soak time to heater removal
- Bead size per side at the time of heater removal
- Total bead size after fusion
- Cooling time under pressure
- Bead temperature at the time of pipe removal

The fused samples were joined and allowed to cool under pressure until cool to the touch using 30-90 seconds per inch of diameter as a cool time guideline. The samples were allowed to cool for an additional 24 hours before cutting into the tensile test sample configuration.

A tensile test sample was cut from each fused pipe interface at 12:00, 3:00, 6:00 and 9:00 positions. The test samples were machined to the attached configuration and a high speed tensile impact test was conducted on all samples.

The results of testing these fusion samples were 100% positive. All of the fusion joints failed in a ductile mode outside the joint area.

Part 2 – Pipe Fusion and Testing – Compare tensile test results using different interfacial pressures.

The heavy wall pipe samples we tested were:

PolyPipe 16” IPS DR 7
KWH Pipe 22” IPS DR11

We fused like pipe to like pipe in this evaluation. There was (1) joint made at the following parameters for each pipe size to be tested:

425º F and 25 psi interface
425º F and 40 psi interface
425º F and 75 psi interface

We recorded the following times and bead sizes in the fusion process:

- Time to get indication of melt
- Soak time to heater removal
- Bead size per side at the time of heater removal
- Total bead size after fusion
- Cooling time under pressure
- Bead temperature at the time of pipe removal

The fused samples were joined and allowed to cool under pressure until cool to the touch using 30-90 seconds per inch of diameter as a cool time guideline. The samples were allowed to cool for an additional 24 hours before cutting into the tensile test sample configuration.

A tensile test sample was cut from each fused pipe interface at 12:00, 3:00, 6:00, and 9:00 positions. The test samples were machined to a dog-bone configuration that is recommended by the British WIS 4-32-08 standard. This test is designed to cause failure in the joint area. We pulled the samples in a high-speed tensile impact machine at a rate of 4” per second. The energy in ft-lbs at yield and failure, the samples pull area and the amount of energy per square inch of area was recorded for all three interfacial area samples. The beads were removed on all samples. In order to mask actual values derived in the test that might allow one to compare strengths between materials, the results are shown as percentages of increased or decreased average strength as compared to that material’s joint strength at 25 psi interfacial.

The results of these tests were:

Pipe 1	25 psi	Average	100%
Pipe 1	40 psi	Average	104%
Pipe 1	75 psi	Average	105%

Pipe 2	25 psi	Average	100%
Pipe 2	40 psi	Average	97%
Pipe 2	75 psi	Average	101%

For both pipe sizes tested, the nominal 75 psi interface pressure joints proved to have a higher tensile strength before failure than 40 or 25 psi interface.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that it is possible to standardize on a single set of butt fusion parameters that can be used for fusing most of the polyethylene gas pipe and municipal and industrial pipe available on the market today. We recognize that the recommended parameters utilized are a small subset of the various fusion parameters utilized today, but believe in the benefit of moving towards a common standardized fusion procedure. The more the industry can move to greater uniformity, efficiency and simplicity in the area of fusion procedures, the more acceptance it will receive in the different industries.

PPI hopes that the inherent value of greater uniformity will provide all the incentive necessary for companies to evaluate the generic procedure in Appendix A as the preferred option for butt fusion joining of PE piping products. Use of this procedure obviously is not mandatory, and every PE pipe producer and pipeline operator retains the option of developing different procedures for its particular products and pipelines.

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 ever pipe producer retains the option of developing 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 generic 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 PE pipe.

SECTION III – BUTT FUSION PROCEDURE TESTING FOR FIELD BUTT FUSION OF PE 4710 PIPE FOR ALL APPLICATIONS.

1.0 SCOPE

A PPI Task Group was developed to make butt fusion joints on PE4710 piping products to the procedures and parameters outlined in ASTM F2620 and do the testing of those joints to qualify the procedure for that piping material. The procedure would be available for use by pipeline operators who would determine whether the procedure is appropriate for use with the PE piping products it employs.

It is important to emphasize that the testing, performed by the PPI Task Group, was intended only to show that the procedures and parameters in ASTM F2620 could be used to butt fuse PE 4710 piping material. This procedure would offer the maximum opportunity to be qualified and used by pipeline operators with a broad range of polyethylene piping products. PE 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 PE piping products.

