Teel

Gas Pipe Manufacturing

Operations, Test Data, and QA Procedures

Updated August 2023

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ISO Certification

Teel Plastics' industrial pipe manufacturing facility is certified to ISO 9001:2015 for its quality management system.

ISO 9001

ISO 9001 is the international standard that specifies requirements for a quality management system (QMS). Organizations use the standard to demonstrate the ability to consistently provide products and services that meet customer and regulatory requirements. To maintain certification, ISO 9001 requires the organization to demonstrate continual improvement.

ASR
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REGISTRAR
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ANAB
ACCREDITED

American Systems Registrar, LLC, a provider of third-party system registration and accredited by the ANSI National Accreditation Board attests that:

TEEL PLASTICS, LLC

1060 TEEL COURT
BARABOO, WI 53913

426 HITCHCOCK STREET
BARABOO, WI 53913

500 INDUSTRIAL COURT
BARABOO, WI 53913

with a scope of:

PRODUCTION OF CUSTOM PLASTIC EXTRUSIONS, INJECTION MOLDING, PRODUCTS AND COMPOUNDED MATERIALS USING NATURAL FIBERS AND SYNTHETIC POLYMERS AND LABORATORY SAMPLING BAGS

has established a quality management system that is in conformance with the International Quality System Standard

ISO 9001:2015

ASR Certificate Number:	5750
Date of Certification:	June 11, 2021
Date of Certification Expiration:	June 10, 2024
Date of Initial Registration:	August 8, 2012
Revision:	
Re-Issue Date:	

Richelle Kinzie
President

CERTIFICATE OF REGISTRATION

Figure 1: Teel's ISO 9001 certification

Manufacturing Facility

Teel's gas pipe is manufactured in an approxximately 435,000 sq. ft. facility capable of extrusion line lengths of 450 feet. The facility includes a state-of-the-art chilled water system. The chiller is designed to cut energy usage up to 30% compared to a conventional chiller. Accessible by rail or truck, the location's six silos can house over 200,000 lbs. of resin each.

Figure 2: Images of Teel's Industrial Court manufacturing facility and product

Print Line

Teel’s gas pipe includes a print line conveying key information about manufacture and composition. Printed data includes:

- Size
- Wall thickness
- Company name
- Material
- Product type
- HDB & fusion code
- ASTM D2513
- No regrind (NR)
- Work order number
- 16-digit code
- Manufacture date
- Time stamp
- Barcode
- Footage marker

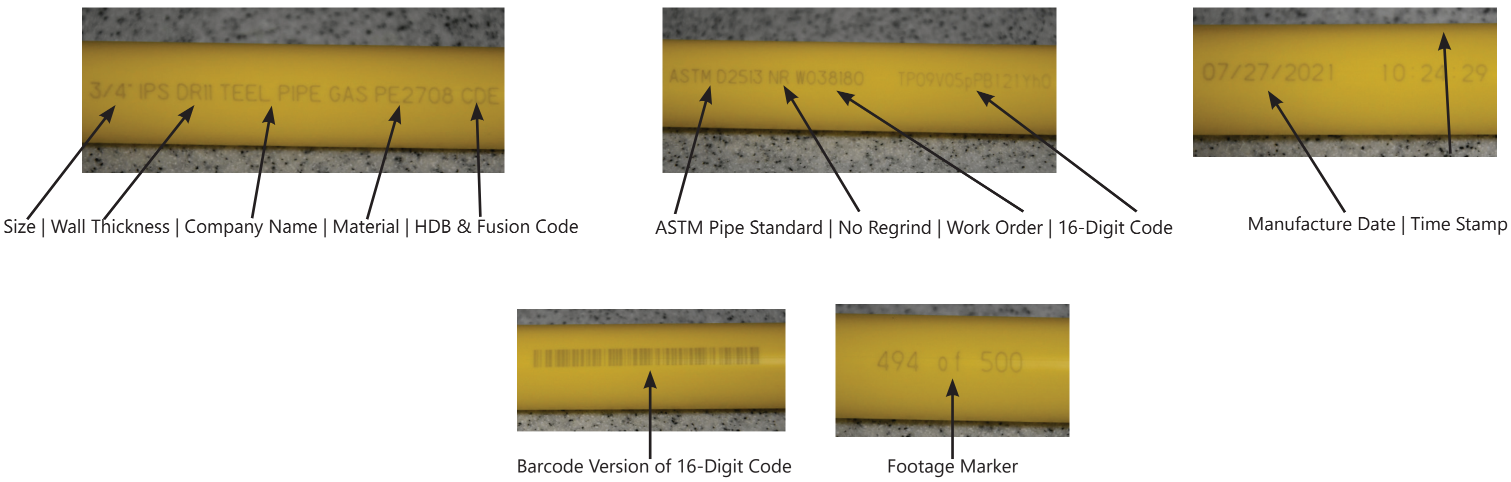


Figure 3: Teel’s print line system in-use and closeups of printing on a pipe product

Specifications and Packaging Data

IPS Pipe Data						Coil Packaging Data						Stick Packaging Data			
Size	SDR	Mat.	Avg. OD (IN)	Min. Wall (IN)	Weight (LBS/FT)	Coil Lengths (FT)	Coil Size ID/OD/W (IN)	Pallet Size (IN)	Coils/ Pallet	Feet/ Pallet	Pallets/ Truck	40FT Sticks/ Bundle	Feet/ Bundle	Feet/ Truck	Bundles/ Truck
1/2"	9.33	MDPE	0.840	0.090	0.091	500	30/43/6-1/2	44	11	5500	26	-	-	-	-
		HDPE													
3/4"	11	MDPE	1.050	0.095	0.122	500	30/43/10-3/8	44	7	3500	26	-	-	-	-
		HDPE													
	11.5	MDPE	1.050	0.091	0.120	500	30/43/10-3/8	44	7	3500	26	-	-	-	-
		HDPE													
1"	11	MDPE	1.315	0.120	0.190	500	30/43/12-1/2	44	5	2500	26	-	-	-	-
		HDPE													
1-1/4"	10	MDPE	1.660	1.166	0.340	500	48/72/7-1/2	44	12	6000	7	-	-	-	-
		HDPE													
2"	11	MDPE	2.375	0.216	0.630	250	48/78/8	78	10	2500	7	98	3920	47040	12
						500	48/78/13	78	7	3500	7				
		HDPE			0.635	1000	48/78/28	78	3	3000	7				
						1500	48/78/38	78	2	3000	7				
3"	11	MDPE	3.500	0.318	1.370	250	70/96/13	96	7	1750	6	50	2000	24000	12
		HDPE			1.378	500	70/96/24	96	4	2000	6				
						1000	70/96/46	96	2	2000	6				
	11.5	MDPE	3.500	0.304	1.307	250	70/96/13	96	7	1750	6	50	2000	24000	12
		HDPE			1.322	500	70/96/24	96	4	2000	6				
						1000	70/96/46	96	2	2000	6				
4"	11	MDPE	4.500	0.409	2.260	500	70/96/41	96	2	1000	6	29	1160	16240	12
		HDPE			2.310	1000	84/116/48	Cradle	1	1000	8				
	11.5	MDPE	4.500	0.391	2.267	500	70/96/41	96	2	1000	6	29	1160	16240	12
		HDPE			2.267	1000	84/116/48	Cradle	1	1000	8				
	13.5	MDPE	4.500	0.333	1.880	500	70/96/41	96	2	1000	6	29	1160	16240	12
		HDPE			1.920	1000	84/116/48	Cradle	1	1000	8				
6"	11	MDPE	6.625	0.602	4.900	-	-	-	-	-	-	13	520	6240	12
		HDPE			5.000	-	-	-	-	-	-				
	11.5	MDPE	6.625	0.576	4.710	-	-	-	-	-	-	13	520	6240	12
		HDPE			4.770	-	-	-	-	-	-				
	13.5	MDPE	6.625	0.491	4.070	-	-	-	-	-	-	13	520	6240	12
		HDPE			4.150	-	-	-	-	-	-				

Measures are approximate and may vary.

CTS Pipe Data					Coil Packaging Data		
Size and Color	**Mat.**	**Avg. OD (IN)**	**Min. Wall (IN)**	**Weight (LBS/FT)**	**Coil Lengths (FT)**	**Packaging ID/OD/W (IN)**	**Coils/Pallet**
1/2” Yellow	MDPE	0.625	0.090	0.064	500 1000	30/43/3-2/3 30/43/6-1/2	18/11
1/2” Black/Yellow Stripe	HDPE	0.625	0.090	0.064	500 1000	30/43/3-2/3 30/43/6-1/2	18/11
1” Yellow	MDPE	1.125	0.090	0.126	500	30/43/11	6
1” Black/Yellow Stripe	HDPE	1.125	0.090	0.126	500	30/43/11	6
1”Yellow	MDPE	1.125	0.099	0.137	500	30/43/11	6
1” Black/Yellow Stripe	HDPE	1.125	0.099	0.138	500	30/43/11	6
1”Yellow	MDPE	1.125	0.101	0.131	500	30/43/11	6
1” Black/Yellow Stripe	HDPE	1.125	0.101	0.141	500	30/43/11	6

Measures are approximate and may vary.

Figure 4: Teel’s gas pipe specifications and packaging data charts

Plastics Pipe Institute Material Listings

Teel's 4710 and 2708 polyethlyene gas pipe materials are listed with the Plastics Pipe Institute (PPI) as meeting applicable standards.

Teel Plastics, Inc. | PE 2708 | Teel MDPE Gas Pipe

Temp (ºF)	MRS (MPa)	CRS (θ,t)	HDB (psi)	HDS (psi)	SDB (psi)	PDB (psig)	Grade
140			800				S
73			1250	800			S*

Teel Plastics, Inc. | PA 42316 | Teel PA-12

Temp (ºF)	MRS (MPa)	CRS (θ,t)	HDB (psi)	HDS (psi)	SDB (psi)	PDB (psig)	Grade
73			3150	1600			S
140			2000				S
180			1600				E-10

Teel Plastics, Inc. | PE 4710 | Teel PE4710 Pipe 1

Temp (ºF)	MRS (MPa)	CRS (θ,t)	HDB (psi)	HDS (psi)	SDB (psi)	PDB (psig)	Grade
73			1600	1000			S*
140			1000				S

Teel Plastics, Inc. | PE 4710 | Teel PE4710 Pipe 2

Temp (ºF)	MRS (MPa)	CRS (θ,t)	HDB (psi)	HDS (psi)	SDB (psi)	PDB (psig)	Grade
140			1000				S
73			1600	1000			S*

Teel Plastics, Inc. | PE 4710 | Teel PE4710 Pipe 3

Temp (ºF)	MRS (MPa)	CRS (θ,t)	HDB (psi)	HDS (psi)	SDB (psi)	PDB (psig)	Grade
73			1600	1000			S*
140			1000				S

Figure 5: Teel's material listings on the PPI website

Qualification Testing for Joining Procedures

Teel's 4710 and 2708 material gas pipe passed the tests required for joining gas pipe per ASTM F2620, specifically ASTM D638 (axial) Tensile Properties, Bend Back per ASTM F2620 Appendix X4, and Quick Burst per ASTM D1599. Teel's pipe is cell class 3 or 4 for melt and should able to fuse with any other pipe material with the same melt flow classification.

