THE DEVELOPMENT & EVOLUTION OF

"PPI TR-33 - Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe"

TN-66

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Plastics Pipe Institute
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1.0 INTRODUCTION AND SCOPE

This Technical Note has been developed to summarize the historical work and knowledge behind the document that is currently referred to as "TR-33 *Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe*" (Link). TR-33 has been relied upon as an industry reference and ultimately formed the basis for ASTM F2620[1]. Recently, there has been an increase in the number of questions related to the testing (materials and participants), test results, and test methods that were used to develop the PPI TR-33 generic butt fusion joining procedures.

2.0 HISTORY AND PURPOSE OF TR-33

In 1999, PPI first published TR-33 "*Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe*" specifically for gas piping applications. This effort addressed requests from several gas operations and PHMSA[2]. The generic butt fusion procedure was intended to harmonize the procedures from the pipe manufacturers as each differed slightly. The effort spanned several years and was conducted as a service to the industry.

In 2006, PPI revised TR-33 to be applicable to PE pipe used in all applications and the title was changed to "*Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe*."

In 2012, PPI revised TR-33 to include Section III that covers the newer PE 2708 and PE 4710 materials as well as larger diameter/thicker wall pipe following the procedures of ASTM F2620.

The above editions constitute the revisions to the main body of the document. Updates to the compendium of manufacturers' letters were made periodically.

As noted in PPI TR-33/2012, Section II, 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 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 and materials. 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.

Upon completion of the task group's initial work in 1999, and to aid industry acceptance of the TR-33 project, many PPI Member Companies performed qualification testing per Title 49 CFR §192.283[3] for numerous products as conveyed in manufacturer's letters of endorsement published in Appendix B of PPI TR-33/99 and subsequent revisions. These letters indicated a manufacturer approved the procedure for use with their products. The letters were removed in the 2012 version. Users were directed to contact the pipe or fittings manufacturer for letters of compliance.

The outcome of the work to develop TR-33 has served the industry well. The generic fusion parameters have been very well tested. Adherence to these procedures has resulted in the successful installation and service of many hundreds of thousands of miles[4] of polyethylene pipe. As industry demands have evolved, the industry recognized that formalization of the procedure was needed. The outcome of this recognition was the development of ASTM F2620 in 2006, an ANSI-accredited standard. Clarification requests and updates to the generic fusion procedure are now being managed through the ASTM committee process.

TR-33 now exists as an industry reference detailing the work conducted to validate the generic fusion procedure with various materials. The most current procedure and practice are within ASTM F2620.

3.0 TR-33 HISTORICAL DETAILS – TESTING SUMMARY

As TR-33 contains 3 sections and several parts/phases to each section reflecting the work done over the years, accessing and comparing this information can be cumbersome. Table 1 provides a summary of data from the various test programs and editions of TR-33. The table provides a consolidated reference of the materials and fusion parameters that were included in each iteration as well as details regarding test conditions.

The following number of joints were prepared and subjected to a number of tests. No failures occurred in any tests conducted on any joints.