PPI hopes that the inherent value of greater uniformity will provide all the incentive necessary for companies to evaluate the procedure in ASTM F2620 as a first option for butt fusion joining of its PE piping products. Use of this procedure obviously is not mandatory, and every PE 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 PE pipe.

2.0 TESTING PROGRAM TO EVALUATE THE USE OF ASTM F2620-11 BUTT JOINING PROCEDURES FOR FIELD JOINING OF PE 4710 POLYETHYLENE PIPING PRODUCTS

The Task Group looked at the ASTM Standard Butt Fusion Procedure F2620 and decided to use similar parameters and procedures for the Three Phase Test Program for different pipe sizes of PE 4710 pipe. Parts of the procedure were further clarified so it is easier to monitor the procedure used and inspect the joints. A minimum heat soak time was added to pipe sizes 14” and larger to insure that the thicker wall pipes receive enough heat before joining. This minimum heat soak time is 4.5 minutes per inch of wall thickness. A maximum open/close (dwell) time was established by wall thickness to make sure the fusion machine is opened, the heater removed and the pipe ends brought together at the fusion pressure in a prompt time. The cool time under fusion pressure was changed from 30-90 seconds per inch of pipe diameter to 11 minutes per inch of wall thickness. This better clarifies the cool time required for pipes of all wall thicknesses and is easier to monitor. All of these changes are outlined in ASTM F2620-11e1.

The three phase program was focused on pipes in different size ranges:

Phase I --- 2” IPS DR11 PE 4710 pipe from different manufacturers and resins for cross fusion compatibility testing

Phase II --- 8” IPS PE 4710 pipe fused to other PE 4710 pipes and also to PE 3608 pipe and PE 2708 pipe for compatibility testing.

Phase III --- 6”IPS DR11, 12” IPS DR11, 20” DIPS DR 11, 28” IPS, DR11 and 36” IPS DR9 PE 4710 pipe sizes were fused to validate the parameters and procedures for a variety of pipe sizes and wall thicknesses.

Phase I --- Pipe Fusion and Testing – 2” IPS pipe size

Five (5) different PE 4710 pipe resins were used to make (10) different cross-fusion combinations for tensile testing and quick burst testing.

All pipe sizes were 2” IPS DR11. The combinations fused and tested were:

CP Chem 9346P8 to Dow DGDA 2490
CP Chem 9346P8 to Total XT 10N
CP Chem 9346P8 to Ineos TUB 121
CP Chem 9346P8 to Equistar Alathon L4904
Dow DGDA 2490 to Total XT 10N
Dow DGDA 2490 to Ineos TUB 121
Dow DGDA 2490 to Equistar Alathon L4904
Total XT 10N to Ineos TUB 121
Total XT 10N to Equistar Alathon L4904
Ineos TUB 121 to Equistar Alathon L4904

The Task Group decided to use parameters that were outside the ASTM F2620 procedure to make sure we had a safety zone around the actual parameters recommended. The parameters used for these fusions were:

375 degree F Heater Surface Temperature and 50 psi interfacial pressure
375 degree F Heater Surface Temperature and 100 psi interfacial pressure
500 degree F Heater Surface Temperature and 50 psi interfacial pressure
500 degree F Heater Surface Temperature and 100 psi interfacial pressure

We recorded the following parameters during the fusion process of each joint:

- Time to get an indication of melt
- Soak time to heater removal
- Pressure during the heat soak cycle
- Total open/close (dwell) time for heater removal
- Fusion pressure
- Cooling time at fusion pressure

The samples were allowed to cool for at least an additional 24 hours before cutting test specimens and conducting the tensile and quick burst tests.

Three separate task group companies made the fusion joints and three task group companies did the tensile tests on these samples. Twelve fusion joints at each parameter condition were made with (24) tensile test specimens made for each condition. The tensile tests were conducted per ASTM F2634 and D638. A total of 250 + tensile tests were conducted in Phase 1. All joints passed the tensile tests in a ductile manner outside the fusion zone.

Twelve fusion joints at each parameter condition were made and quick burst tested per D1599. A total of 40 quick burst tests were conducted in Phase 1 with three fusion joints in each test pipe. All joints passed the quick burst tests with failures in the pipe and not the fusion joint.