Summary

1. ASTM D638 tensile testing requirements specify that the percent elongation at break for each test sample shall exceed 50%, which is beyond the yield strength of 2708 and 4710 material. Teel pipe tested at greater than 50% elongation with a butt fusion in the middle.
2. ASTM F2620 bend back testing specifies that to the unaided eye, test samples must not show any indication of brittle cracking or crazing in the ID surface. The images below of the tested samples show no cracking or separation.
3. ASTM 1599 quick burst testing requirements specify that test samples shall fail in a ductile manner and not at the weld. Additionally, for the sizes of Teel pipe tested, the burst pressure must equal at least 2520 psi hoops stress for 2708 material and at least 2900 psi hoops stress for 4710 material. Teel's gas pipe samples failed in a ductile manner outside of the fusion location and met the psi requirements.

Details

Below is fuller information on the results of each test preformed from the testing report by the third-party testing firm, PSILAB (https://www.psilab.net/capabilities).
Tensile Properties: Tensile properties were determined in general accordance with ASTM D638-14, *Standard Test Method for Tensile Properties of Plastics.* Test specimens were machined into Type I specimens directly from the pipe walls with the full pipe wall thickness intact. Each specimen was machined with the butt-fusion at the middle of the gauge area. Testing was conducted at 2.0 inches/min using crosshead displacement for elongation readings. Each specimen was taken to a minimum of 50% elongation.

ASTM D638 Tensile Properties - HDPE to HDPE				
Sample #	Width , in	Thickness, in	Tensile Strength @ Yield, psi	Elongation @ yield, %
1	0.504	0.227	3,289	8.8
2	0.499	0.224	3,304	8.6
3	0.501	0.230	3,337	8.7
4	0.503	0.231	3,297	8.7
5	0.501	0.232	3,299	8.8
Average			**3,305**	**8.7**
Std. Dev.			**19**	**0.1**

ASTM D638 Tensile Properties - HDPE to MDPE				
Sample #	Width , in	Thickness, in	Tensile Strength @ Yield, psi	Elongation @ yield, %
1	0.500	0.227	2,685	6.7
2	0.502	0.223	2,657	7.0
3	0.499	0.230	2,636	7.2
4	0.501	0.228	2,671	7.1
5	0.503	0.227	2,615	6.9
Average			**2,653**	**7.0**
Std. Dev.			**28**	**0.2**

ASTM D638 Tensile Properties - MDPE to MDPE				
Sample #	Width , in	Thickness, in	Tensile Strength @ Yield, psi	Elongation @ yield, %
1	0.499	0.230	2,502	10.0
2	0.500	0.221	2,535	10.1
3	0.500	0.228	2,577	9.9
4	0.501	0.227	2,589	10.1
5	0.499	0.228	2,575	9.8
Average			**2,555**	**10.0**
Std. Dev.			**36**	**0.1**

Figure 6: Teel's 4710 and 2708 tensile properties test data

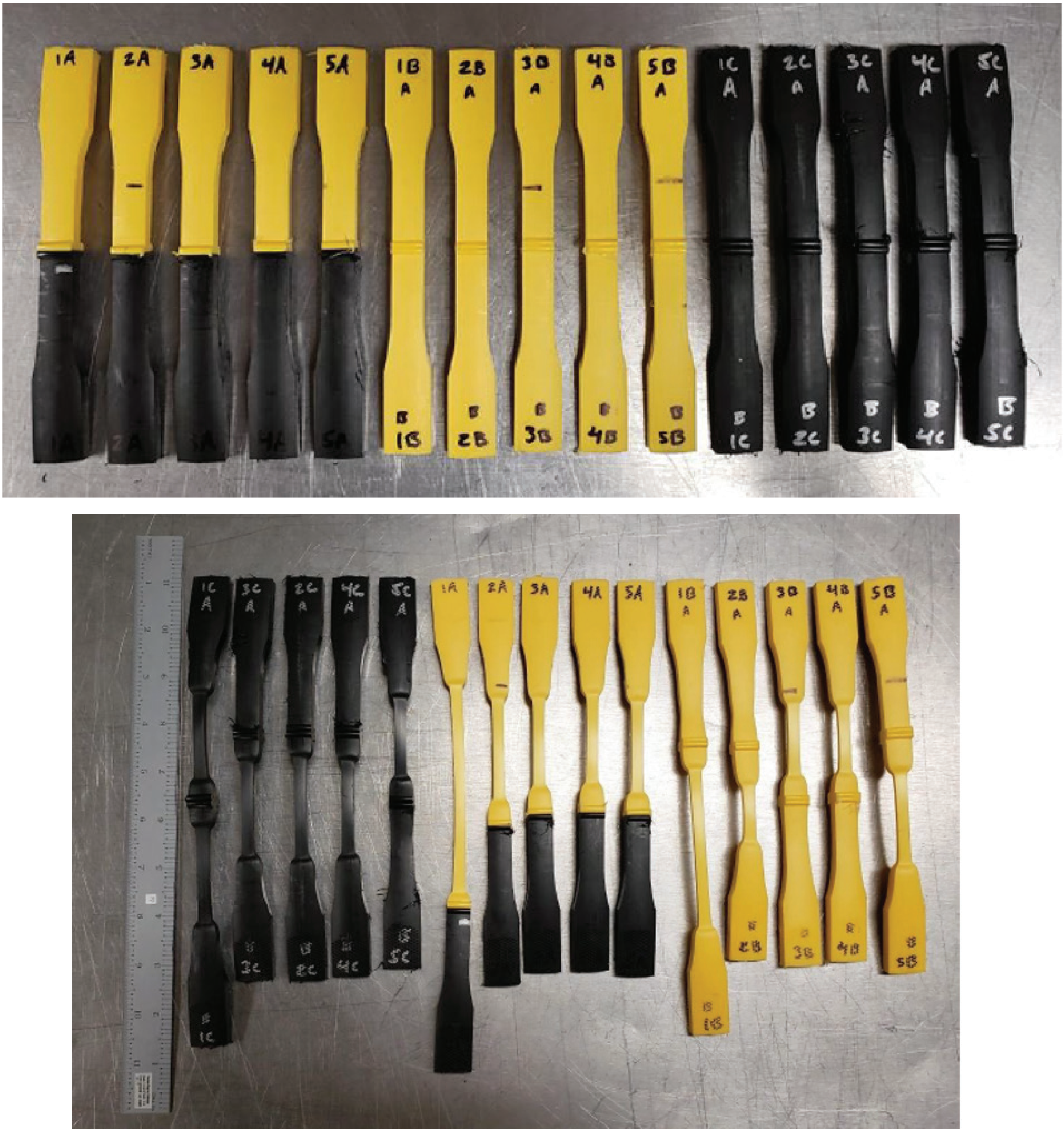


Figure 7: Teel's tensile properties test samples before and after testing

Bend Back

Bend Back testing was performed in accordance with ASTM F2620-13, *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings; Appendix X4, BEND BACK TESTING OF FUSED JOINTS*. Test specimens were machined into 1" x 12" test straps with the butt-fusion at the midpoint of each strap. Five specimens from each sample group were tested.

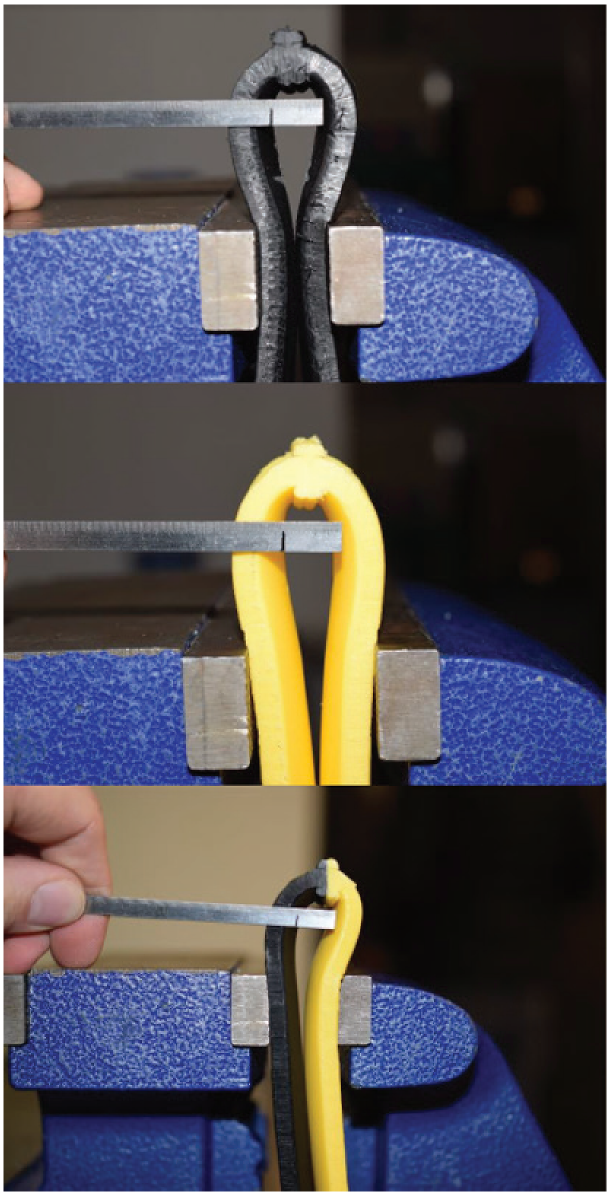


Figure 8: Teel's bend back test samples after testing

Quick Burst

Quick Burst testing was performed in accordance with ASTM D1599-18, *Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings, condition A*. Five specimens from each of the three sample groups were tested. Although ASTM D1599 requires rupture between 60 and 70 seconds, the client requested that only three of the five quick burst tests for each of the three samples achieve burst within the required 60 to 70 seconds. No dimensions were taken on the specimens per the clients' request; therefore, actual hoop stresses for each test specimen were not determined.

ASTM 1599 Quick Burst - HDPE to HDPE				
Sample Number	Sample ID	Time to Burst, sec	Burst Pressure, psi	Failure Mode
1	10	66	767	All samples failed in a ductile manner outside of the fusion locations.
2	12	70	767	
3	13	71	754	
4	14	68	755	
5	15	69	761	
Average		**69**	**761**	

ASTM 1599 Quick Burst - HDPE to MDPE				
Sample Number	Sample ID	Time to Burst, sec	Burst Pressure, psi	Failure Mode
1	41	65	612	All samples failed in a ductile manner outside of the fusion locations.
2	42	65	617	
3	43	64	608	
4	44	66	618	
5	45	64	615	
Average		**65**	**614**	

ASTM 1599 Quick Burst - MDPE to MDPE				
Sample Number	Sample ID	Time to Burst, sec	Burst Pressure, psi	Failure Mode
1	68	70	586	All samples failed in a ductile manner outside of the fusion locations.
2	69	66	599	
3	70	65	607	
4	71	64	600	
5	75	70	588	
Average		**67**	**596**	

Figure 9: Teel 2710 and 2708 quick burst test data

Figure 10: Teel's 2710 and 2708 quick burst test samples after testing

Field and Laboratory Performance Tests

Teel's 4710 and 2708 gas pipe have been field tested by third-party testing firm GTI (https://www.gti.energy/). Each test and its results are included below.

HDD Installation Test

For this test, Teel MDPE and HDPE gas pipe samples were installed via HDD in GTI's pipe farm. Prior to installation, the following procedures were performed on each pipe:

1. Butt-fusion joints were made equidistantly along the length of the pipe in accordance with PPI TR-33.
2. Squeeze-offs were performed equidistantly along the length of each pipe in accordance with PPI TN-54.

The pipes were then pulled through clay soil and buried in clay under 60 psig internal air pressure for up to six months. At time intervals of approximately 500, 1,000, 2,000, and 4,000 hours, three 16"-long specimens were randomly exhumed and subjected to quick burst testing in accordance with ASTM D1599. Specimens were selected to include either a butt-fusion joint or a squeezed-off location. A total of 24 quick bursts were performed (i.e., 12 tests for each pipe material).