- Section I: 480 Joints
- Section II: 26 joints
- Section III: 298 joints

Table 1: TR-33 timeline summary

Year	Document Title	Sections - Scope	IFP Test (psi)	Fusion Temperature Test (ºF)	Part/Phase	Materials Tested	Sample Quantity	Fusion Conditions	Tests Performed
1994	DOT requests assistance from PPI to promote greater uniformity in the joining procedures utilized by gas utilities in the butt fusion of polyethylene (PE) gas piping products								
1999	Generic Butt Fusion Joining of Polyethylene Gas Pipe	**Section I:** Generic Butt Fusion Procedure Testing for Field Joining of ASTM D2513 Gas Piping listed in Appendix B1	50 - 100 60 - 90	375 - 475 400 - 450	1	2" DR 11 "like" materials: Example: Phillips Marlex TR-418 fused to Phillips Marlex TR-418.	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 and min/max interfacial pressures 60-90 psi were used in this testing. In addition, sample fusions at heater face temperatures (375 °F and 475 °F) and interfacial pressures (50 and 100 psi) were made and tested to examine conditions for fusion outside the initially generic parameters.	After fusion of the samples, tensile and quick-burst tests were conducted in accordance with the requirements of Title 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 hoop stress.
			50 - 100	375 - 475	2	2" DR 11 "unlike" materials: Example: Phillips Marlex TR-418 fused to Union Carbide DGDA 2400.	For **MDPE**: There were nine (9) joints made at each joining parameter, for a total of 18 joints.	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 475 °F / 100 psi and 375 °F / 50 psi. The remainder of the fusion procedures remained the same as Part 1.	
						For HDPE materials, the Task Group selected three (3) HDPE materials for evaluation: Chevron 9308, Novacor HD2007-H and Fina 3344 that were cross-fused.	For **HDPE**: 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.	For **MDPE** to **HDPE**: Nine (9) joints were made at each of the two extended parameter combinations, for a total of 18 joints.		
			50 - 100	375 - 475	3	8" DR 11 "unlike" materials: MDPE: UCC2400 fused to Phillips Marlex TR-418 UCC2400 fused to Chevron 9301 UCC2400 fused to Solvay Fortiflex K38-20-160	For **MDPE**: 10 joints each combination for a total of 30 joints. In effect, this would provide representative results for all medium density polyethylene except Uponor Aldyl A MDPE.	The joints were made at the same parameters as before with five (5) made at 475 °F / 100 psi interface and five (5) made at 375 °F / 50 psi interface.	
						HDPE: 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	For **HDPE**: 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.		
							For **MDPE** to **HDPE**: 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.		

Table 1: TR-33 timeline summary (continued)

Year	Document Title	Sections - Scope	IFP Test (psi)	Fusion Temperature Test (ºF)	Part/Phase	Materials Tested	Sample Quantity	Fusion Conditions	Tests Performed
2006	Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe	**Section II**: Generic Butt Fusion Procedure for Field Joining of ASTM F714, ASTM D3035 and AWWA C906 Piping	60 - 90	400 - 450	1	Part 1: Pipe Fusion and Testing – (5) different pipe manufacturers pipe samples with various wall thickness. 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 Yellow	4 joints at each condition for each pipe sample for a total of 20 joints	400 °F and 60 psi interface 400 °F and 90 psi interface 450 °F and 60 psi interface 450 °F and 90 psi interface	Part 1: 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 and a high speed tensile impact test was conducted on all samples.
			25 - 75	425	2	Part 2: Pipe Fusion and Testing – Compare tensile test results using different interfacial pressures. PolyPipe – 16" IPS DR 7 KWH Pipe – 22" IPS DR11	1 joint at each condition for each pipe size for a total of 6 joints	425 °F and 25 psi interface 425 °F and 40 psi interface 425 °F and 75 psi interface	Part 2: The test samples were machined to a dog-bone configuration that is recommended by the British WIS 4-32-08 standard[5]. 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.
2012	Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe	**Section III**: Butt Fusion Procedure Testing for Field Butt Fusion of PE4710 Pipe for All Applications	50 - 100	375 - 500	**I**	**Phase I** --- 2" IPS DR11 PE 4710 pipe from different manufacturers and resins for cross fusion compatibility testing. 2" DR11: CPChem 9346P8 to Dow DGDA 2490 CPChem 9346P8 to Total XT 10N CPChem 9346P8 to Ineos TUB 121 CPChem 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	Twelve fusion joints at each parameter condition were made with (24) tensile test specimens made for each condition. A total of 40 quick burst tests were conducted in Phase 1 with three fusion joints in each test pipe.	375 ºF and 50 psi interface 375 ºF and 100 psi interface 500 ºF and 50 psi interface 500 ºF and 100 psi interface	The tensile tests were conducted per ASTM F2634[6] and D638[7]. 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[8].
				375 - 500	**II**	**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. DR 11 Equistar L4904 PE 4710 to DR 9 PE 3608 pipe DR 13.5 Dow DGDA 2490 PE 4710 to DR 13.5 Ineos TUB 121 PE 4710 DR 11 Total XT10N PE 4710 to DR 11 PE 2708 pipe	Six fusion joints at each parameter condition were made for tensile test with 24 tensile test joints made for each condition. Three fusion joints at each parameter condition were made for each pipe combination.	375 ºF and 50 psi interface 375 ºF and 100 psi interface 500 ºF and 50 psi interface 500 ºF and 100 psi interface	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[9] or F714[10]. We tested a total of 36 joints with all passing the requirements in the D3035 or F714 standards.
				375 - 475	**III**	**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. 6" IPS DR11 Total XT10N 12" IPS DR11 CP Chem H516HP 20" DIPS DR11 Total XT10N 28" IPS DR11 Equistar L4904 36" IPS DR9 Dow DGDA 2492	There were (22) joints made with 112 tensile tests on the joints and 32 tensile tests on the pipe.	375 ºF and 50 psi interface 375 ºF and 100 psi interface 475 ºF and 50 psi interface 475 ºF and 100 psi interface 425 ºF and 75 psi interface	These joints were 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.

