



Butt Fusion Theory and Practice

Teel

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Quick History and Overview of Teel

- Founded: 1951 in Baraboo, WI
- Total employees: 500+
- Four manufacturing facilities in Baraboo with 650,000 sq. ft. under roof
- Producing pressure pipe since 2011
- ISO Certifications
 - ISO 9001:2015
 - ISO 17025:2017 (Analytical Laboratory)
 - ISO 13485:2016 (Medical)
- Participate in highly regulated end markets



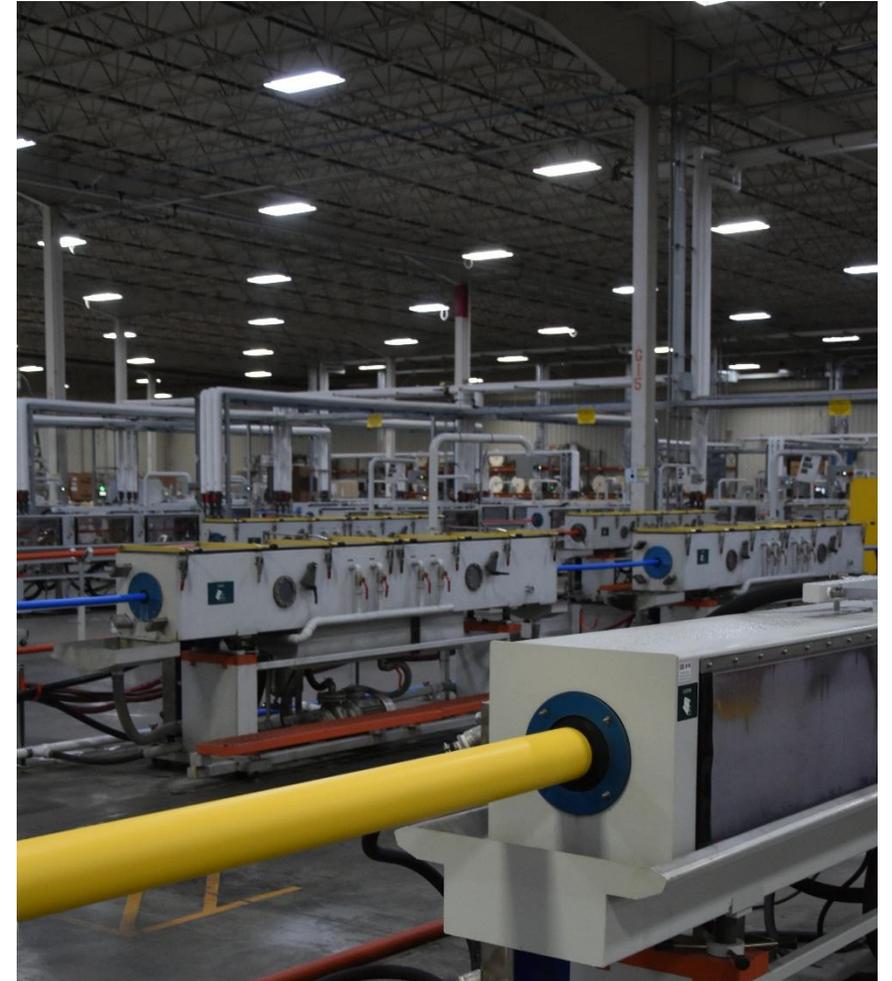
Industrial Pipe Facility

- Located in Baraboo, WI
 - ISO 9001-certified facility
- Rail siding with 8 silos (>200k lbs/silo)
- 14 extrusion lines
 - Capacity of >80 million lbs per year of PE pipe products
- Pipe sizes from ½" - 6"
- Plant operates 24/7 except for holidays



Industrial Pipe Facility

- Currently operating in 420k square feet
- Internal storage space available for WIP and gas pipe to protect product integrity
- Space to add additional Pipe manufacturing lines in 2026-2027
 - Trench/grids for two additional extrusion lines
 - In 2025, operating 14 extrusion lines



Background on Fusion

4" IPS DR11 TEEL PIPE GAS PE2708 CDE ASTM D2513 NR W021740

1" TEEL PIPE GAS PE4710 CEE ASTM D2513 NR W052622

Footnote c to Table 5: Pipe Category in ASTM D2513-18a

^c When a PE pipe or fitting is marked per 7.2 or 7.5 with the letter “E,” it affirms that the manufacturer has verified the applicability of generic fusion joining with their products in accordance with PPI TR-33 and PPI TR-41 by joining to itself and to other “E” materials and testing the joints in accordance with applicable regulations. However, qualification of joining procedures by operators in accordance with applicable regulations may still be required. Information about manufacturers who have verified PPI TR-33 and PPI TR-41 generic fusion joining with their products is found in PPI TR-33 and PPI TR-41. Consult PPI and the manufacturer for additional information.



TEEL PIPE GAS PE4710 CEE ASTM D2513 NR W052622

PPI's TR-33

- Response to a 1994 request by PHMSA because of a “proliferation” of similar, but slightly varying fusion procedures
- Testing used the following variables
 - Density
 - Reactor Process
 - Catalyst Family
 - Melt Flow Index (MFI or MI)
 - Pipe Size
 - Fusion Pressure
 - Fusion Temperature
- Excluded proprietary resin products

Results

- Way of making resin had no effect
- Density had no effect
- Pipe size had no significant effect
- Fusion worked from 25psi to 100psi and from 375°F to 500°F

- Critical factor is melt flow
 - Class 3 (MI 0.4-0.15g/min)
 - Class 4 (HLMI 20-4g/min)

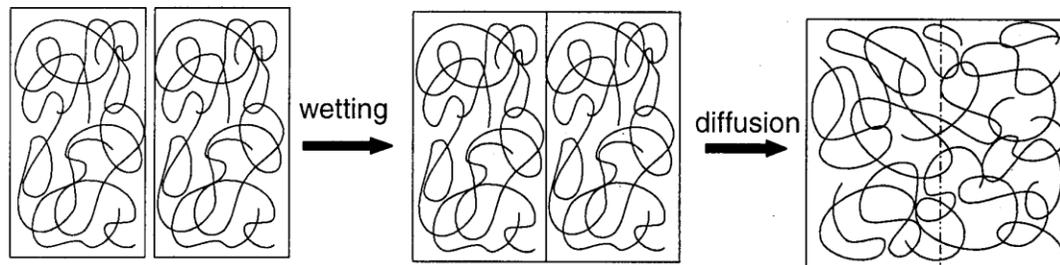
Current State of the Regulation

- TR-33's procedure was formalized as ASTM F2620
- TR-33 was code approved* until early 2019
- Currently, the "code approved" procedure is ASTM F2620-19
- ASTM F2620 is the only procedure generically approved to work across all pipe materials marked E without further testing

Fundamentals of Fusion

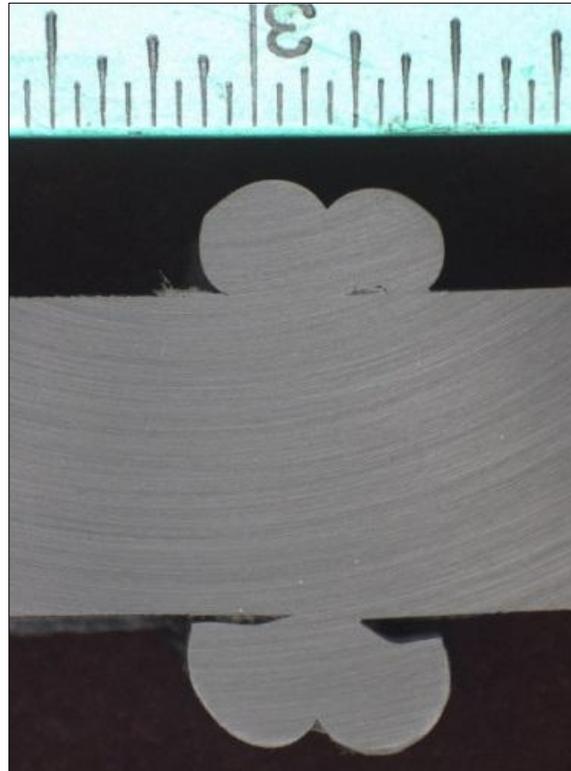
What happens during butt fusion?

- The molten ends of polyethylene pipes or fittings are pressed into intimate contact such that the interfacial pressure exceeds the hydrostatic force to a sufficient degree that molten material from both parts is held in intimate contact allowing wetting intermolecular diffusion to occur. The material must then cool in a controlled manner allowing a plane of co-crystallization to be formed with molecules from both parent parts.