Figure 11: Field test HDD installation in progress

Above-Ground Installation Test

For this test, Teel MDPE and HDPE gas pipe samples were installed under 60 psig of internal air pressure above ground on top of the HDD installation location in GTI's pipe farm. Prior to installation, 12 coupling joints were made using either HDPE or MDPE socket fusion couplings.

Socket fusions were performed in accordance with ASTM F2620-20, *Standard Practice for Heat Fusion of Polyethylene Pipe and Fittings*. At time intervals of approximately 500, 1,000, 2,000, and 4,000 hours. Three 16"-long specimens of each pipe sample were randomly extracted and subjected to quick burst testing in accordance with ASTM D1599. A total of 24 quick bursts were performed (i.e., 12 tests for each pipe material).

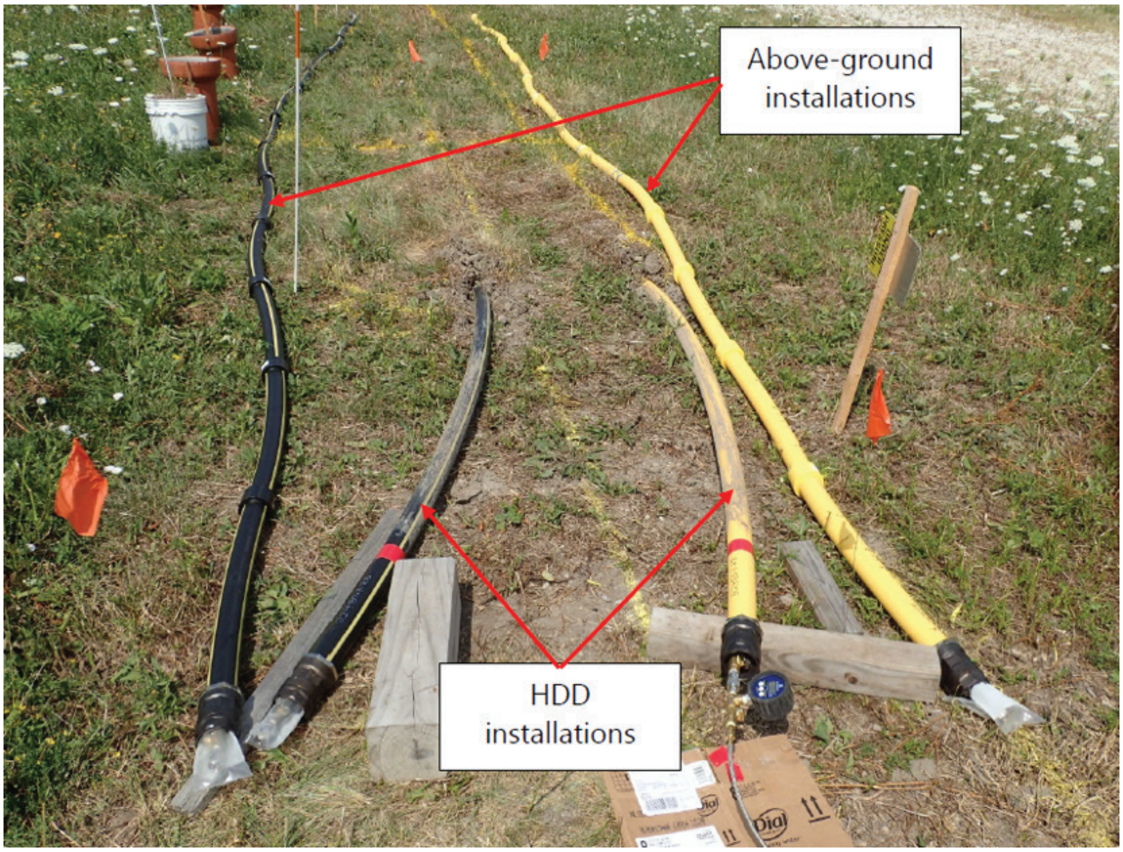


Figure 12: Completed above-ground and HDD installations

Field Test Results

All of Teel's samples, both the butt-fused and squeezed-off assemblies HDD installed and the socket-fused assemblies installed above ground, failed in a ductile manner when tested according to ASTM 1599 and meet the hydrostatic burst pressure requirements of ASTM D2513-18a. All sample failures occurred in the pipes and all the fusions were intact. Test result summary data is below.

Table 3. Summary of HDPE Burst Test Results

GTI Sample ID	Installation Method	Specimen Type	Extraction Frequency	Average Burst Pressure (psig)	Average Hoop Stress (psi)	Failure Mode and Location
202439	Above-ground	Socket-fused assembly	500-h	814 ± 2	3,892 ± 8	Ductile rupture of pipe
			1,000-h	820 ± 9	3,958 ± 46	Ductile rupture of pipe
			2,000-h	835 ± 5	3,996 ± 22	Ductile rupture of pipe
			4,000-h	788 ± 6	3,747 ± 31	Ductile rupture of pipe
202444*	HDD	Butt-Fused and Squeezed-off assembly	500-h	817 ± 13	3,863 ± 60	Ductile rupture of pipe
			1,000-h	821 ± 9	3,922 ± 42	Ductile rupture of pipe
			2,000-h	836 ± 4	3,999 ± 19	Ductile rupture of pipe
			4,000-h	792 ± 8	3,798 ± 38	Ductile rupture of pipe

* Sample ID assigned to butt-fused and squeezed-off assemblies made with HDPE Sample 202439

Table 4. Summary of MDPE Burst Test Results

GTI Sample ID	Installation Method	Specimen Type	Extraction Frequency	Average Burst Pressure (psig)	Average Hoop Stress (psi)	Failure Mode and Location
202440	Above-ground	Socket-fused assembly	500-h	663 ± 0	3,140 ± 2	Ductile rupture of pipe
			1,000-h	680 ± 1	3,217 ± 11	Ductile rupture of pipe
			2,000-h	688 ± 2	3,199 ± 8	Ductile rupture of pipe
			4,000-h	644 ± 1	3,055 ± 22	Ductile rupture of pipe
202445*	HDD	Butt-Fused and Squeezed-off assembly	500-h	664 ± 11	3,129 ± 52	Ductile rupture of pipe
			1,000-h	673 ± 7	3,170 ± 32	Ductile rupture of pipe
			2,000-h	677 ± 9	3,164 ± 34	Ductile rupture of pipe
			4,000-h	655 ± 6	3,083 ± 48	Ductile rupture of pipe

* Sample ID assigned to butt-fused and squeezed-off assemblies made with MDPE Sample 202440

Figure 13: Field test summary data

Laboratory Testing

GTI also performed a series of lab tests on Teel's gas pipe, Each test type is listed below with its purpose:

1. Long-term Hydrostatic Strength (LTHS) Tests
   i. Long-term installed pipe performance tests predicting the life of Teel gas pipe installations.

2. Dynamic Thermo-Mechanical Analysis (DTMA)
   i. Determine the visco-elastic characteristics of the material

3. Tensile Testing
   i. Tested in accordance with ASTM D638 die cut from the pipe

Long-term Performance of Teel Pipe

To determine Teel gas pipe's long-term performance, GTI performed LTHS tests on one set of PE2708 MDPE Teel pipe and one set of PE4710 HDPE Teel pipe. The LTHS tests were performed at 23°C, 40°C, 60°C, and 80°C. The results are shown below in figure 14 and figure 15. The model curves on these figures are the GTI lifetime prediction model (LPM) fitted to the LTHS data and using the horizontal activation energy obtained by DTMA.

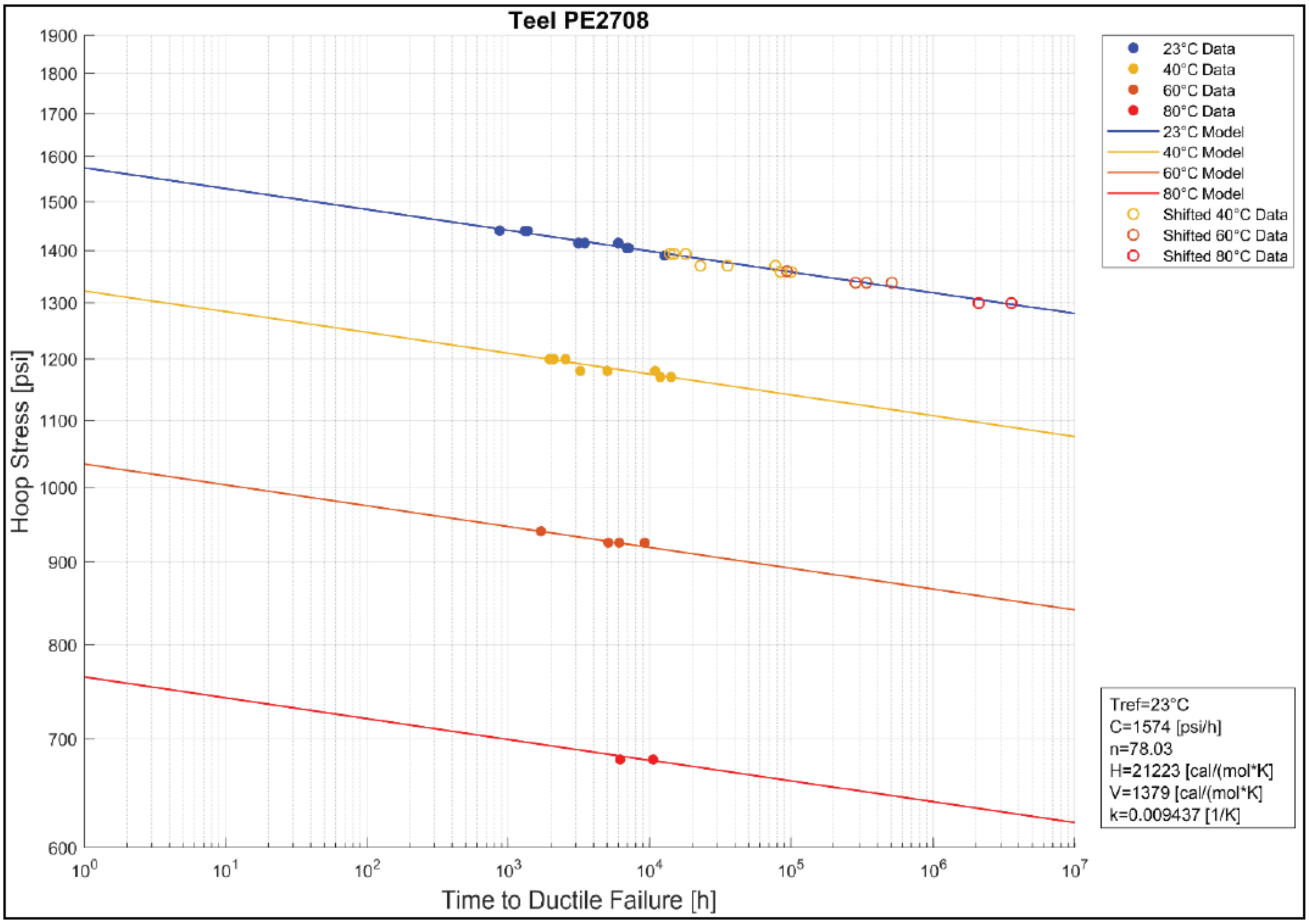


Figure 14: PE2708 LTHS test results. LPM parameters are shown in bottom right text box.