<u>Phase II</u> --- Pipe Fusion and Testing – 8” IPS pipe size

The Task Group continued testing of PE 4710 piping material with a larger diameter and heavier wall pipe size. The fusion joints were made between different resins of PE 4710 and between PE 4710 and standard PE 3608 and PE 2708 piping materials. These joints were tested using tensile tests and sustained pressure tests at elevated temperatures. The combinations fused and tested were:

8” IPS DR 11 Equistar L4904 PE 4710 to 8” IPS DR 9 PE 3608 pipe
8” IPS DR 13.5 Dow DGDA 2490 PE 4710 to 8” IPS DR 13.5 Ineos TUB 121 PE 4710
8” IPS DR 11 Total XT10N PE 4710 to 8” IPS DR 11 PE 2708 pipe

The Task Group decided to use parameters that were outside the ASTM F2620 procedure to make sure we had a safety zone around the actual parameters recommended. The parameters used for these fusions were the same as in Phase 1:

375 degree F Heater Surface Temperature and 50 psi interfacial pressure
375 degree F Heater Surface Temperature and 100 psi interfacial pressure
500 degree F Heater Surface Temperature and 50 psi interfacial pressure
500 degree F Heater Surface Temperature and 100 psi interfacial pressure

We recorded the following parameters during the fusion process of each joint:

- Time to get an indication of melt
- Soak time to heater removal
- Pressure during the heat soak cycle
- Total open/close (dwell) time for heater removal
- Fusion pressure
- Cooling time at fusion pressure

The samples were allowed to cool for at least an additional 24 hours before cutting test specimens and conducting the tensile and 80° C sustained pressure tests.

Three separate task group companies made the fusion joints and three task group companies did the tensile tests on these samples. Six fusion joints at each parameter condition were made with (24) tensile test joints made for each condition. Three fusion joints at each parameter condition were made for each pipe combination. The tensile tests were conducted per ASTM F2634 and D638. A total of 312 tensile tests were conducted in Phase II. All joints passed the tensile tests in a ductile manner outside the fusion zone. We then conducted elevated temperature (80º C) sustained pressure testing per ASTM D3035 or F714. We tested a total of 36 joints with all passing the requirements in the D3035 or F714 standards.

<u>Phase III</u> --- Pipe Fusion and Testing – Variety of pipe sizes from 6" to 36" and up to 4" wall thickness

The Task Group continued testing of PE 4710 piping material with a larger diameter and heavier wall pipe size. The fusion joints were made on pipe made from PE 4710 resins and were made using the following pipe sizes and at the following parameters. These joints were fused by two different member companies and tested by performing tensile impact testing per ASTM F2634 on the samples from these joints. We also tested the parent pipe to compare the tensile strength between the joint and the pipe.

The Task Group decided to use parameters that were outside the ASTM F2620 procedure to make sure we had a safety zone around the actual parameters recommended:

375 degree F Heater Surface Temperature and 50 psi interfacial pressure
375 degree F Heater Surface Temperature and 100 psi interfacial pressure
475 degree F Heater Surface Temperature and 50 psi interfacial pressure
475 degree F Heater Surface Temperature and 100 psi interfacial pressure

We recorded the following parameters during the fusion process of each joint:

- Time to get an indication of melt
- Soak time to heater removal
- Pressure during the heat soak cycle
- Total open/close (dwell) time for heater removal
- Fusion pressure
- Cooling time at fusion pressure

The pipes tested are listed below:

6” IPS DR11	Total XT10N PE 4710 Resin
12” IPS DR11	CP Chem H516HP PE 4710 Resin
20” DIPS DR11	Total XT10N PE 4710 Resin
28” IPS DR11	Equistar L4904 PE 4710 Resin
36” IPS DR9	Dow DGDA 2492 PE 4710 Resin