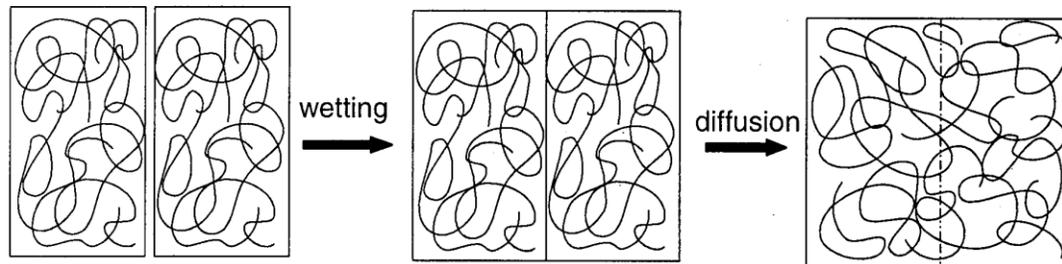
Butt Fusion

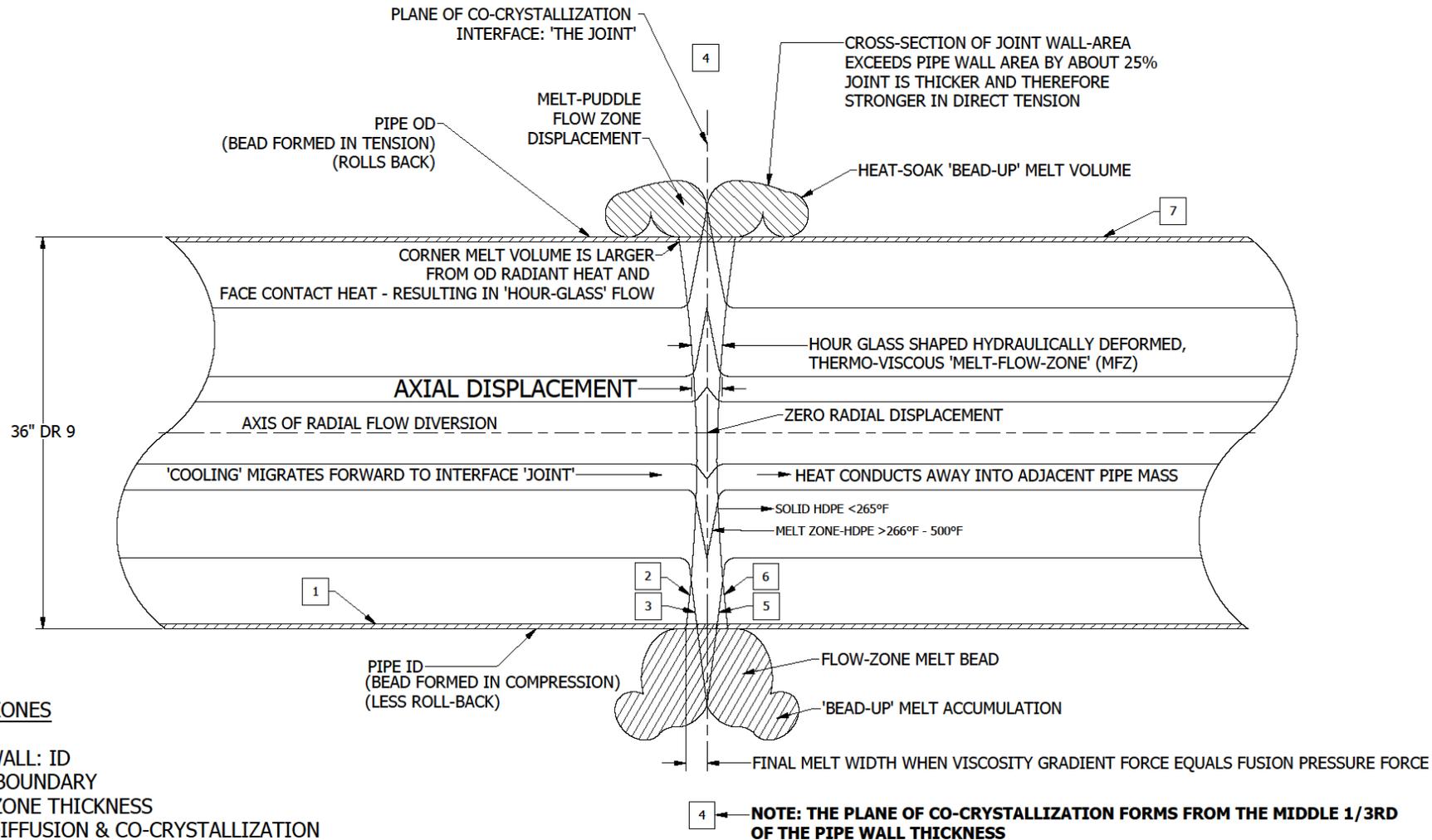
- Align, clean, face, melt, and press together creating a monolithic joint



Autohesion and Aspect Ratio

- Polyethylene is “autohesive”
 - Molten material will mix together if held under pressure
 - It will prefer mixing to staying put
- Polyethylene molecules are long
 - Thousands of times as long in one direction compared to the other
 - Allows crystals to form with some molecules from each part

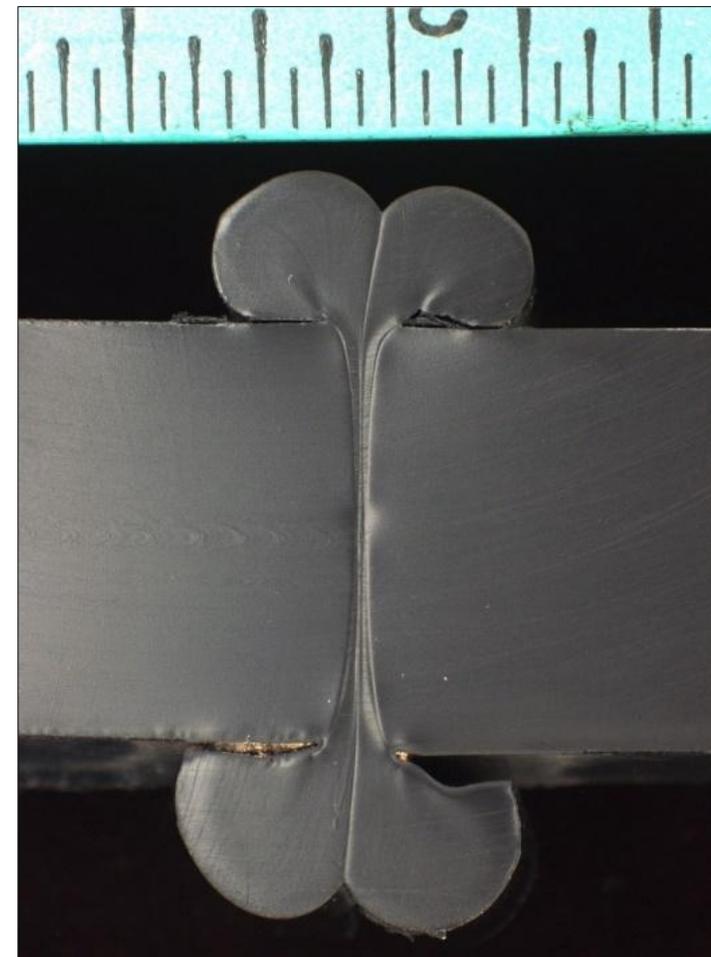
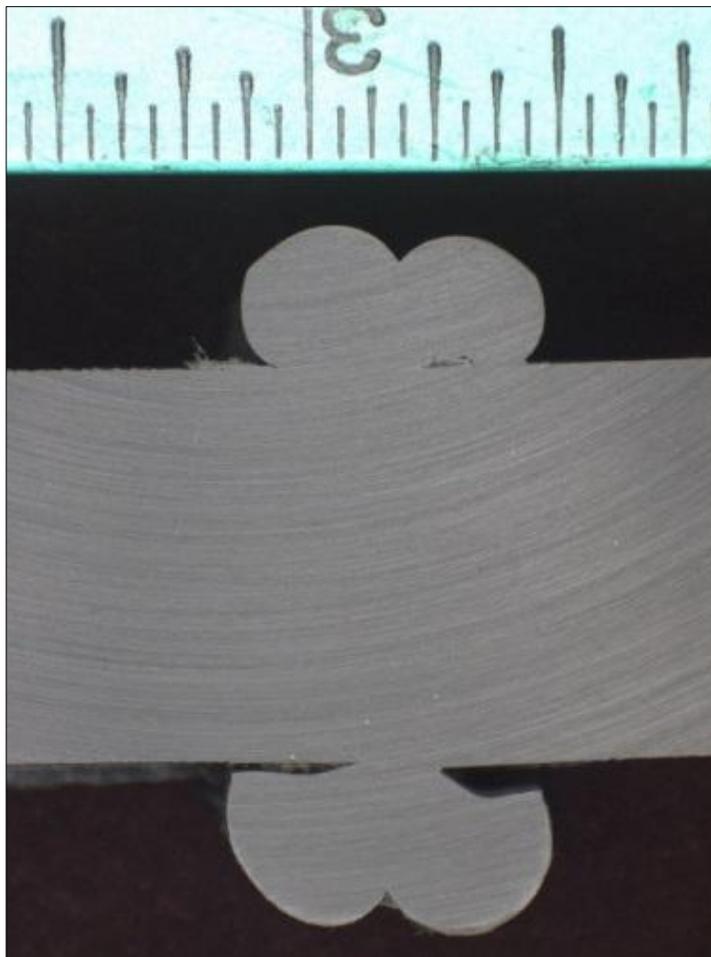




FUSION JOINT ZONES

1. SOLID PIPE WALL: ID
2. SOLID-MELT BOUNDARY
3. MELT-FLOW-ZONE THICKNESS
4. THE JOINT: DIFFUSION & CO-CRYSTALLIZATION
THICKNESS \approx 25-50 MICRONS \approx 0.001 - 0.002 INCHES
5. MELT-FLOW-ZONE THICKNESS
6. SOLID-MELT BOUNDARY
7. SOLID PIPE WALL: OD