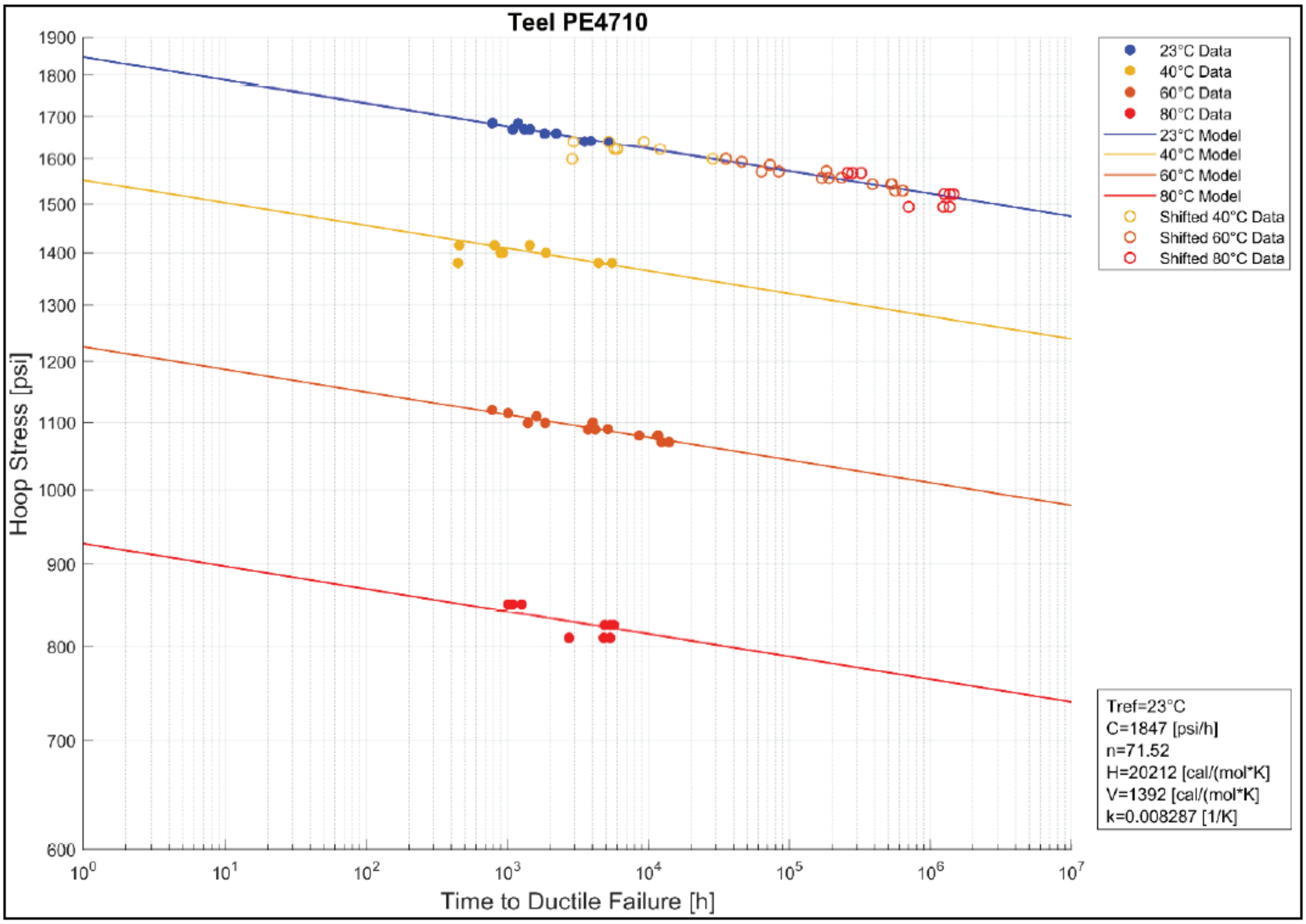


Figure 15: PE4710 LTHS test results. LPM parameters are shown in bottom right text box.

The performance quality of Teel's gas pipe was then examined by evaluating the LTHS performance versus a virtual upper performance bound. The upper performance bound was established by taking the highest engineering yield stress that was obtained by the 1-hour break tensile tests at 23°C and using it as the 1-hour intercept in the LPM model. The resulting "best yield" reference curves for the PE2708 and PE4710 are shown in figure 16 and figure 17 below.

Equivalent stress intensification factors (SIFs) were obtained by the ratio of the "best yield" model to the actual LTHS test data. The SIFs were then plotted on a histogram for inspection of their distribution (figures 18 and 19). The distribution reflects the manufacturing quality of the pipe, where the tighter the distribution, the higher the quality. Both material sets exhibited tight SIF distributions with a similar mean SIF.

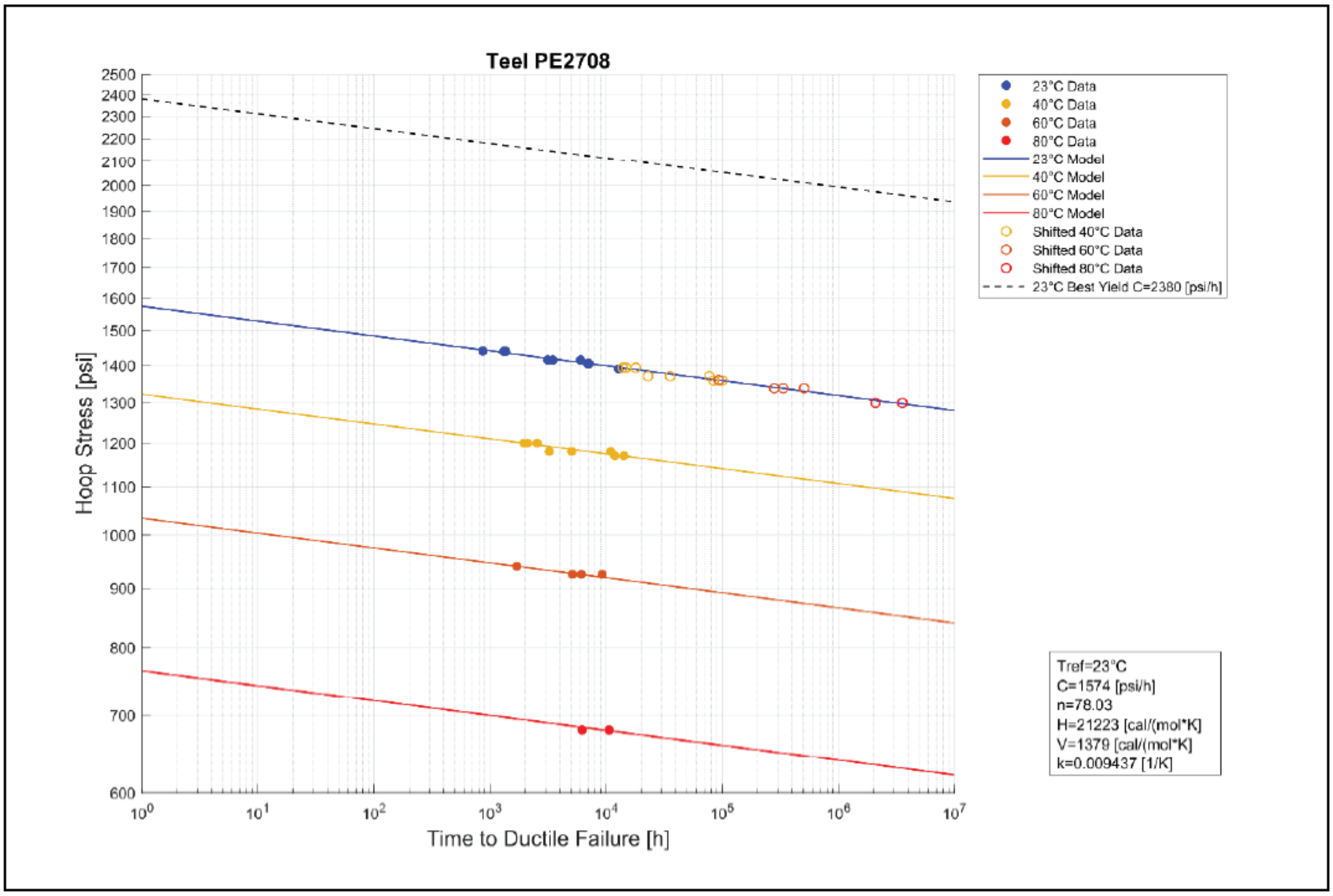


Figure 16: PE2708 LTHS test results with "best yield reference curve.

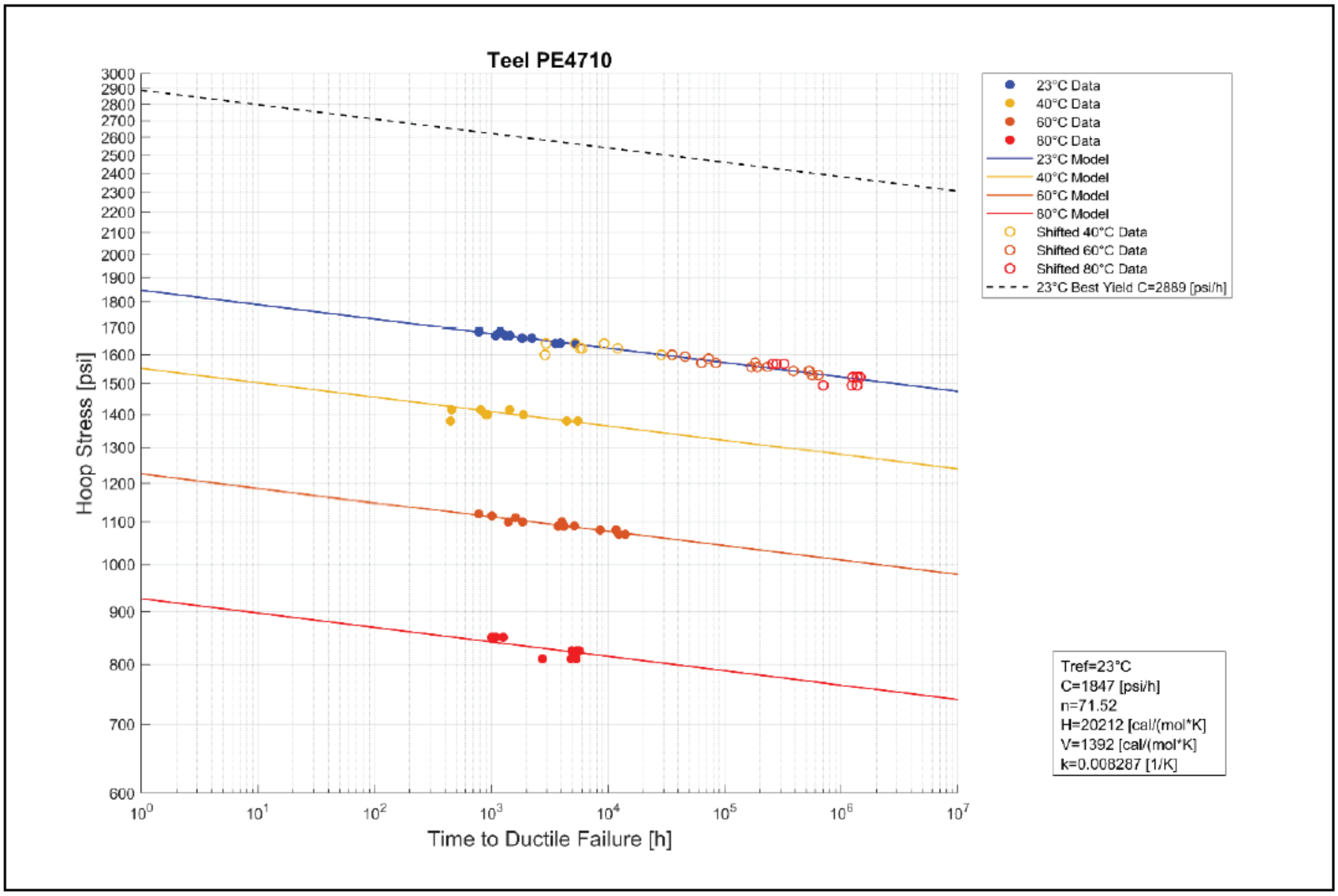


Figure 17: PE4710 LTHS test results with "best yield reference curve.