Note: IFP – Interfacial Pressure

4.0 RESIN REFERENCES

Table 2 summarizes the resins used in each Section of TR-33. The MI (2.16 kg / 10 min at 190 °C) of the resins ranged from 0.04 to 0.20 and the HLMI (21.6 kg / 10 min at 190 °C) ranged from 5.5 to 13 at the time of testing.

Table 2: Resins Tested in Each Section of TR-33[a]

Section 1 (as taken from TR-33/1999)	**Section II** (as taken from TR-33/2006)	**Section III** (as taken from TR33/2012)	**Material designation**	**MI 2.16 kg (g / 10 min)**	**HLMI 21.6 kg (g / 10min)**
Phillips TR480	--	--	PE 3408	0.11	13
Solvay K44-15-123	--	--	PE 3408	0.12	13
Solvay K44-08-123*	--	--	PE 3408	0.08	8.5
Chevron 9346	--	--	PE 3408	0.08	10
Chevron 9308	--	--	PE 3408	0.10	10
Novacor HD-2007-H	--	--	PE 3408	0.07	8.5
Union Carbide 2480	--	--	PE 3408	0.10	12
Fina 3344	--	--	PE 3408	0.10	8
Phillips TR418	--	--	PE 2406	0.12	--
Chevron 9301	--	--	PE 2406	0.20	--
Solvay K38-20-160	--	--	PE 2406	0.20	--
Novacor 2100	--	--	PE 2406	0.15	--
Union Carbide 2400	--	--	PE 2406	0.20	--
--	KWH	--	--	--	--
--	Phillips	--	--	--	--
--	Plexco	--	--	--	--
--	PolyPipe	--	--	--	--
--		Chevron Marlex 9346P8	--	--	9
--	--	Dow DGDA 2490	PE 4710	--	7.5
--	--	Chevron Marlex H516HP	PE 4710	--	9.0
--	--	Dow DGDA 2492	PE 4710	--	5.5
--	--	Total XT10N	PE 4710	--	7.5
--	--	Ineos TUB121	PE 4710	--	8.5
--	--	Equistar L4904	PE 4710	--	7.0

*Referenced within TR-33 but no evidence of being used in testing.

[a] Ownership changes or company name changes may have occurred since the testing was originally conducted. The following table provide the current ownership information. Specific grades may no longer be available. Contact the current manufacturer for current availability and grade designations.

- Union Carbide grades are Dow Chemical
- Solvay grades are INEOS Olefins & Polymers USA
- Phillips grades are Chevron Phillips Chemical Company
- FINA grades are Total Petrochemicals
- Plexco samples are Performance Pipe
- Equistar grades are LyondellBasell

5.0 TEST SAMPLE CONFIGURATION

This section describes the sample configuration utilized for testing in Section III. Figure 1 provides the configuration for tensile testing and Figure 2 provides the configuration for quick burst test. Dimensions shown are for IPS 2 pipe. Figure 3 provides the configuration used for elevated temperature pressure testing.