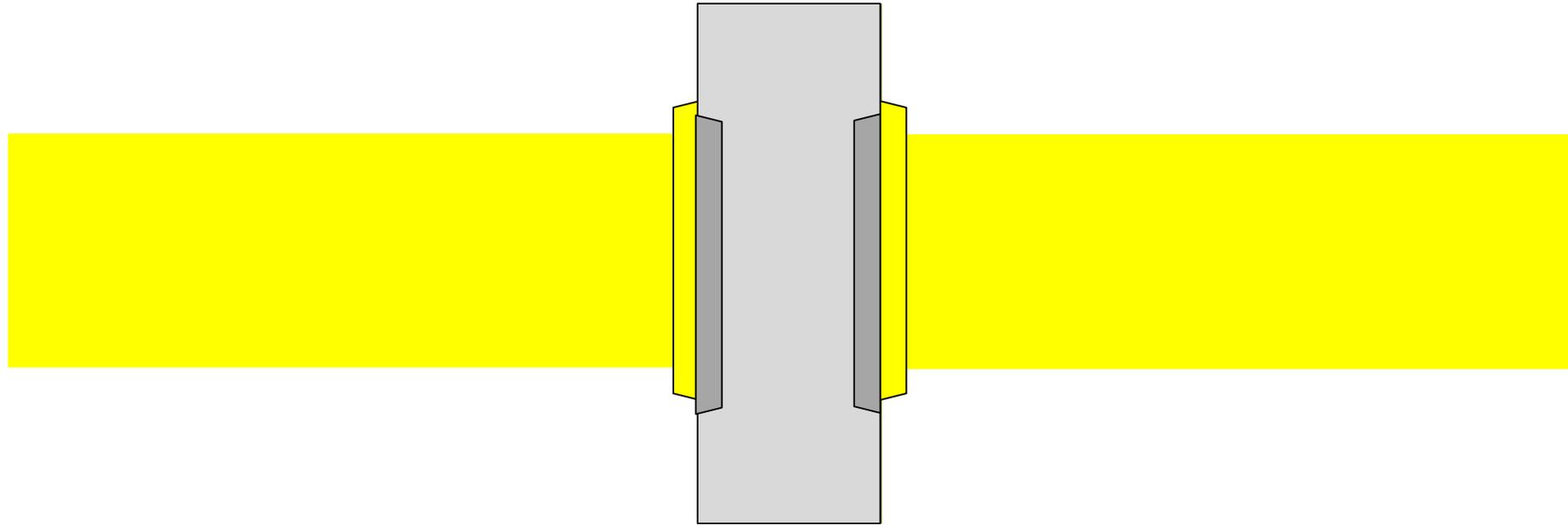
Figure taken from PPI's TN-51: Polyethylene Pipe Butt Fusion Structure, Process, and Terminology, The Plastics Pipe Institute



Implications

- The bead is not the joint; it only indicates whether the procedure was done correctly
- Pressure is not forcing the pipe to bond; the prescribed pressure is the best pressure
- The material flows a long way; it needs to be molten
- The “joint” is thin; even small contamination issues can be a source of failure

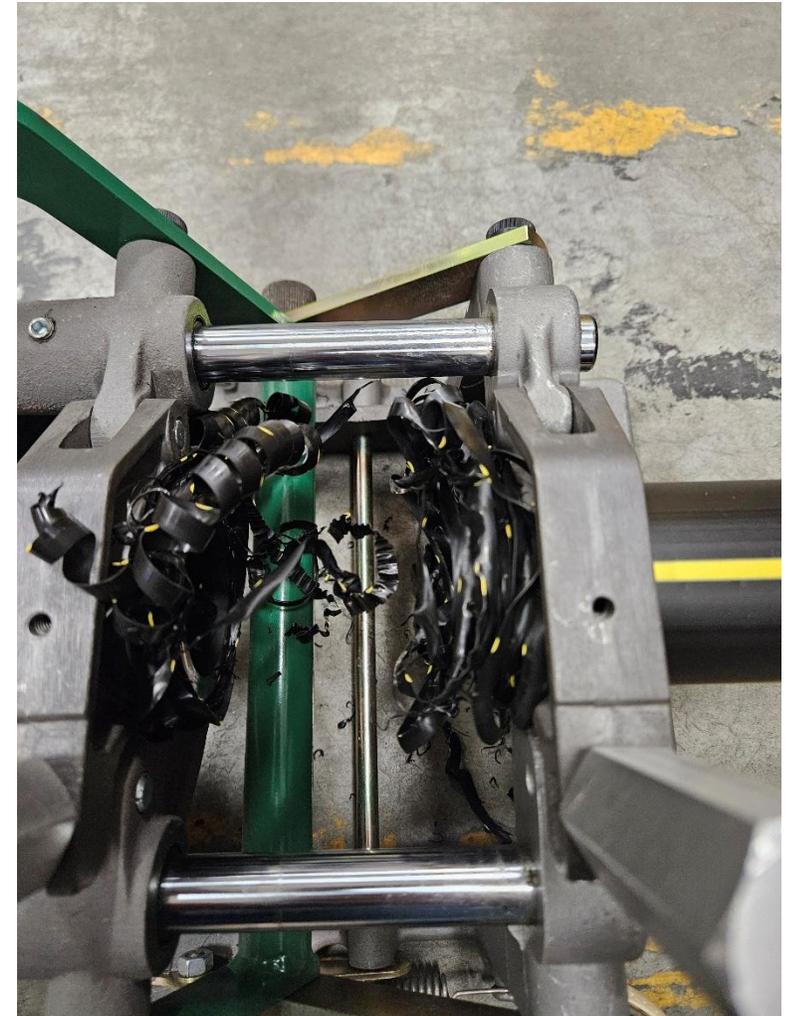
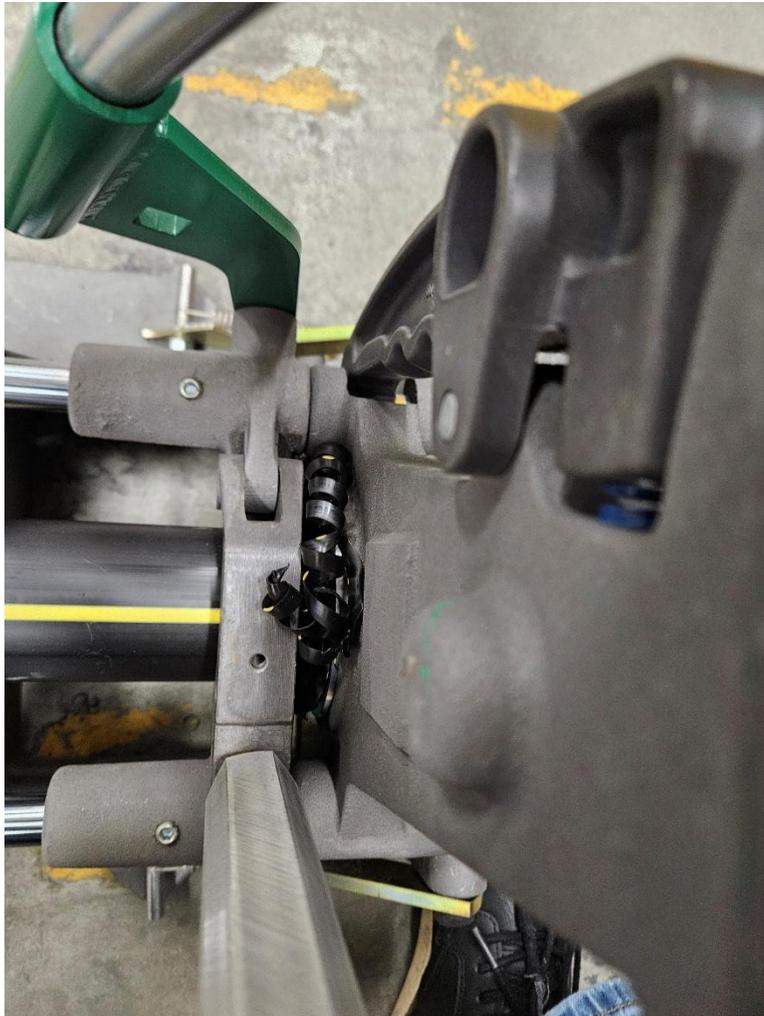
Fusion Process