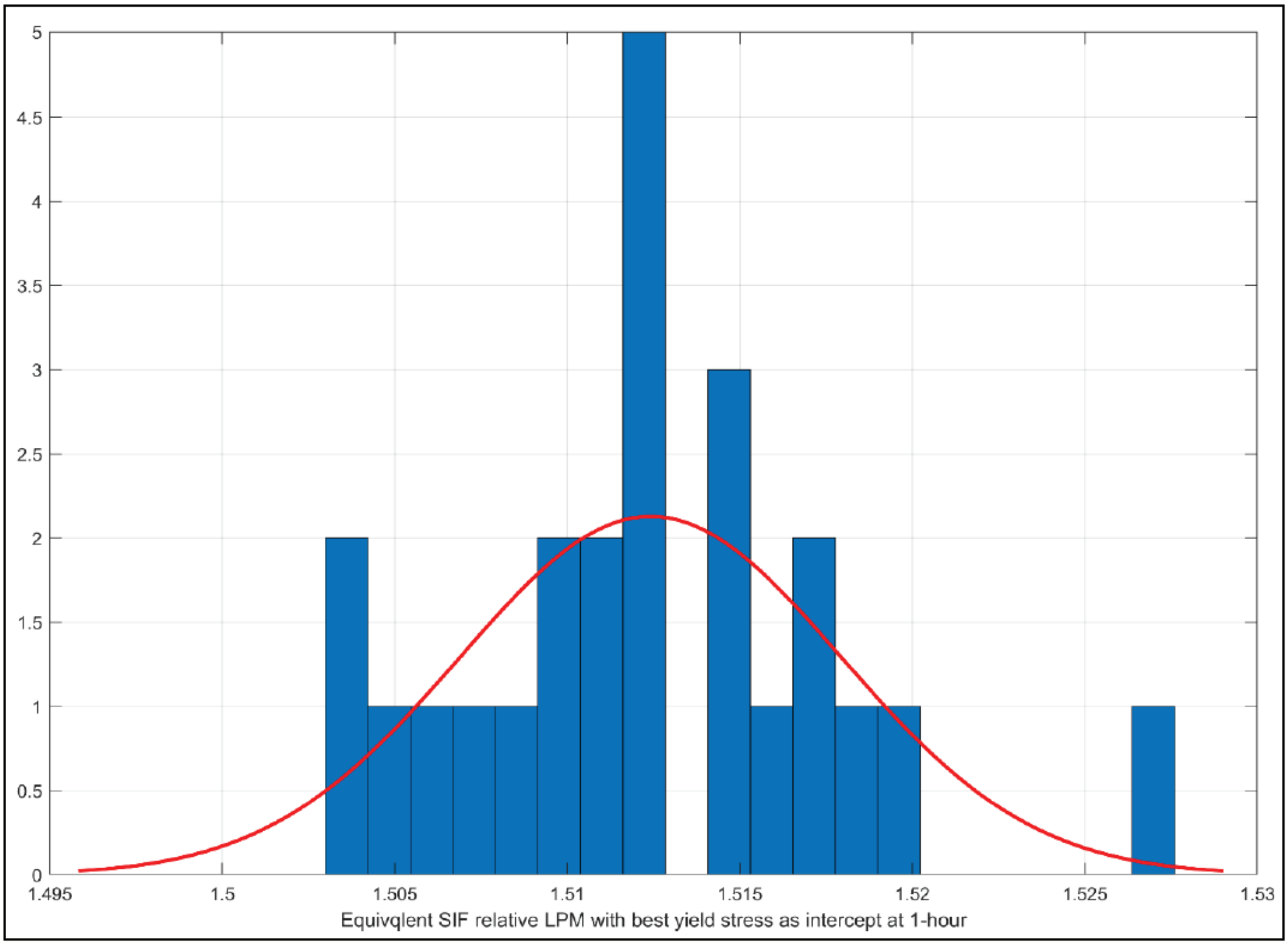


Figure 18: PE2708 LTHS SIF histogram with normal distribution fit. Mean SIF=1.5124.

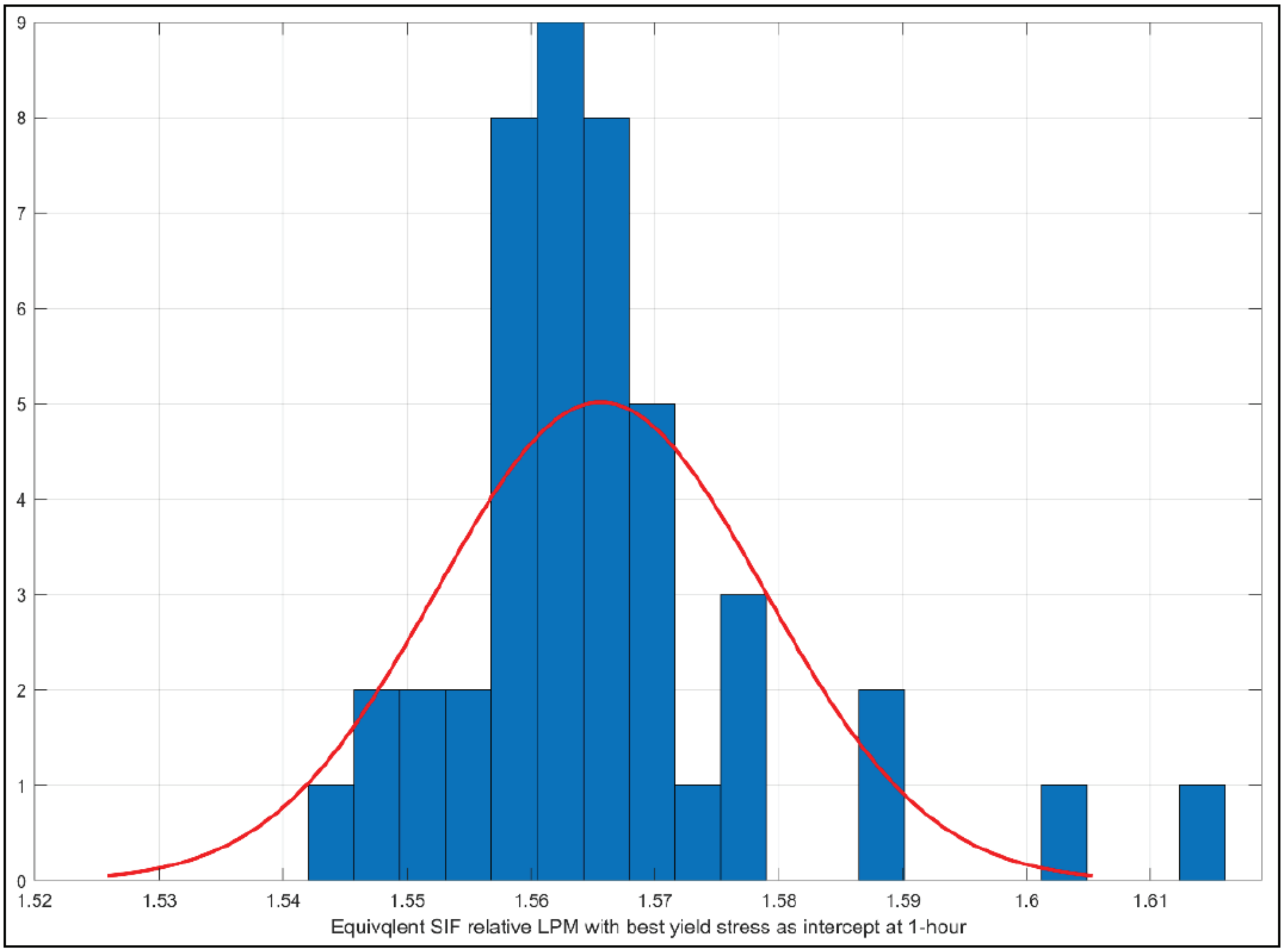


Figure 19: PE4710 LTHS SIF histogram with normal distribution fit. Mean SIF=1.5656.

GTI Energy Quality Audit

In summer 2023, Teel was audited by GTI Energy for the quality of its gas pipe production operations. GTI is an industry leader in the verification of gas pipe production for PHMSA-regulated markets. Below is summary information and a list of highlights.

Scope

The audit focused on the extrusion process for Teel's MDPE gas pipe and all supporting processes required by ISO 9001:2015. The criteria of the audit were ISO 9001:2015, Teel Plastics' internal procedures, ASTM D2513-18a, and the observed test methods referenced in ASTM D2513-18a for pipe and resin.

Quality Performance Commendation

According to GTI's audit summary: *"The company's commitment to quality is apparent. Teel Plastics is accredited to three quality management systems: ISO 9001:2015 for industrial products, ISO 13485:2016 for medical devices, and ISO 17025:2017 for laboratory competence. Teel Plastics has decided to adopt one comprehensive standardized quality management system for all products instead of creating one for medical devices with more prescriptive requirements and one for gas and conduit pipes. Thus, the company enters the natural gas pipe market with already well-developed quality habits doing more than the minimum required."*

Teel's performance also impressed a Teel customer who participated in the audit and stated, *"We frequently observed the mindset of going above and beyond minimum requirements. This mindset is reflected in the positive audit scores, especially in the technically focused areas: product testing, training, control of outputs, and traceability."*

World-class Ratings

Teel received world-class ratings in several areas, including:

Training

- Generic training requirements for any employee position are defined, and training is provided during the onboarding process
- Job-specific training checklists include requirements on how employees are to be trained

Document Control

- Notification of changes go to HR to assign training to affected employees
- Employees can see training they need to complete on individualized dashboards

Risk Management

- The risk assessment process and corrective actions were both rated excellent
- Corrective actions taken were well documented
- All nonconformances are logged and documented

Product Testing

- All inspection and testing requirements are documented per material and work order
- Testing beyond the minimum required is done on each work order

Overall Rating

Teel scored a Silver rating overall. More details are available in the full report.

ASTM D2513 Testing Schedule

Teel tests its gas pipe products in compliance with ASTM D2513. In certain instances, Teel exceeds the standard's requirements, testing more frequently. The tests performed are outlined in Figure 20 below, and those highlighted in yellow indicate where Teel exceeds the ASTM standard requirements. (Full charts on next page).