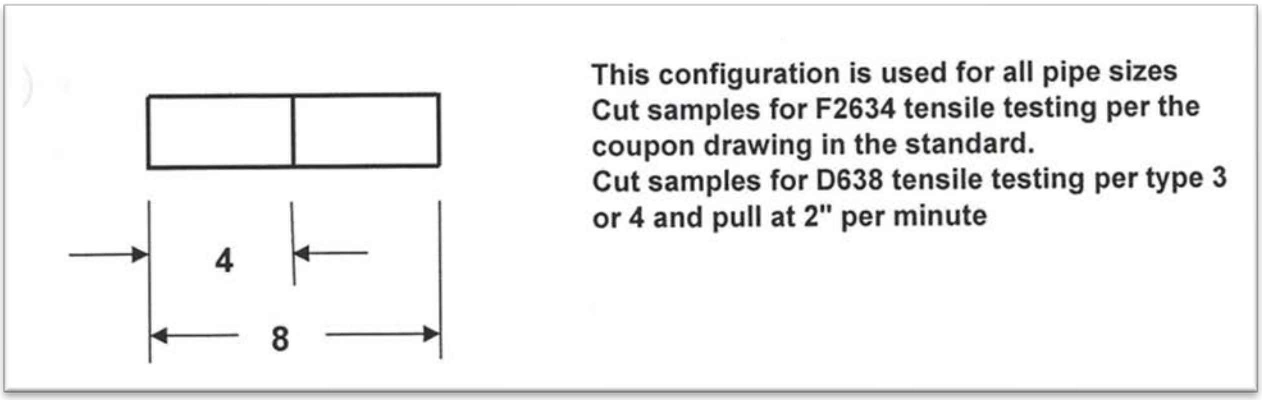

Figure 1 - Fusion Joint Configuration for Tensile Testing per ASTM F2634 or ASTM D638 - all pipe sizes (dimension in inches)

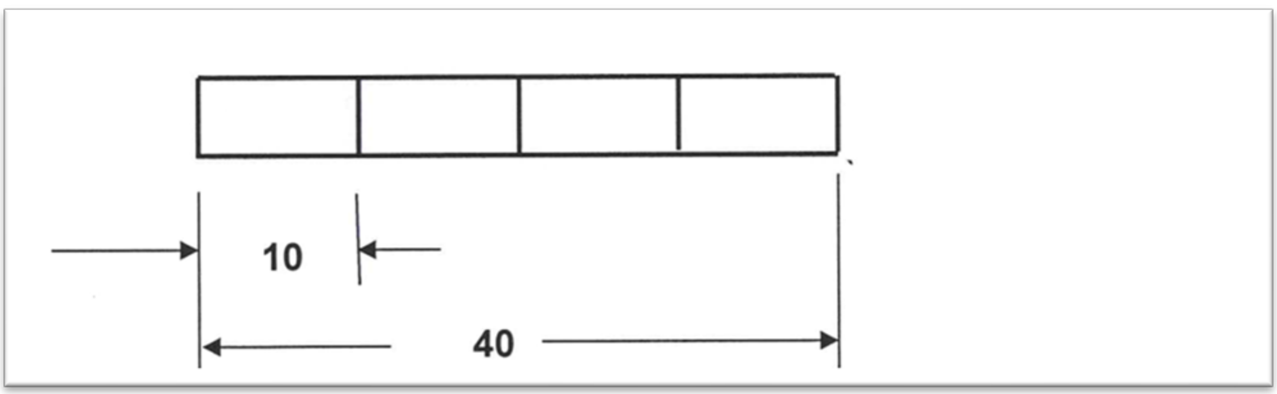

Figure 2 – Fusion Joint Configuration for Quick Burst Testing for IPS 2 pipe (dimension in inches)