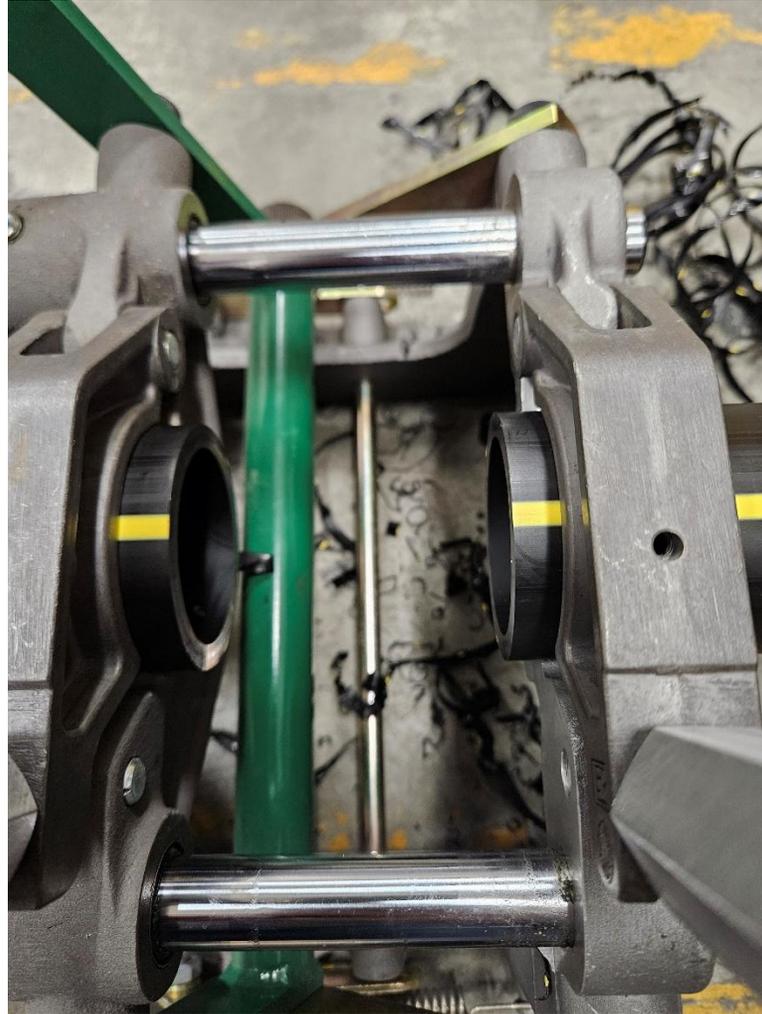
Align and Clamp



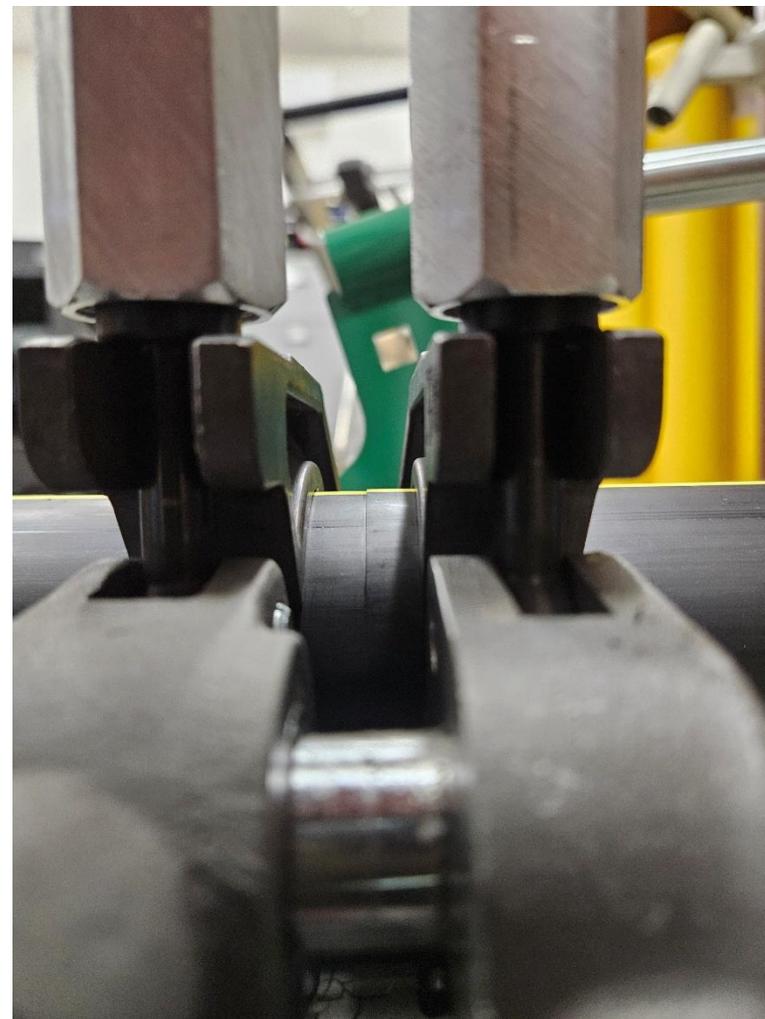
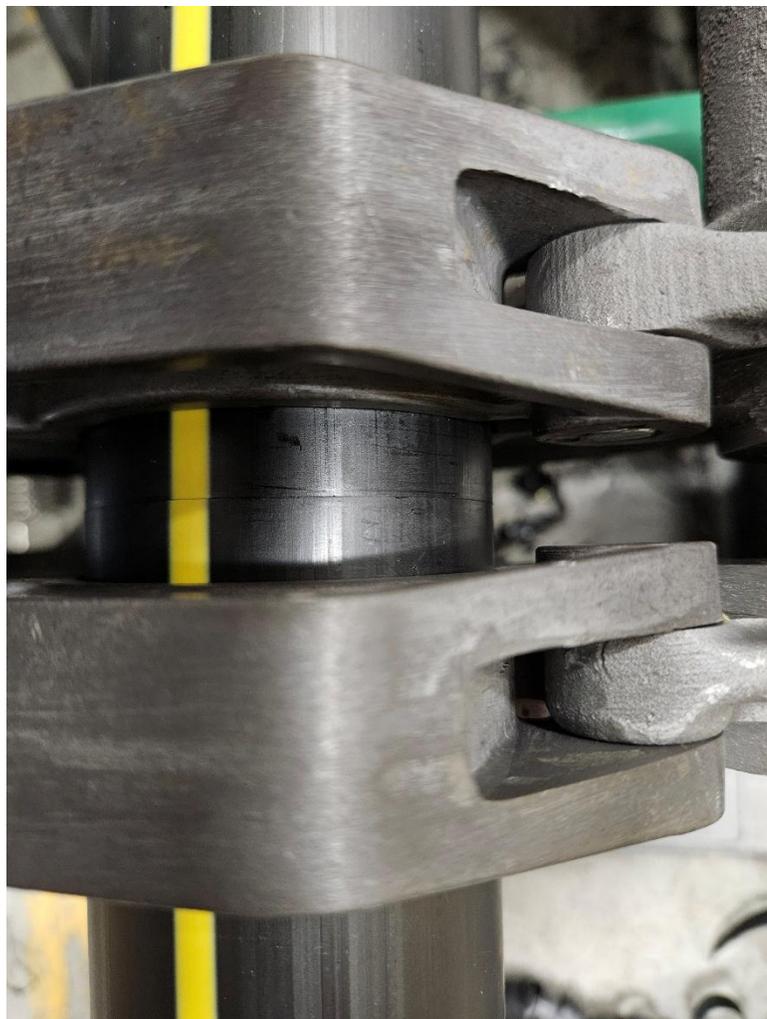
Clean and Face