Figure 23: Teel's testing schedule in compliance with ASTM D2513

Material Requirements

Material Requirements	D2513 Section	ASTM Frequency	Teel Frequency	Provider/Tester
General	4.1	5 years	5 years	PPI
Rework Material	4.2	Virgin only	Virgin only	Teel Plastics
Documentation	4.3	All Production Work Orders	All Production Work Orders	Teel Plastics
Classification	4.4	All material lots	All material lots	Material supplier
Resistance to Slow Crack Growth	4.5	All material lots	All material lots	Material supplier
Additive Classes	4.6	All material lots	All material lots	Material supplier
Thermal Stability	4.7	All material lots	All material lots	Material supplier
Hydrostatic Design Basis Substantiation	4.8	All material lots	All material lots	Material supplier
Resistance to Rapid Crack Propagation	4.9	All material lots	All material lots	Material supplier
UV Resistance	4.10	All material lots	All material lots	Material supplier
Melt Index/Density	5.60	Not Required	All material lots	Teel Plastics

Pipe Requirements

Pipe Requirements	D2513 Section	ASTM Frequency	Teel Frequency	Provider/Tester
General	5.1	All Production Work Orders	All Production Work Orders	Teel Plastics
Workmanship	5.2	All Production Work Orders	All Production Work Orders	Teel Plastics
Pipe and Tubing Dimension and Tolerance	5.3	All Production Work Orders	All Production Work Orders and QA Inspection	Teel Plastics
Minimum Hydrostatic Burst Pressure	5.4	All Production Work Orders - Start up/Once Weekly	All Production Work Orders - Once/Shift	Teel Plastics
Chemical Resistance	5.5	1x	1x	Material supplier
Melt Index/Density	5.6	1x - Melt Index Only	All Production Work Orders	Teel Plastics
Sustained Pressure	5.7	2x per year (per size and material <2 and >2.5")	2x per year (per size and material <2 and >2.5")	Teel Plastics
Elevated Temperature Service	5.8	1x	1x	Material supplier
HDB Validation for PE Pipe	5.9	1x	1x	Material supplier
Resistance to Rapid Crack Propagation	5.10	1x	1x	Material supplier
Inside Surface Ductility	5.11	1x	All Production Work Orders	Teel Plastics
Squeeze Off	5.12	1x	1x	Teel Plastics
Heat Fusion	5.13	1x	1x	Teel Plastics

Figure 20: Teel's testing schedule in compliance with ASTM D2513

Inline Gauging

Sikora X-Ray Technology

Teel uses Sikora X-Ray technology for inline gauging. The Sikora units measure in 2-axis and determine wall accuracy to 0.0002”. The system scans three times per second, meaning at 25fpm, it achieves 7.2 scans per foot. Part temperature is not a factor in the Sikora’s operation. Below is a white paper with a fuller explanation of how it works.

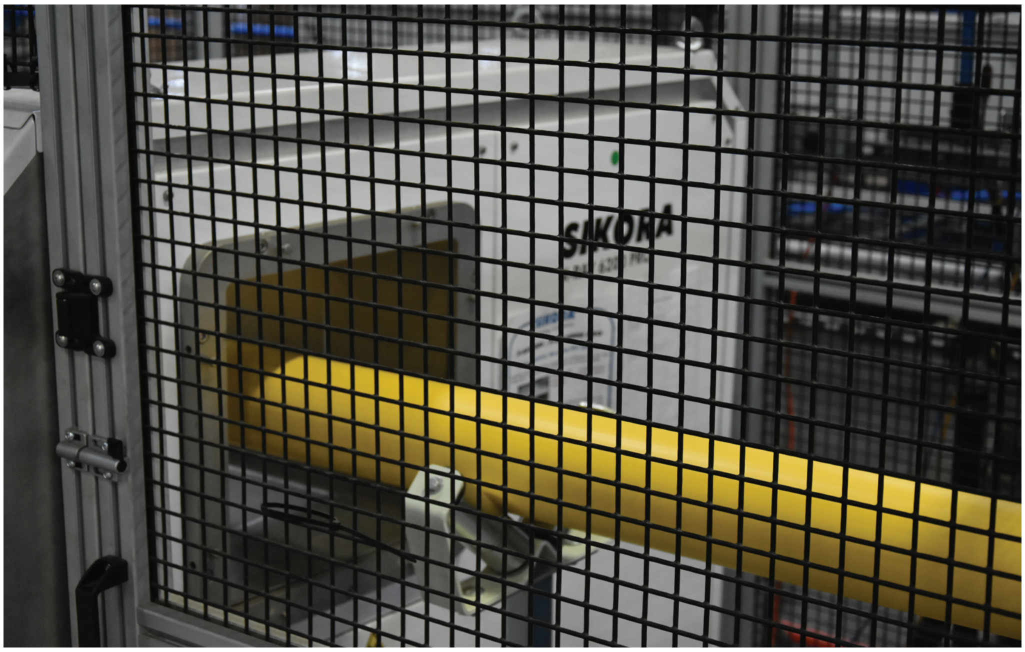


Figure 21: Teel’s Sikora units inline

Teel Pipe: Small Diameter Gas Pipe In-Line Inspection

January 27, 2022

Background

Teel Pipe produces coil and stick GAS pipe for sizes ≤1.00CTS on a specialized line using a SIKORA X-RAY 6000 PRO series measurement device for continuous in-line inspection of the pipe.

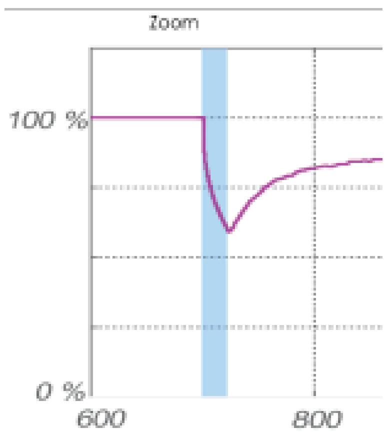
SIKORA AG, headquartered in Bremen, Germany, is the supplier of this technology and have been producing inline measurement and control products since 1973. Teel has been using X-ray technology for in-line inspection of our products since 2016. Teel selected this technology for use in highly regulated markets because of the ease of operation and data acquisition for quality control as well as the ease of operator interface.

Inspection Process

The SIKORA X-RAY 6000 PRO uses X-rays instead of sound for measurement and data collection. The use of X-rays means the data is not subject to issues from water quality or part temperature as ultrasonic devices are. While in operation, the X-RAY 6000 PRO captures data on the pipe three times per second. This cycle is completed in a very short aperture time of 3ms - 6ms or less, which eliminates any vibrational impact. The device uses linear X-ray sensors with >3,000 pixels to ensure highest accuracy.

Data collected includes OD, ID, ovality, wall thickness, minimum wall thickness, concentricity, and eccentricity. The values are correlated to offline inspection reports for final part dimensions to take account of any shrinkage.

The logic of the inspection cycle utilizes intensity to determine its measurements. As the X-rays travel through the pipe, the material causes attenuation with crisp start and stop points. The start and stop points of high attenuation are represented graphically in the image at right and correspond to wall thickness. The distance the radiation travels through the pipe wall is inverse to the intensity.



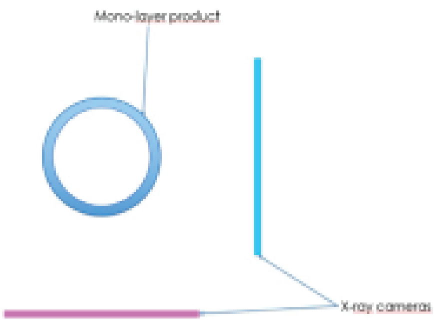
→A short distance results in high intensity and a strong signal

→A long distance results in low intensity and a weak signal

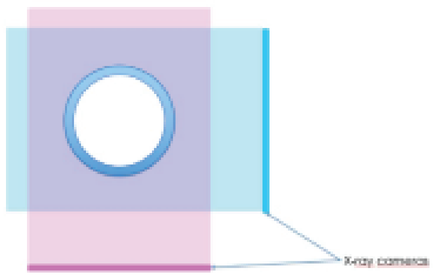
The areas shown in the graph are created for two axes showing four distinct wall segments. These walls are measured in real time as the process is running. On a product running 25 feet per minute, or five inches per second, a three measurement per second frequency results in a scan every 1.66” of the pipe. This scan is captured and averaged with three other scans to provide a value for the wall thickness. This data is then processed to determine average and minimum wall thicknesses. The averaging of scans is needed to create a best-fit model for inner and outer wall.

Post capture analyzing, which also happens in real time, fits the wall measurement points into two overlapping rectangles. These rectangles each have an ellipse fit into them using a best-fit method and the tangent points of the defined rectangles. One ellipse is the outer wall of the pipe, and the second ellipse is the inner wall of the pipe. The analysis of these two ellipses allows the maximum and minimum wall thicknesses to be determined within a few degrees of accuracy compared to physical measurements of the pipe. It also allows the wall thickness at any point of the part (360°) to be determined with high accuracy.

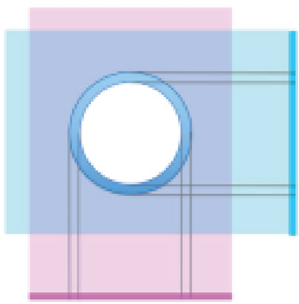
A Visual Step-Through of the Process



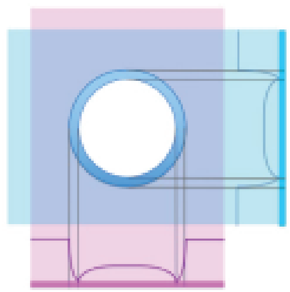
1-We start with the object and the X-ray cameras.



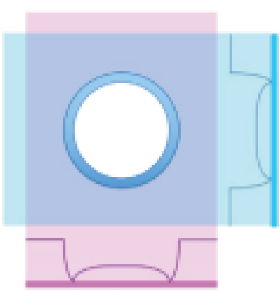
2-The system flashes (3Hz). Cameras measure the intensity.



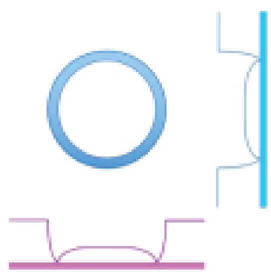
3-Grey lines mark the areas, where changes will appear.



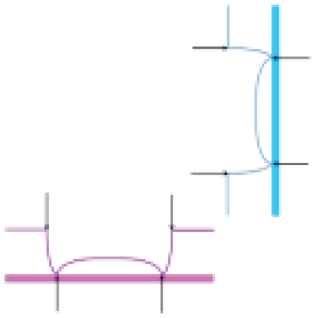
4-Attenuation causes a change of intensity on the cameras.



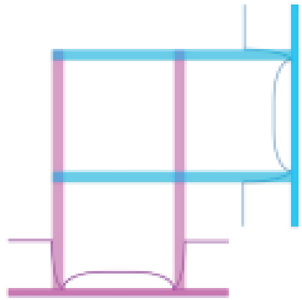
5-Shown intensity- curves are the result of changed intensity.



6-Shown intensity- curves are the result of changed intensity

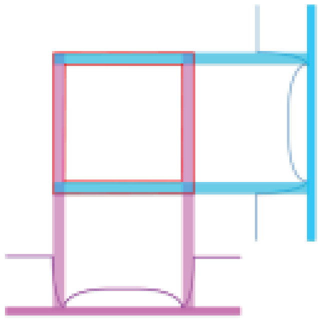


7-Points where changes in attenuation appear are clearly identified

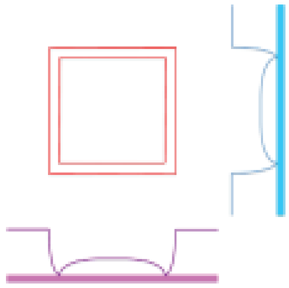


8-The width of each intensity-drop defines a beam.