Pipe Size	**No. of Joints**	**Heater Surface Temp º F**	**Interfacial Pressure PSI**	**Total No. of Tensile Tests**
6” IPS DR11	2	425	75	8
12” IPS DR11	1	375	50	4
12” IPS DR11	1	375	100	4
12” IPS DR11	1	475	50	4
12” IPS DR11	1	475	100	4
12” IPS DR11	2	425	75	8
20” DIPS DR11	1	375	50	4
20” DIPS DR11	1	375	100	4
20” DIPS DR11	1	475	50	4
20” DIPS DR11	1	475	100	4
20” DIPS DR11	2	425	75	8
28” IPS DR11	2	425	75	8
36” IPS DR9	1	375	50	8
36” IPS DR9	1	375	100	8
36” IPS DR9	1	475	50	8
36” IPS DR9	1	475	100	8
36” IPS DR9	2	425	75	16

The fused joints in the 36” pipe were over 4” in wall thickness and were machined to approximately 2” in wall in order to test in the tensile machine. There were (22) joints made with 112 tensile tests on the joints and 32 tensile tests on the pipe. The results showed all the joints failed in a ductile manner.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that when the butt fusion procedure, outlined in ASTM F2620-11e1 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings, is used to join PE 4710 piping material, the pipeline owner can expect leak free butt fusion joints that are as strong as, if not stronger than, the pipe when subjected to pressurization, tension and/or bending. As the polyethylene industry moves to broader uniformity, efficiency and simplicity in the area of fusion procedures, the more acceptance PE will receive in the different piping markets.

APPENDIX A

Generic Butt Fusion Joining Procedure for Field Joining PE (Polyethylene) Pipe

Note: The procedure, outlined in Appendix A, was used to make the joints in Section I and Section II of this document. The procedure shown in ASTM F2620 -11e1 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings was used in making the joints in Section III with the parameter exceptions shown in that Section. ASTM F2620 is a refined and expanded copy of this Appendix and should be used as the guide for further qualification.

This Appendix is intended to be used only in conjunction with PPI's Technical Report TR-33 that more fully explains the background, scope and purposes of the PPI generic procedure. 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 PE pipe in a gas pipeline. Any copying or reproduction of this procedure without this footnote and the accompanying TR-33 is a violation of the copyright.

This procedure is intended for butt fusion joining of PE fuel gas pipe produced in accordance with (ASTM D2513), excluding Dupont Aldyl A MDPE, Uponor Aldyl A MDPE and Phillips Driscopipe 7000 and 8000 HDPE[4]. It also is intended for butt fusion joining of PE potable water, sewer and industrial pipe manufactured in accordance with ASTM F714, ASTM D3035, AWWA C-901 and AWWA C-906, as well as other PE pipe and fitting standards listed in Appendix C.

Butt Fusion Procedure Parameters:

Generic Fusion Interface Pressure Range[5]	60-90 psi (4.14-6.21 bar)
Generic Heater Surface Temperature Range	400 - 450°F (204-232ºC)

Butt Fusion Procedures:

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.

[4] Dupont Aldyl A MDPE, Uponor Aldyl-A and Phillips Driscopipe 7000 and 8000 were not included in the study.

[5] Interfacial pressure is used to determine fusion joining pressure settings for hydraulic butt fusion machines when joining specific pipe diameters and DR's. Interfacial pressure in NOT the gauge pressure.

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

1.0 <u>SECURE</u>

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.

2.0 <u>FACE</u>

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. 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 that faces are square, perpendicular to the pipe centerline on each pipe end and with no detectable gap.

3.0 <u>ALIGN</u>

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. Re-face the pipe ends and remove any chips from re-facing operation with a clean, lint-free cotton cloth.

4.0 <u>MELT</u>

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 is made 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 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 400-450°F (204-232°C). 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 polyethylene 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 below for approximate melt bead sizes.

Table 2. 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)
Above 12" through 24" (above 315mm-630mm)	1/4"-7/16" (6-11mm)
Above 24" through 36" (above 630mm-915mm)	About 7/16" (11mm)
Above 36" through 63" (above 915mm-1600mm)	About 9/16" (14mm)

5.0 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 double rollback 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.

6.0 HOLD

Hold the joint immobile under fusion force until the joint has cooled adequately to develop strength. Allowing proper cooling times 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 for approximately 30-90 seconds per inch of pipe diameter or until the surface of the melt bead is cool to the touch.

Avoid pulling, installation or rough handling for an additional 30 minutes. Additional time may be required for pipes with a wall thickness greater than 2".