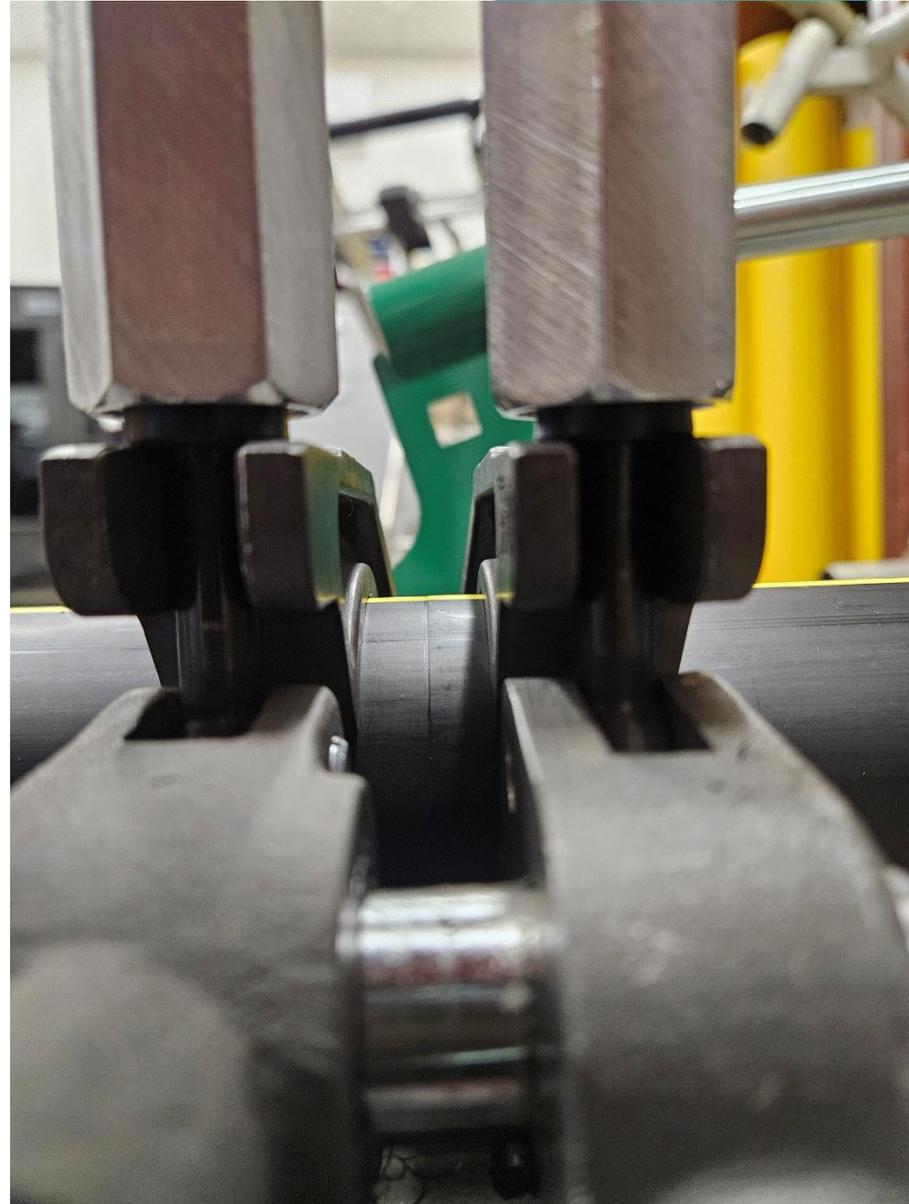


Remove Debris

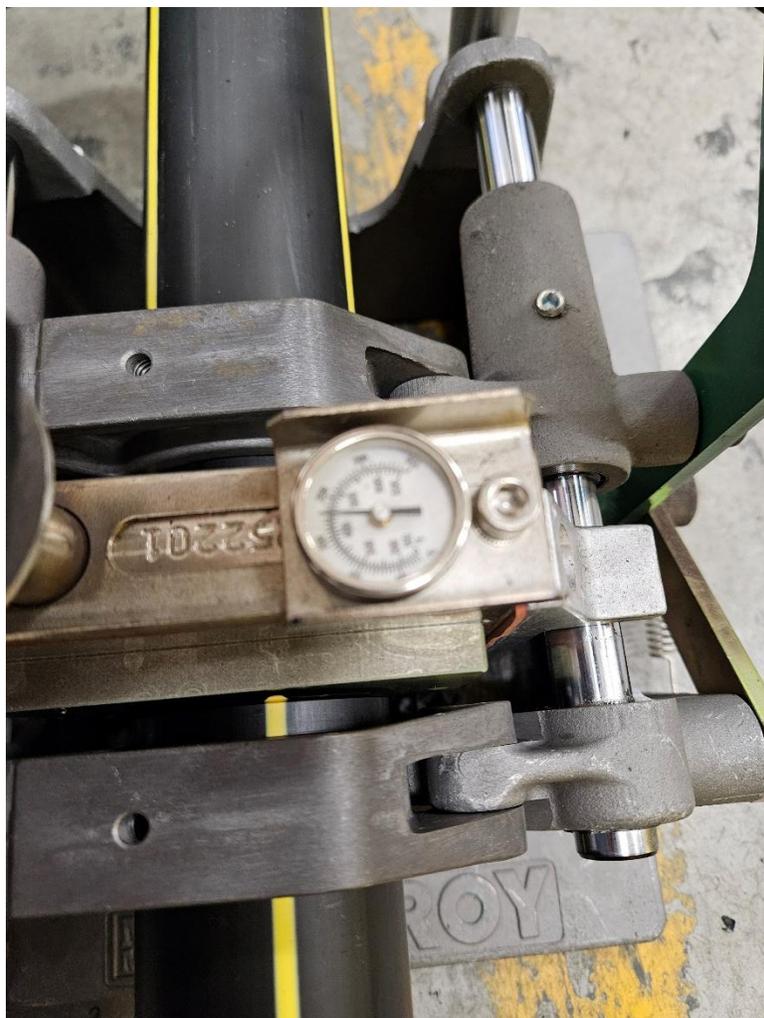


Check Alignment

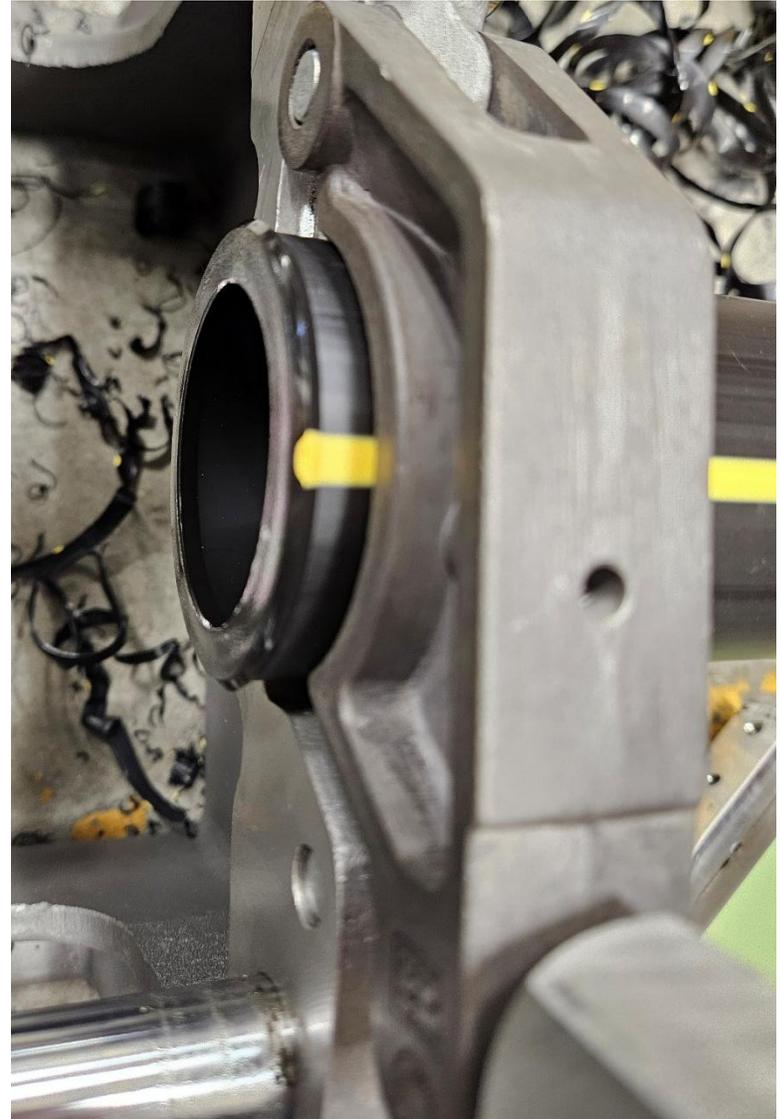




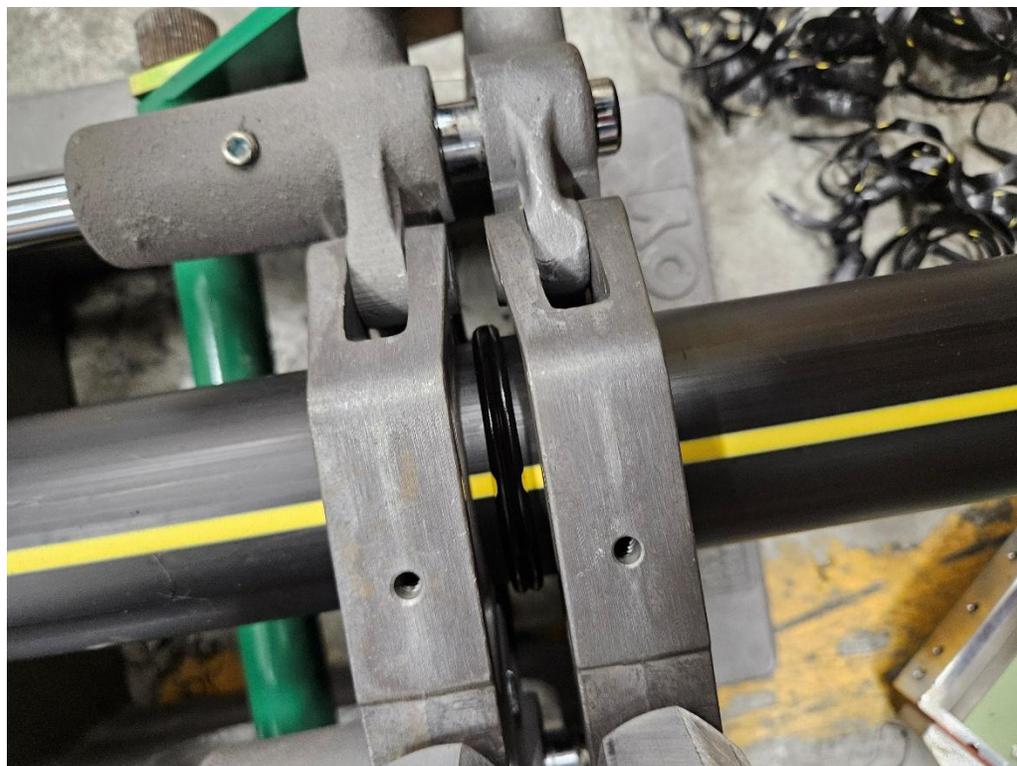
Heat