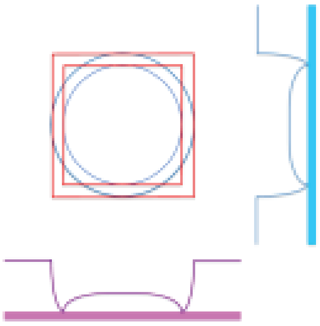
A. Juncture of the 4 beams defines a rectangle.
B. (Here a rectangle with similar side-lengths = square)



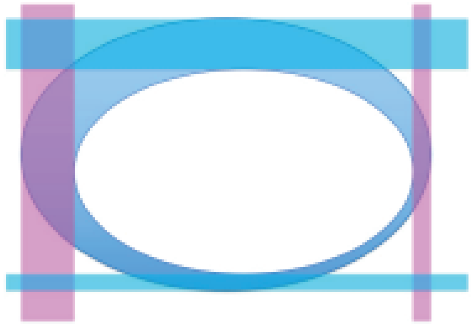
9-This rectangle consist of an inner- and outer rectangle.



10-This rectangle consist of an inner- and outer rectangle.



11-The rectangles define two circles
-> the inner and outer Ø tangent points

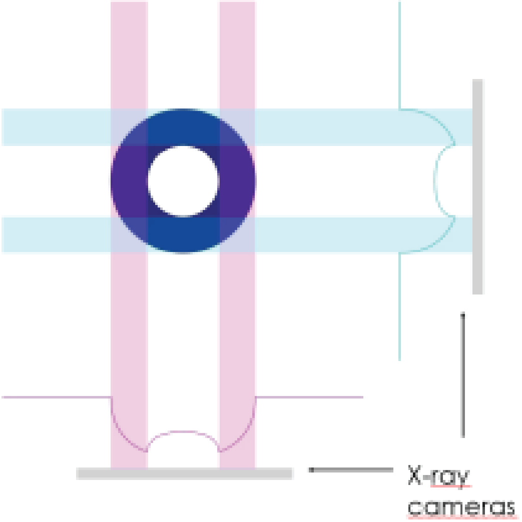


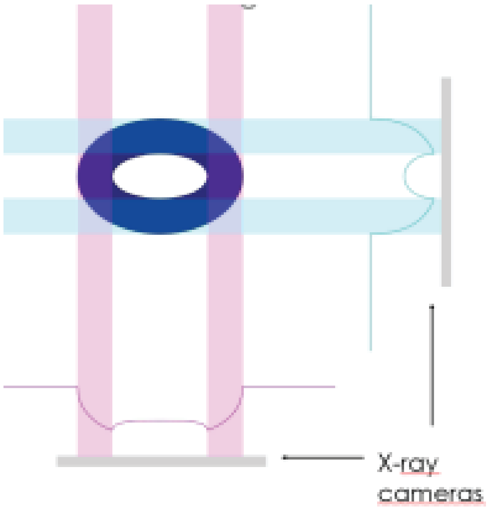
12-If the ellipse is not perfectly round, we see a more realistic example as above:

A. Position of both ellipses are clearly defined.
B. Eccentricity and ovality can clearly be identified
C. This allows determination of the wall-thickness at every point.

Ellipse Model Ovality

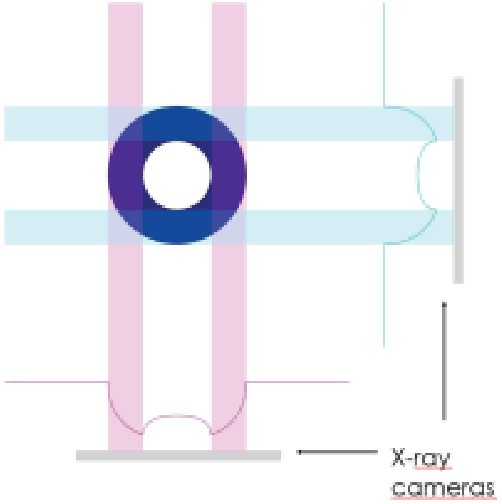
Model of Ovality capture showing the difference in long and short axes in the pipe using the correlating low or high intensity signal. This will determine the ovality using a standard max minus min calculation.

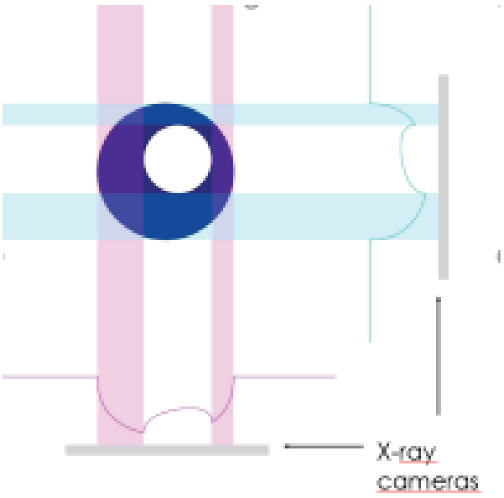




Ellipse model - Eccentricity

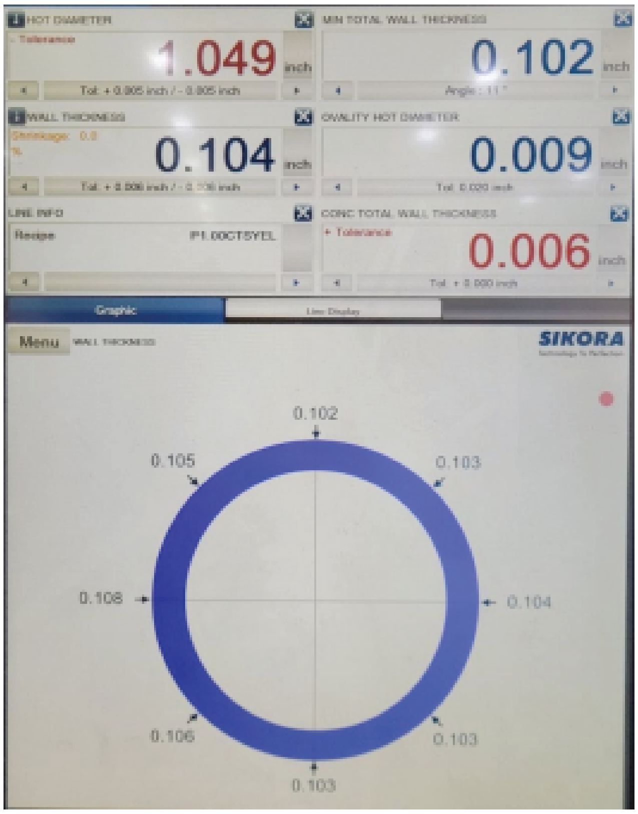
Model of Eccentricity capture showing the difference in long and short distance and the correlating low or high intensity signal. This will determine the area of minimum wall thickness and the relative center point of the two ellipses.





Summary

The X-ray inspection method measures the differences in low and high intensity signal. This shows wall thickness and uses ellipse-based analysis to model the pipe wall. The process outlined completes a full cross-sectional analysis of the pipe product (in 360°). Using elliptical data combined with eccentricity models enables a SIKORA X-RAY 6000 PRO to determine the min wall thickness location on the pipe within a resolution of 1°. The data can be accessed, saved, and stored for future reference.



Digital Display of Output in use at Teel – upper right component illustrates the Min. Total Wall Thickness as an example.

Diagrams courtesy of Sikora USA. For more information, please go to [X-RAY 6000 PRO - Sikora]

Please contact Teel Pipe for any questions on content or for more information on pipe.

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Figure 22: Teel's small diameter gas pipe in-line inspection white paper.

Gas Pipe Joining Procedures

Polyethylene Gas Pipe Hydraulic Butt Fusion Procedure

Introduction

This document has been developed to assist workers responsible for the butt fusion joining of Teel Plastics piping products used in gas and energy applications. This procedure is in alignment with ASTM F2620 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings. Refer to ASTM F2620 for more specific butt fusion information, guidance, and safety information when using #28, #412, and #618 fusion machines.

Equipment

The equipment needed for hydraulic butt fusion includes the proper hydraulically operated butt fusion machine for the pipes being fused, a facing unit, a heating unit for heating the ends of the pipe and the proper inserts for the pipe sizes to be butt fused. Pipe support rollers and stands are also needed to bring the pipes to be fused in alignment with the fusion machine centerline. With the McElroy #28 Fusion Machine, a 120VAC power supply is needed so a generator is usually required. Consult the fusion machine manufacturer's information on the generator size required. Some hydraulic butt fusion machines are self-contained and have their own generator.

Set-Up Guidelines

1. Make sure that the butt fusion equipment used meets the manufacturer's specifications and is in good working order before using.
2. Make sure the fusion machine operator has been trained properly on the hydraulic butt fusion machines being used, typically in accordance with ASTM F3190.
3. Set-up the fusion machine in a level area if possible. If the hydraulic carriage is removed from the rolling or track carriage and operated at ground level, pipe rollers are available for better alignment to the fusion machine centerline and to protect the pipe as it is pulled down the pipeline.
4. If the hydraulically operated fusion machine is being operated on the carriage, install a pipe support stand or McElroy PolyPorter®, about half the length of the pipe segment to be installed, on both ends of the fusion machine to help with alignment.

5. Check the print-line on the pipe to be butt fused to make sure it meets the pipe specified for the job.
6. Make sure the proper pipe size inserts are installed in the fusion machine clamps to match the pipe OD to be butt fused.

Rev. 02

January 2020

Procedure

Note: See ASTM F2620 Section 8 for the complete butt fusion procedure.

After setting up the pipe supports and starting the fusion machine, plug in the heating unit to the appropriate voltage outlet on the fusion machine carriage. Set the heater temperature to approximately 440° F and allow time to heat up before proceeding with the fusion process. The heater's surface temperature should be 425° F ± 25° F. This should be confirmed before each fusion with an infrared or surface pyrometer in center area of the heater surface.

Setting Hydraulic Pressures for Steps in Fusion Process

If using a McElroy #28, #412 or #618 fusion machine, shift the front selector valve, on the front of the hydraulic manifold, to the up position (FACE). Then shift the top lever valve to the left until the movable carriage bottoms out. Adjust the top pressure reducing valve until the gauge reads less than 100 psi. Then move the front selector valve to the middle position (HEAT) and adjust the middle pressure reducing valve as low as possible. Then move the selector valve to the bottom position (FUSE) and set the pressure to about 150psi until actual fusion pressure is calculated**.**

Clean, Install, and Clamp

Clean the pipe ends, before placing in the fusion machine, with a clean, dry, lint-free cloth like cotton. Set the pipe ends into the fusion machine with the ends protruding inside the inner jaws about 1" – 1 ¼" and clamp the pipes until firm resistance is felt. Tighten the outer jaws slightly more to prevent slippage.

Face

Install the facing unit into the fusion machine between the two pipe ends. Shift the front selector valve to the up position (FACE), turn on the facing unit and shift the top carriage control valve to the left to bring the pipe ends in contact with the facing unit. Adjust the Facing pressure reducing valve up or down as needed to keep the pipes in contact with the facing unit but not causing it to stall. Continue the facing until the facer body meets mechanical stops. Turn the facer off and wait for it to stop, shift the top carriage control valve to the right and open the carriage. Stop the carriage and remove the facing unit and the pipe shavings from the machine. Brush any loose shavings away from the pipe ends with a clean, dry, lint-free cloth. **Do not touch the pipe ends with your hand or anything that could contaminate the pipe ends.**

Align

Bring the pipe ends together at the facing pressure and check for any "hi-lo" OD misalignment or gaps. If there is a little misalignment, always tighten the high side down. Then snug both clamp knobs down a little to prevent slippage. There should be no gaps between the pipe ends before heating.