7.0 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 2-2 ½ times the bead height above the pipe and the beads should be rounded and uniformly sized all around the pipe circumference. The v-groove between the beads should not be deeper than half the bead height above the pipe surface. 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. (See Appendix D for bead configuration). Visually unacceptable joints should be cut out and re-fused using the correct procedure. (See manufacturer's visual inspection guidelines)

Figure A-1. Visually unacceptable mitered joint

Visually mitered (angled, off-set) joints should be cut out and re-fused (straight or coiled pipe).

Coiled pipe is available in sizes through 6” IPS. Coiling may leave a bend 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 coiled pipe before joining pipe sizes larger than 3” IPS.)

2. If there is still curvature present, install the pipe ends in the 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 A-2.

3. If there is still a curvature present, another option would be to install a straight piece of pipe between the two coiled pipes.

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

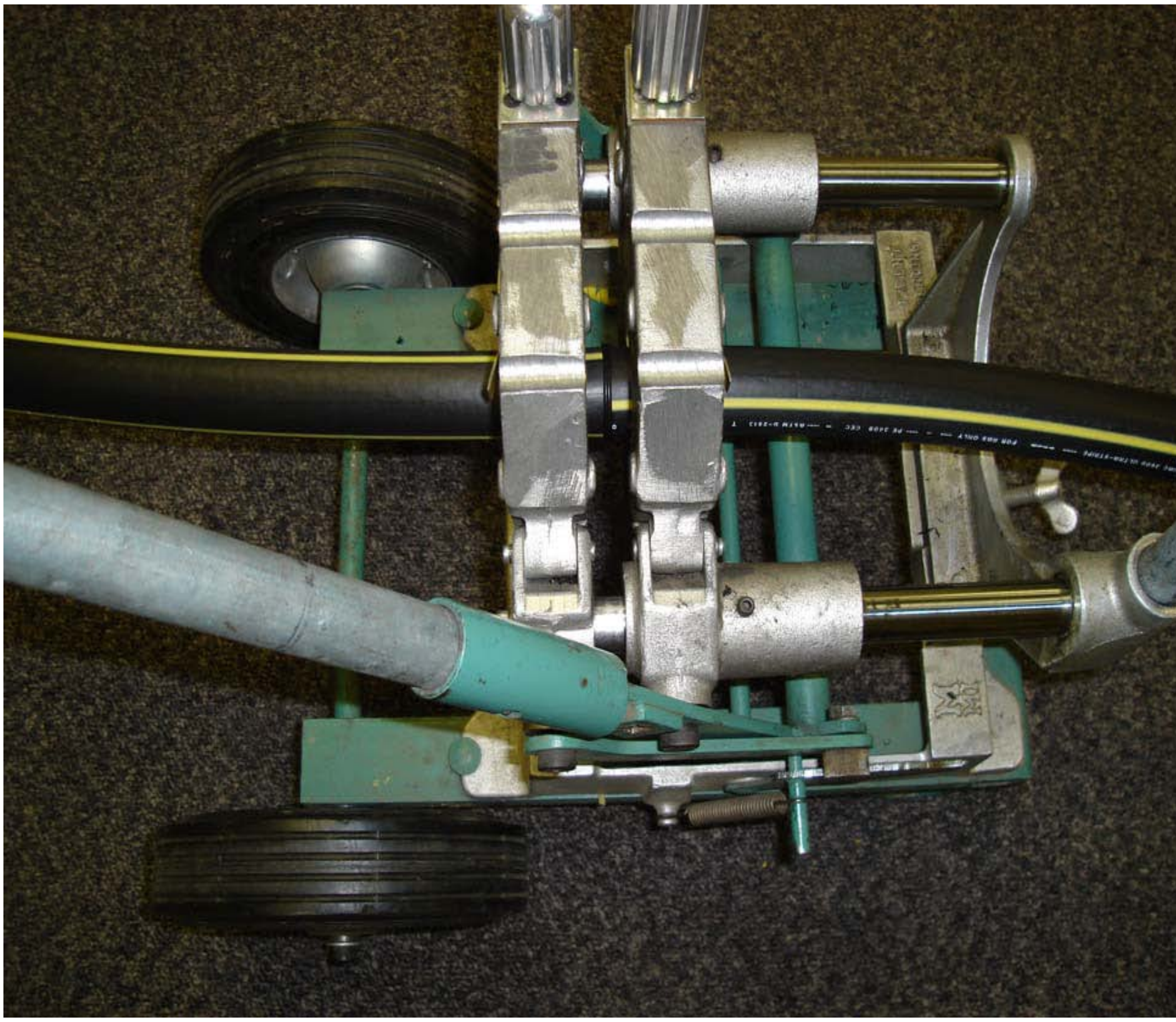


Figure A-2. Alignment of Coiled Pipe Ends Through a Butt Fusion Machine

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 fittings manufacturer for letters of compliance.