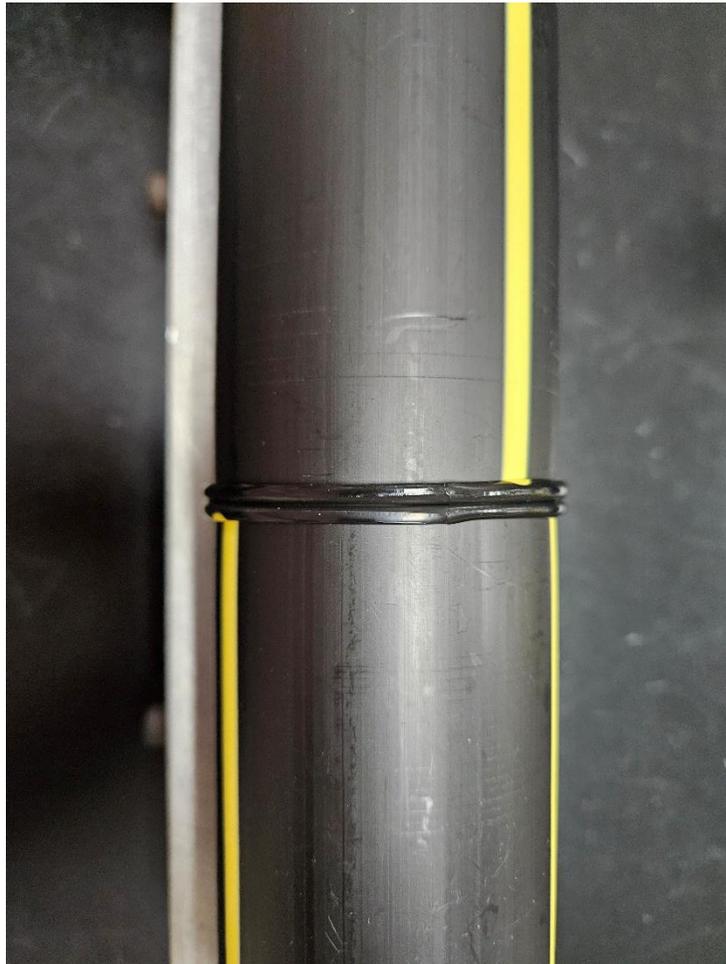
Inspect



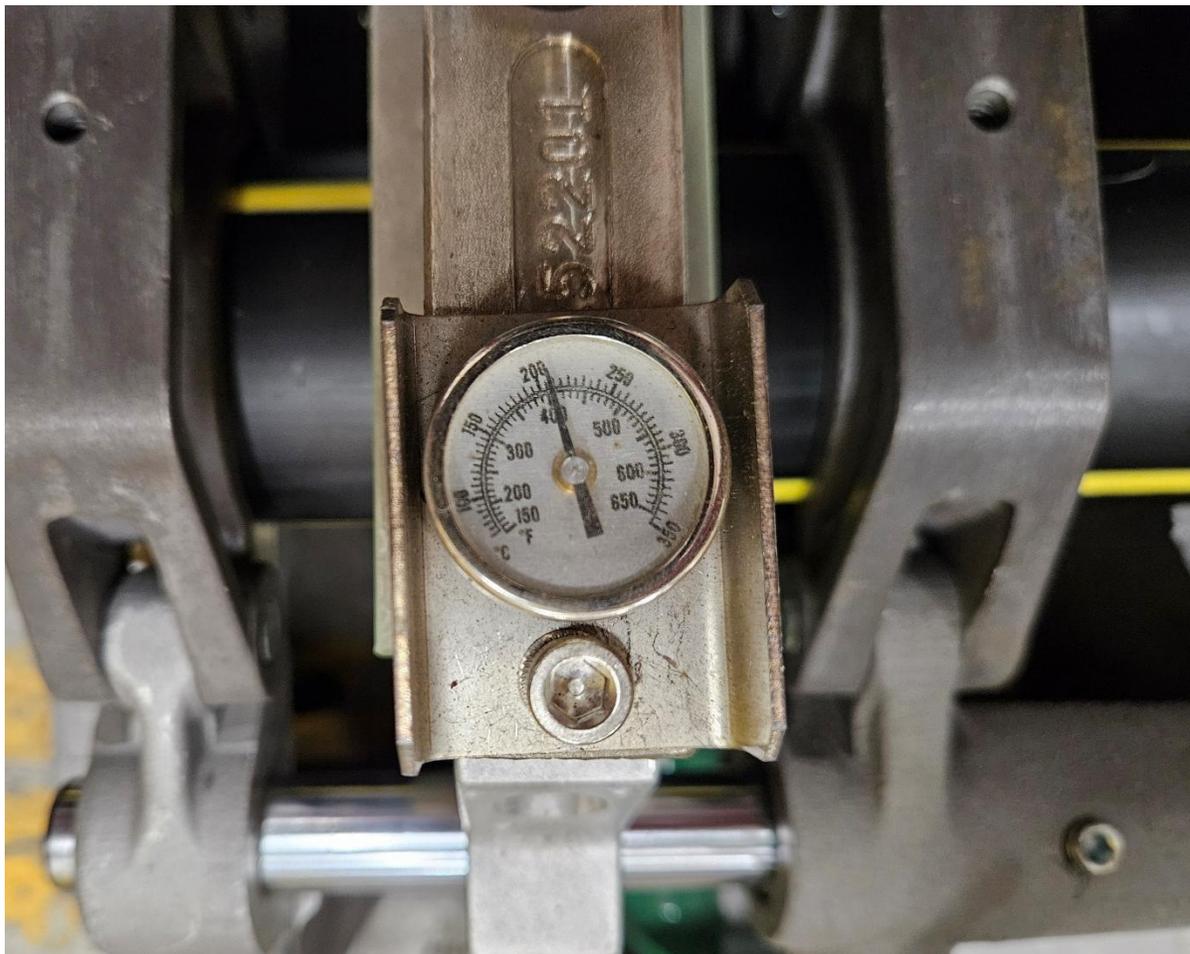
Fuse and Cool



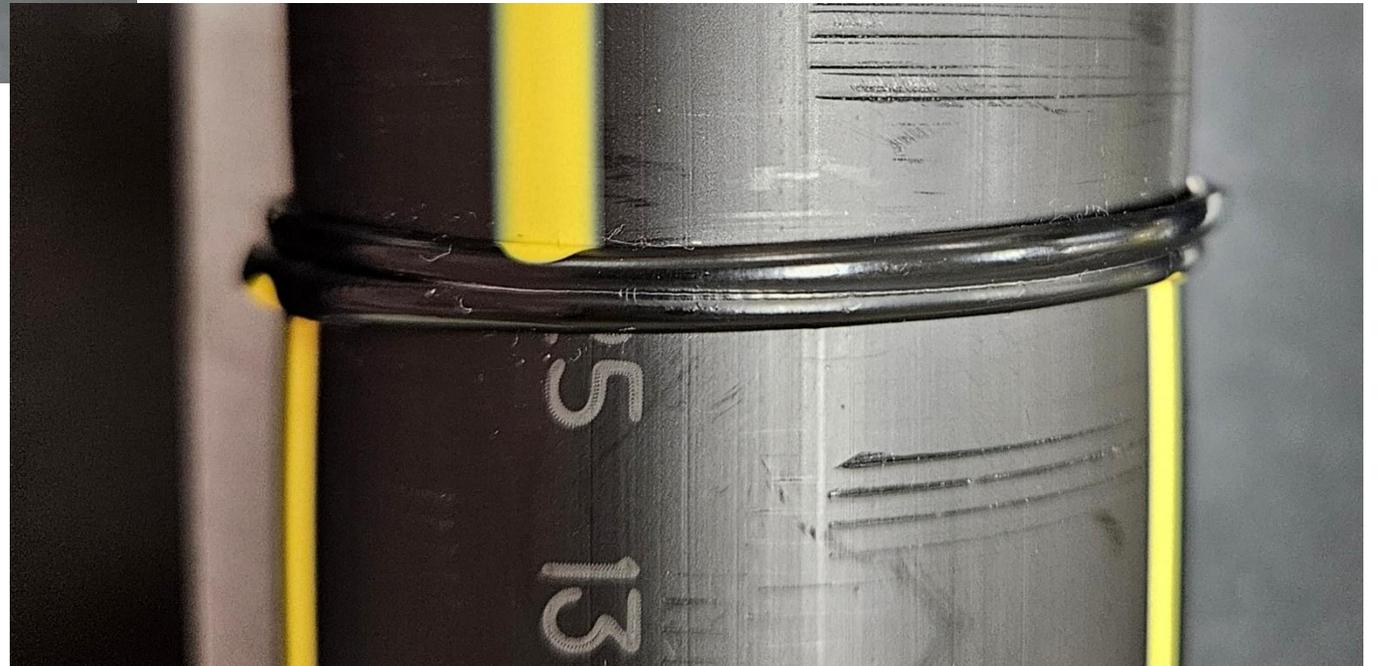
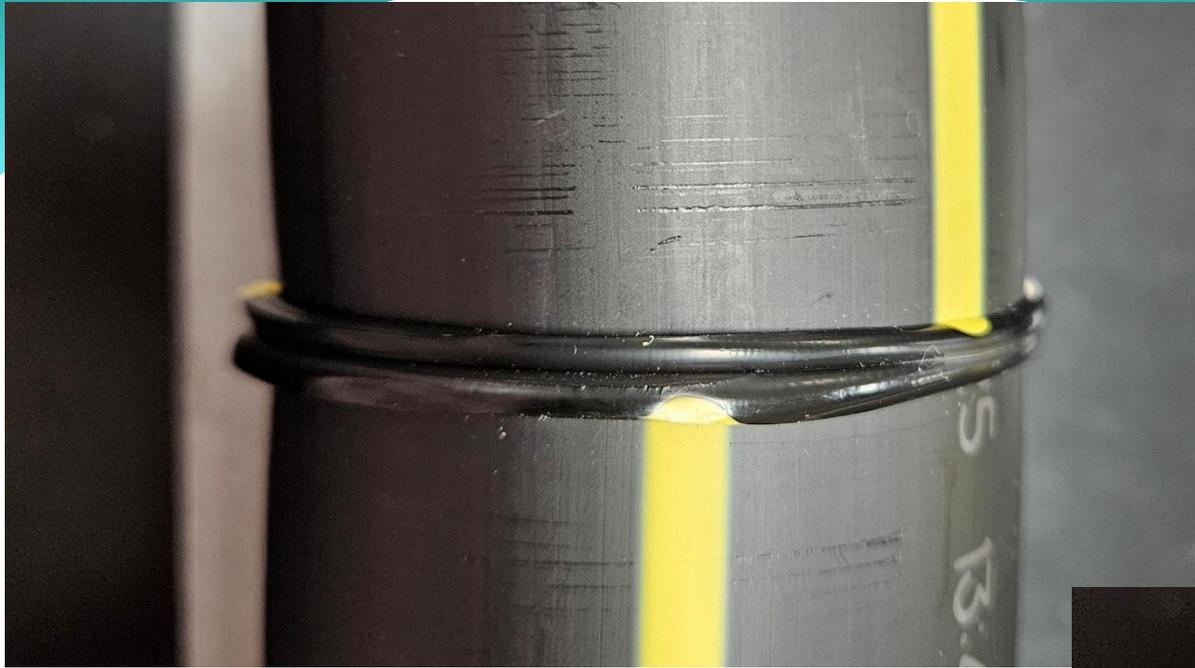
Bad Weld Examples

