Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe

TR-33/2003

Foreword

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 and 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 website.

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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 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 operators efforts to qualify the procedure, reduce costs, and simplify DOT's enforcement duties.

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 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. Endorsement letters from Charter Plastics, CSR Polypipe, KWH

Pipe, North American Pipe, Phillips Driscopipe, PLEXCO and Uponor are in Appendix B. Typical photographs of properly made butt fusion joints are in Appendix C.

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.

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's Aldyl A MDPE products and Phillips Driscopipe's D8000 HDPE piping products were sufficiently different from the remainder of the materials being discussed that they were not included in the test program. The manufacturers should be contacted for more information on particular joining procedures for those products. Only current commercially available products (see Appendix B) 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 in Section IV. 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 producers 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 HDPE.)

Again 2" IPS SDR11 PE pipe was chosen. The Task Group members reviewed the information presented in Table 1 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 combination 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 a 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 a 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 a 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/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), 1,000 hour test using 580 psi (40 bar) hoop stress. As with the 2" IPS testing, all joints passed every test conducted.

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 Driscopipe D8000 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.

ACKNOWLEDGEMENTS

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

Phillips Driscopipe
PLEXCO
CSR PolyPipe
Central Plastics
Uponor
Charter Plastics
Solvay
Fina
KWH Pipe
North American Pipe
McElroy Manufacturing
T.D. Williamson

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.	HD2007H	.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	

APPENDIX A

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

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 PE fuel gas pipe (per ASTM D2513) which have a grade designation (in accordance with ASTM D3350) of PE24 and PE34, excluding Uponor Aldyl A MDPE and Driscopipe D8000 HDPE.

Butt Fusion Procedure Parameters:

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

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.

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.

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. This operation provides for a perfectly square face, perpendicular to the pipe centerline on each pipe end and with no detectable gap.

Align

Remove any pipe chips from the facing operation and any foreign matter with a clean, untreated, lint-free cotton cloth. 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 adjusting clamping jaws until the outside diameters of the pipe ends match. The jaws must not be loosened or the pipe may slip during fusion.

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 periodically to insure proper temperature of the heating tool face. 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.

Plug in the heater and bring the surface temperatures up to 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. Continue to hold the components in place, 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, the heater should be removed. The bead size is dependent on the pipe size. For 2" IPS pipe, a bead size of approximately 1/16" should be present and for 8" IPS pipe, a bead size of 1/8" – 3/16" should be present before removing the heater.

Joining

After the pipe ends have been heated for the proper time, the heater tool is removed and the molten pipe ends are brought together with sufficient force to form a double rollback

bead against the pipe wall. The fusion force is determined by multiplying the interfacial pressure, 60-90 psi (4.14-6.21 bar,) by the pipe area.

For manually operated fusion machines, a torque wrench may be used to accurately apply the proper force. For manual machines without force reading capability of a torque wrench, the correct fusion joining force is the force required to roll the melt beads over to the pipe surface during joining. 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; the internal and external drag need to be added to this figure to obtain the actual fusion pressure required by the machine.

Hold

The molten joint must be held immobile under pressure until cooled adequately to develop strength. Allowing proper times under pressure for cooling 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 bead is cool to the touch.

The pulling, installation or rough handling of the pipe should be avoided until the joint cools to ambient temperature (roughly an additional 30 minutes.)

APPENDIX B

LETTERS OF ENDORSEMENT FROM PPI MEMBER COMPANIES