APPENDIX C

Municipal and Industrial Applications

Materials that have been pre-qualified to be joined by this generic fusion procedure are within the nominal melt index range of 0.05 to 0.25 gm/10 minutes (190°C/ 2.16 Kg), or a high load melt flow of 6 to 17 gm/10 minutes (190°C/21.6 Kg), and a nominal density range of 0.936 to 0.955 gm/cc.

Materials within this melt index and density range were included in the study and can be joined by this methodology. However, PE materials outside of this range may also be able to be joined by this generic method, but they have not been included in this study. Contact the manufacturer to verify that their products can be joined by this generic method.

Qualified materials are typically used in the production of pipe and/or fittings that are manufactured according to the following standards:

ASTM
D2104 Polyethylene (PE) Plastic Pipe, Schedule 40

D2239 Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter

D2447 Polyethylene (PE) Plastic Pipe, Schedules 40 to 80, Based on Outside Diameter

F2620 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings

F2634 Standard Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints using Tensile-Impact Method

D3035 Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter

D3261 Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing

F714 Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Outside Diameter

F771 Polyethylene (PE) thermoplastic high-pressure Irrigation Pipeline Systems F 810 Smooth wall Polyethylene (PE Pipe for Use in Drainage and Waste Disposal Absorption Fields

AWWA

C-901 Polyethylene (PE) Pressure Pipe, Tubing, and Fittings, 1/2“through 3” for Water Service

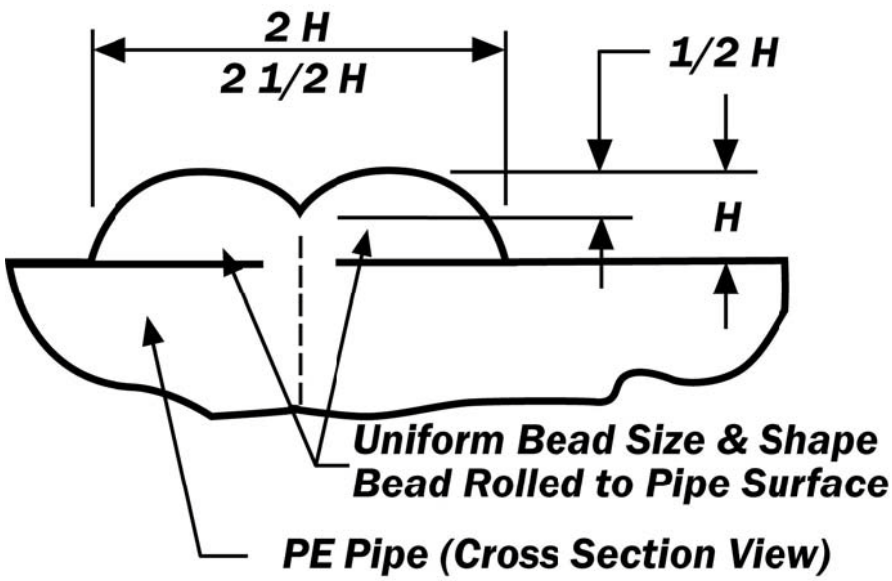
C-906 Polyethylene (PE) Pressure Pipe and Fittings, 4” through 63” for Water Distribution

CSA

B 137.1 Polyethylene Pipe, tubing and Fittings for Cold Water Pressure Services

APPENDIX D

ILLUSTRATION OF A PROPERLY MADE BUTT FUSION JOINT



Note: When butt fusing to molded fittings, the fitting side bead may have an irregular appearance. This is acceptable provided the pipe side bead is correct.

This bead configuration DOES NOT apply to joints made with Dupont Aldyl A MDPE, Uponor Aldyl A MDPE or Phillips Driscopipe 7000 and 8000 HDPE.