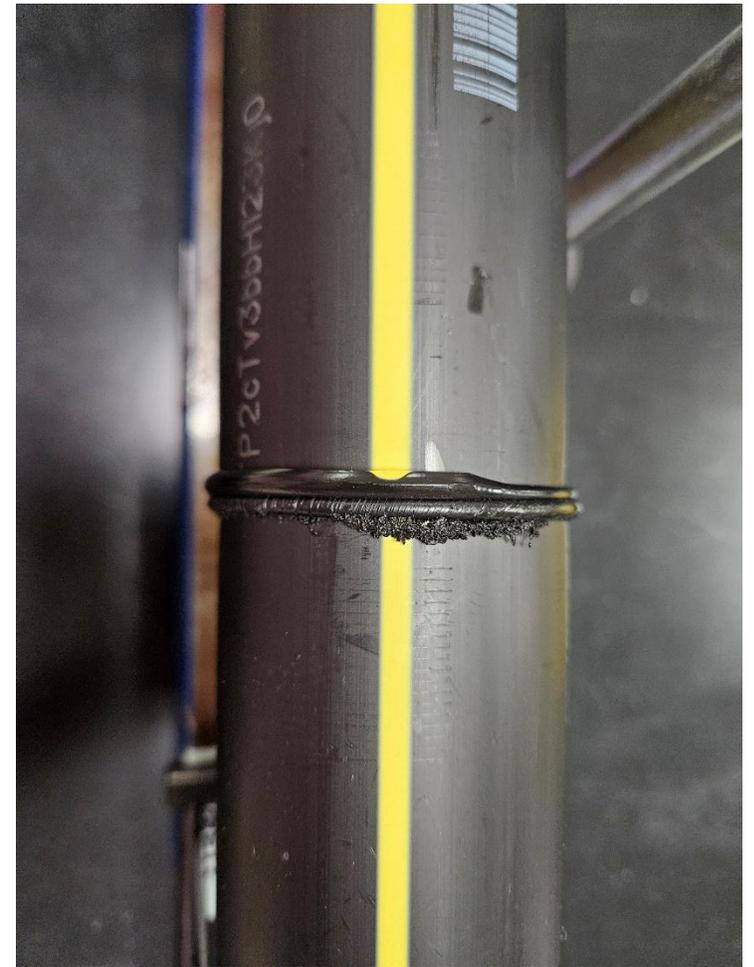
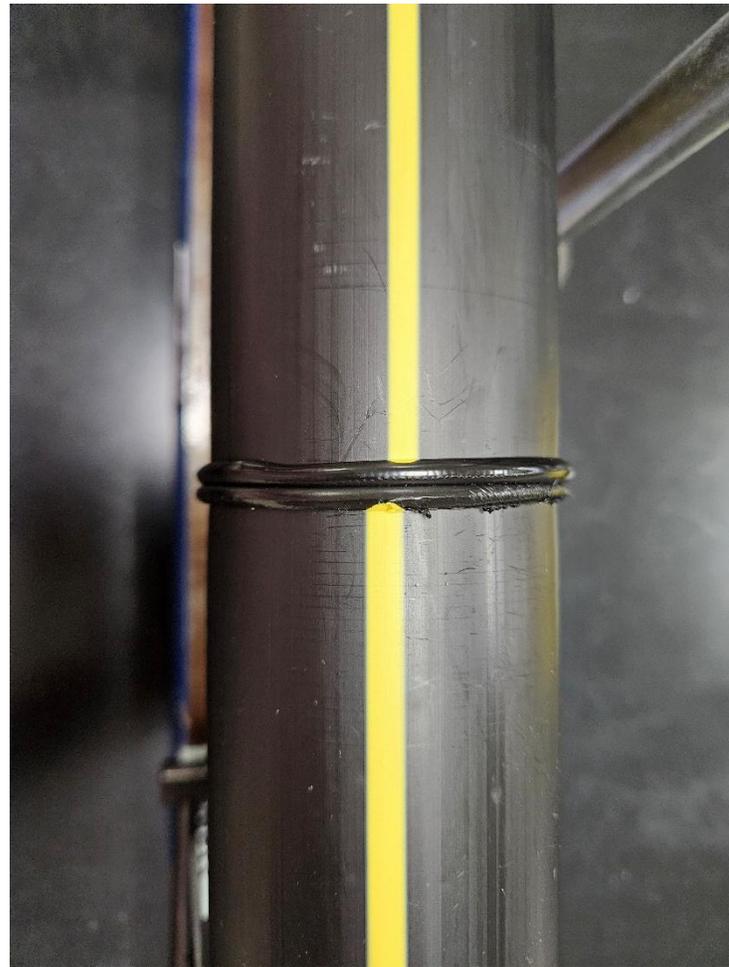