At this point, you need to read the Drag Pressure of the carriage on the gauge. To do this, you need to move the top carriage control valve to the left until the pipe ends are about 2" apart and move the carriage control valve to the center position to stop the carriage. Move the selector valve to the middle position (HEAT) and then shift the top carriage control valve to the left and read the pressure on the gauge. If the carriage does not move, adjust the middle pressure reducing valve slowly until the carriage starts moving and read the pressure. On most high force machines, this is between 30-50psi with one stick of pipe in the movable jaws. Let the pipe ends meet. The next step is to calculate the fusion joining pressure for the pipe that is being joined. For this, you will need the pipe size and DR (i.e. 4" IPS DR11) and have the McElroy McCalc app installed and open on your phone, IPad or computer. Input the information requested on the fusion machine being used, select the ASTM F2620 procedure, input the pipe size and DR or wall thickness, input 75psi for the interfacial pressure and input the Drag Pressure. The App will calculate the fusion pressure to set on the machine. Shift the selector valve to the bottom position (FUSE) and adjust the pressure with the bottom pressure reducing valve to the pressure indicated on the McCalc app.

Formula

The formula for calculating the fusion pressure set on the fusion machine is:

$$\text{Pressure (gauge) (psi)} = \frac{\text{Pipe Area (in}^2\text{) x Interfacial Pressure (75 psi)}}{\text{TEPA (in}^2\text{) of Fusion Machine}} + \text{Drag Pressure (psi)}$$

Heat

Verify the heater surface temperature is 425 degrees F ± 25° F with a pyrometer. Clean the heater faces with a clean, dry, lint-free, non-synthetic cloth like cotton and install the heater on the guide rods of the fusion machine between the two faced pipe ends. Shift the Selector valve to the (FUSE) position and shift the carriage control valve to the left to bring the pipe ends against the heater. Once in complete contact and an indication of melt is observed around the pipe circumference, shift the front selector valve to the center position (HEAT) and then shift the top carriage control valve to the center position to lock the carriage position. This is the start of the heat soak cycle and you should not apply hydraulic pressure during this time. Heat the pipe ends until the proper melt bead size is formed between each heater surface and pipe ends. For 14" pipe and larger, there is a minimum heat soak time of 4.5 minutes per inch of pipe wall thickness that must be met in addition to the bead size before removing the heater. See Table 3 in Section 8 of ASTM F2620 fusion standard for the minimum melt bead size to reach before removing the heater.

Material Options	Mat.	Heater Surface Temp. (°F)	Melt Bead Size (IN)	Max. Heater Plate Removal Time (SECS)	Min. Cooling Time (MINS)
2" IPS - SDR 11 Yellow	MDPE	425 ± 25	1/16	8	2.38
2" IPS - SDR 11 Black/Yellow Stripe	HDPE	425 ± 25	1/16	8	2.38
4" IPS - SDR 11.5 Yellow	MDPE	425 ± 25	3/16	10	4.3
4" IPS - SDR 11.5 Black/Yellow Stripe	HDPE	425 ± 25	3/16	10	4.3
6" IPS - SDR 11.5 Yellow	MDPE	425 ± 25	3/16	15	6.34
6" IPS - SDR 11.5 Black/Yellow Stripe	HDPE	425 ± 25	3/16	15	6.34

Remove the Heater

After achieving the proper melt bead size, shift the front selector valve to the bottom position (FUSE) and then shift the top carriage control valve to the right to open the movable jaw of the machine until both pipe ends separate from the heater. Stop the carriage by shifting the top carriage control valve to the center position. Remove the heater, inspect the pipe ends for the proper melt pattern (smooth with no marks or contamination). Then bring the pipe ends together by shifting the top carriage control valve to the left. The melt beads will roll back to the pipe surface. Maintain that hydraulic pressure for the entire cool cycle.

In Table 6 in Section 8 of the ASTM F2620 fusion standard, you will find the maximum time allowed to open the carriage, remove the heater and bring the pipe ends together for the fusion cycle. This depends on the pipes wall thickness.

Fuse/Cool

Let the fusion joint cool in the machine for a minimum of 11 minutes per inch of wall thickness (i.e. ½" wall pipe will need 5.5 minutes of cool time minimum).

An additional 30-60 minutes of cooling time is recommended prior to rough handling or backfilling of the pipe depending on pipe wall thickness and ambient temperature.

Inspect

After the cool cycle is completed, move the top carriage control valve to the center position and unclamp the jaws from the pipe. Visually inspect the fusion joint for the proper bead appearance. It must have a complete and uniform double rollback. Inspect the bead for signs of contamination. Refer to ASTM F2620 for visual acceptance pictures and illustrations.

Pictures provided by McElroy Manufacturing, Inc.

Polyethylene Gas Pipe Manual Butt Fusion Procedure

Introduction

This document has been developed to assist workers responsible for the butt fusion joining of Teel Plastics piping products in the gas and energy applications. This procedure is in alignment with ASTM F2620 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings. Please refer to ASTM F2620 for more specific butt fusion information, guidance, and safety information when using manually powered fusion machines

Equipment

The equipment needed for manual butt fusion include the proper manually operated butt fusion machine for the pipes being fused (such as the McElroy #2LC, Pit Bull®14 and Pit Bull®26), a facing unit, a heating unit for heating the ends of the pipe, and the proper inserts for the pipe sizes to be butt fused. Pipe support rollers and stands are also needed to bring the pipes, to be fused, in alignment with the fusion machine centerline. A 120VAC power supply is required so a generator is usually required. Consult the fusion machine manufacturer's information on the size generator required.

Set-Up Guidelines

1. Ensure the fusion equipment used meets the manufacturer's specifications and is in good working order before using.
2. Make sure the fusion machine operator has been trained properly on the manual butt fusion machines being used, typically in accordance with ASTM F3190.

3. Set up the fusion machine in a level area if possible. If operated at ground level, pipe rollers are available for better alignment to the fusion machine centerline and to protect the pipe as it is pulled down the pipeline.
4. If the manually operated fusion machine is equipped with a stand, install a pipe support stand or McElroy PolyPorter®, about half the length of the pipe segment to be installed, on both ends of the fusion machine to help with alignment.
5. Check the print-line on the pipe to be butt fused to make sure it meets the pipe specified for the job.
6. Make sure the proper pipe size inserts are installed in the machine clamps to match the pipe OD to be butt fused.

Rev. 02

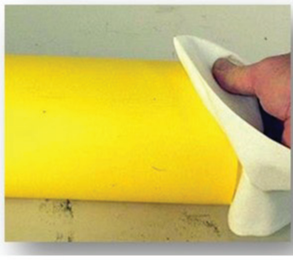
January 2020

Procedure

Note: See ASTM F2620 Section 8 for the complete butt fusion procedure.

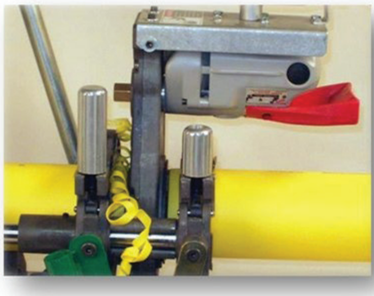
After setting up the fusion machine and the pipe supports, plug in the facing unit and the heating unit to the appropriate voltage outlet (usually 120VAC). Set the heating tool's temperature to approximately 440° F and allow time to heat up before proceeding with the fusion process. The heaters surface temperature should be 425° F ± 25° F. This should be confirmed before each fusion with an infrared or surface pyrometer in center area of the heater surface.

Clean, Install and Clamp



Clean the pipe ends, before placing in the fusion machine, with a clean, dry lint-free cloth like cotton. Set the pipe ends into the fusion machine with the ends protruding inside the jaws about ¾" and clamp the pipes until firm resistance is felt.

Face

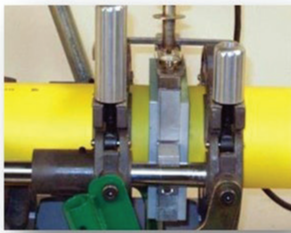


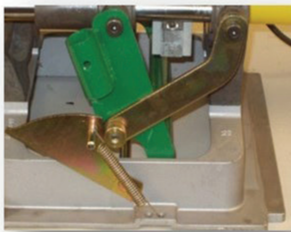
Install the facing unit into the fusion machine between the two pipe ends. Turn on the facing unit and manually move the movable jaw to make the facing unit meet both pipe ends. Keep constant light pressure against the facing unit until the facer body bottoms out on the mechanical stops. Turn the facer off, back off the movable jaw and remove the facer and shavings from the machine. Brush any loose shavings away from the pipe ends with a clean, dry lint-free cloth. **Do not touch the pipe ends with your hand or anything that could contaminate the pipe ends.**

Align

Bring the pipe ends together and check for any "hi-lo" OD misalignment or gaps. If there is a little misalignment, always tighten the high side down. Then snug both clamp knobs down a little to prevent slippage. There should be no gaps between the pipe ends before heating.

Heat

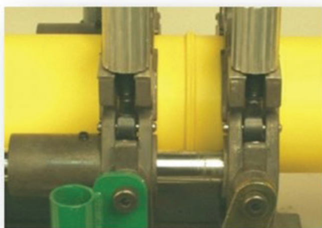




Verify the heater surface temperature is 425° F ± 25° F with a pyrometer. Clean the heater faces with a clean, dry lint-free cloth like cotton and install the heater on the guide rods of the fusion machine between the two faced pipe ends. Bring the pipe ends against the heater with light force to ensure full contact. Engage the locking cam if one is available. This is the heat soak cycle and you should not apply any force during this time. Heat the pipe ends until the proper melt bead size is formed between each heater surface and pipe end. (For 2" and 3" IPS pipe sizes, a 1/16" bead on each side of the heater should be attained. For 4" through 8" IPS pipe sizes, a 3/16" bead on each side of the heater should be attained.)

Material Options	Mat.	Heater Surface Temp. (°F)	Melt Bead Size (IN)	Max. Heater Plate Removal Time (SECS)	Min. Cooling Time (MINS)
2" IPS - SDR 11 Yellow	MDPE	425 ± 25	1/16	8	2.38
2" IPS - SDR 11 Black/Yellow Stripe	HDPE	425 ± 25	1/16	8	2.38
4" IPS - SDR 11.5 Yellow	MDPE	425 ± 25	3/16	10	4.3
4" IPS - SDR 11.5 Black/Yellow Stripe	HDPE	425 ± 25	3/16	10	4.3
6" IPS - SDR 11.5 Yellow	MDPE	425 ± 25	3/16	15	6.34
6" IPS - SDR 11.5 Black/Yellow Stripe	HDPE	425 ± 25	3/16	15	6.34

Remove the heater



After achieving the proper melt bead size, open the movable jaw of the machine until both pipe ends separate from the heater. Remove the heater, inspect the pipe ends for the proper melt pattern (smooth with no marks or contamination). Then bring the pipe ends together and applying just enough force to have the melt beads roll back to the pipe surface. Hold that force for at least 10-15 seconds and if the machine has a locking cam engaged, you can stop applying force and wait for the joint to cool.

Fuse/Cool

Let the fusion joint cool in the machine for a minimum of 11 minutes per inch of wall thickness (i.e. ½" wall pipe will need 5.5 minutes of cool time minimum). If the fusion machine does not have a locking cam, then the fusion force will need to be manually held for the entire cool time.

An additional 30-60 minutes of cooling time is recommended prior to rough handling or backfilling of the pipe depending on pipe wall thickness and ambient temperature.

Inspect

Visually inspect the fusion joint for the proper bead appearance. It must have a complete and uniform double rollback. Check the bead for signs of contamination. Refer to ASTM F2620 for visual acceptance pictures and illustrations.

Pictures provided by McElroy Manufacturing, Inc.

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Figure 23: Teel's gas pipe fusion documents