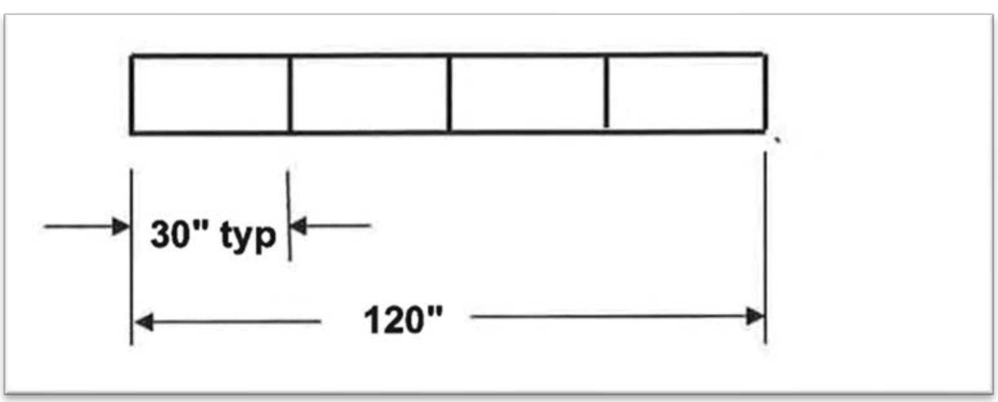

Figure 3 - Fusion Joint Configuration for 80°C Testing of IPS 8 pipe

6.0 INDUSTRY VALIDATION OF THE FUSION PARAMETERS

In a joint GTI/OTD study[11], GTI studied the impact of fusion parameters on fusion joint quality. The work demonstrated that the fusion box defined in PPI TR-33 is robust. A different author, Mr. Jim Johnston of McElroy Manufacturing, Inc., showed how the ASTM F2620 fusion parameter window is more conservative in comparison with PPI TR-33 procedure[12].

Additionally, the hundreds of thousands of miles of PE pipe successfully fused, initially on the basis of the TR-33 and subsequently on the basis of ASTM F2620, has provided real world validation of the robustness of the fusion parameters.

7.0 CONCLUSION

The technical work reported in TR-33 remains fundamental to the PE piping industry as it established the basis for current and most prevalent fusion practices in the industry. It formed the basis for requirements within the US Code of Federal Regulations, Title 49 CR §192.283. This Technical Note provides an overview of the work conducted with additional details of the scope of work, not previously reported, that underpinned the findings reported in TR-33.

PPI does not intend to further update TR-33; however, PPI intends to continue to make TR-33-2012 available for download. As such, it is intended that this document complements TR-33 providing additional support to those in the industry with an interest in fusion.

8.0 ENDNOTES

[1] ASTM F2620, 2006 Edition, December 1, 2006 - *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*, ASTM International, West Conshohocken, PA, 2006

[2] Pipeline and Hazardous Materials Safety Administration (PHMSA), an agency of the United States Federal Department of Transportation.

[3] Title 49 CFR § 192.283 - Plastic pipe: Qualifying joining procedures, United States Code of Federal Regulations.

[4] PLASTIC PIPING DATA COLLECTION INITIATIVE STATUS REPORT, American Gas Association Plastic, May 3, 2018

[5] WIS 4-32-08 *SPECIFICATION FOR THE FUSION JOINTING OF POLYETHYLENE PRESSURE PIPELINE SYSTEMS USING PE80 AND PE100 MATERIALS*, UK Water Industry.

[6] ASTM F2634 *Standard Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints using Tensile-Impact Method*¸ ASTM International, West Conshohocken, PA.

[7] ASTM D638 *Standard Test Method for Tensile Properties of Plastics*, ASTM International, West Conshohocken, PA.

[8] ASTM D1599 *Standard Test Method For Resistance To Short-Time Hydraulic Pressure Of Plastic Pipe, Tubing, And Fittings*, ASTM International, West Conshohocken, PA.

[9] ASTM D3035 *Standard Specification For Polyethylene (PE) Plastic Pipe (DR-PR) Based On Controlled Outside Diameter*, ASTM International, West Conshohocken, PA.

[10] ASTM F714 *Standard Specification For Polyethylene (PE) Plastic Pipe (DR-PR) Based On Outside Diameter*, ASTM International, West Conshohocken, PA.

[11] DTPH5614H00001 *Effects of Hydrocarbon Permeation on Plastic Strength and Fusion Performance, GTI Project Number 21565*, prepared for the U.S. Department of Transportation – Pipeline and Hazardous Materials Safety Administration – Office of Pipeline Safety, 2015, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=554

[12] Johnston, J., *Comparison of Procedures Between ASTM F2620 and PPI TR-33*, American Gas Association symposium, 2019.