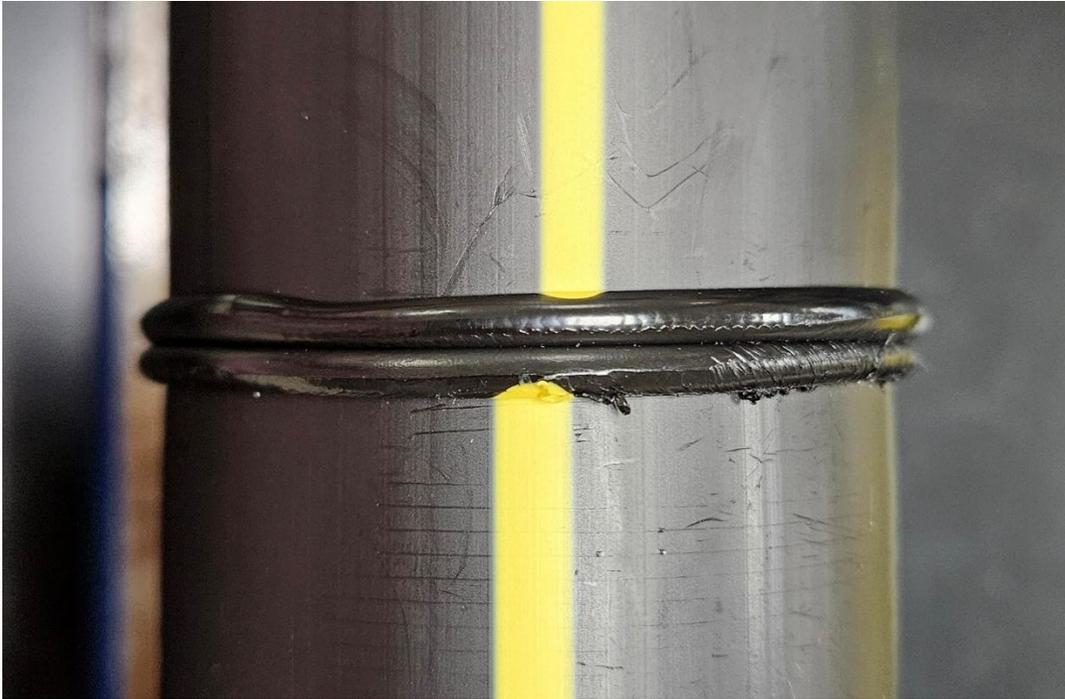


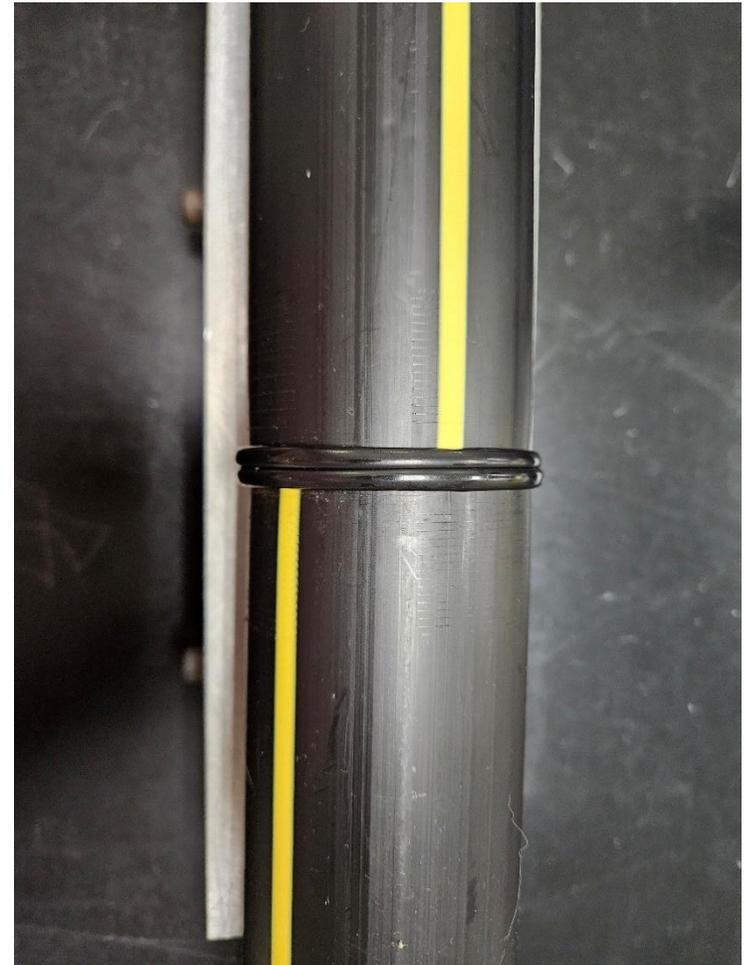
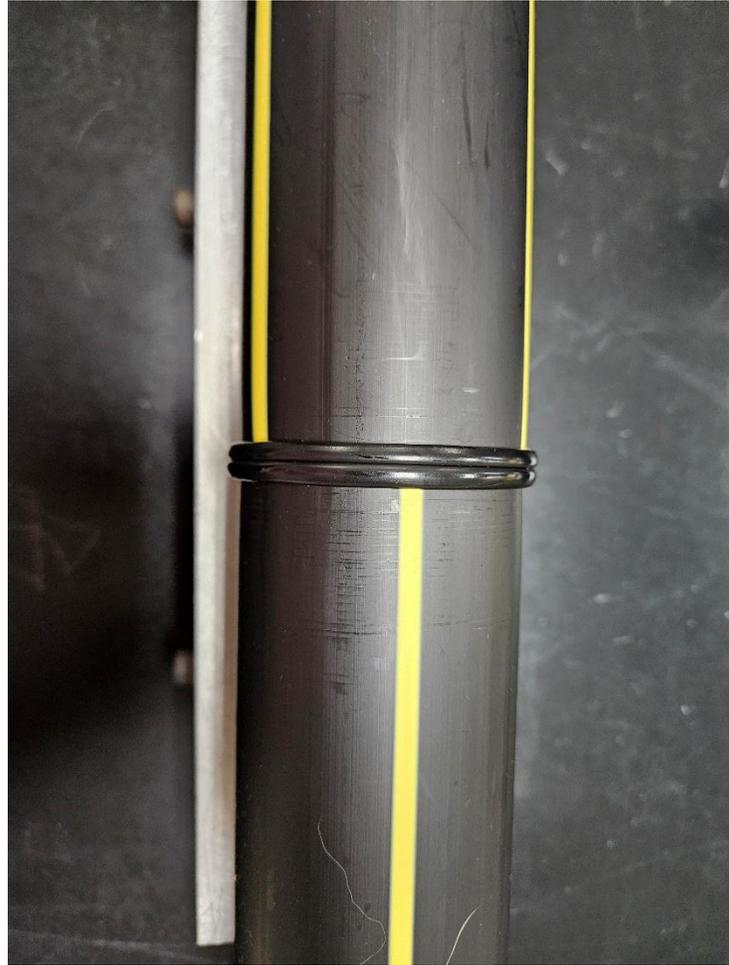
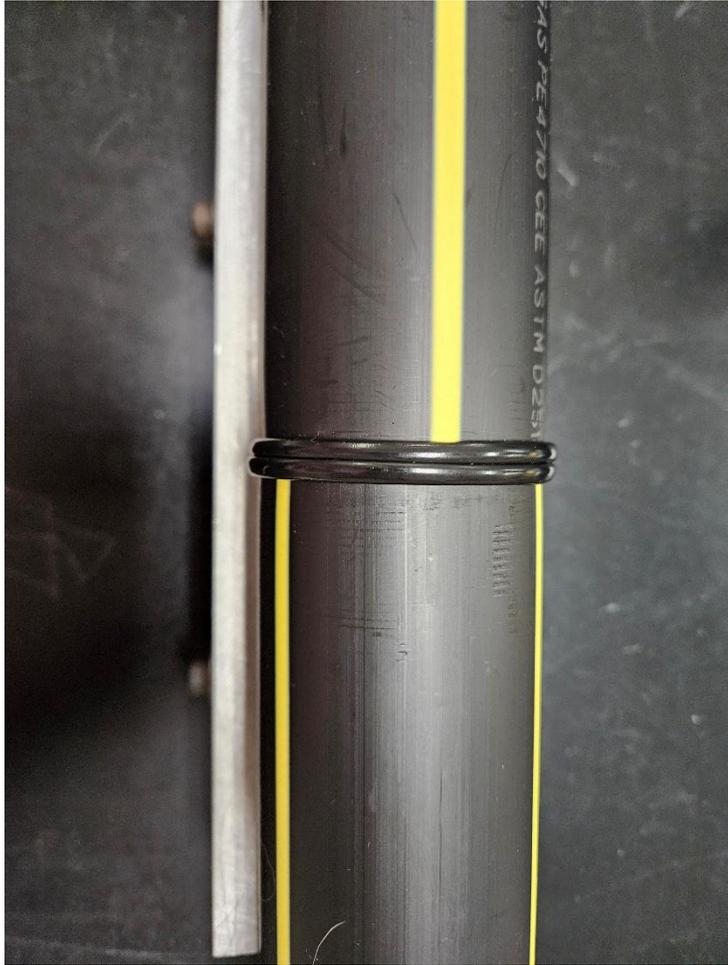


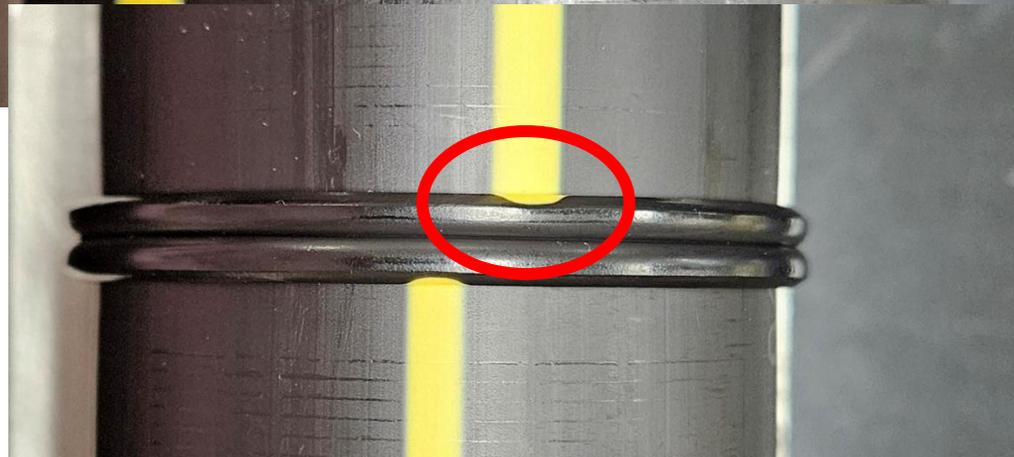
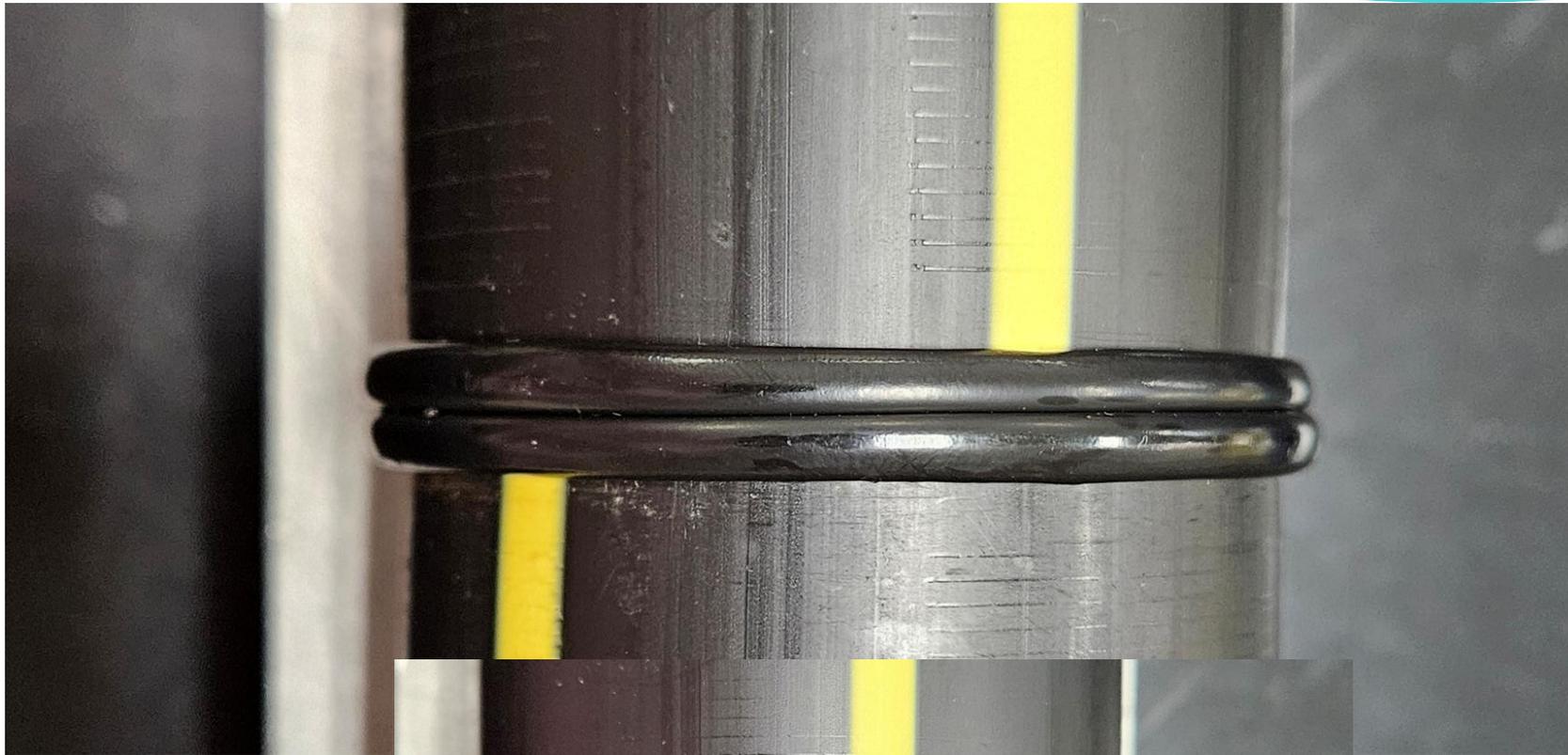


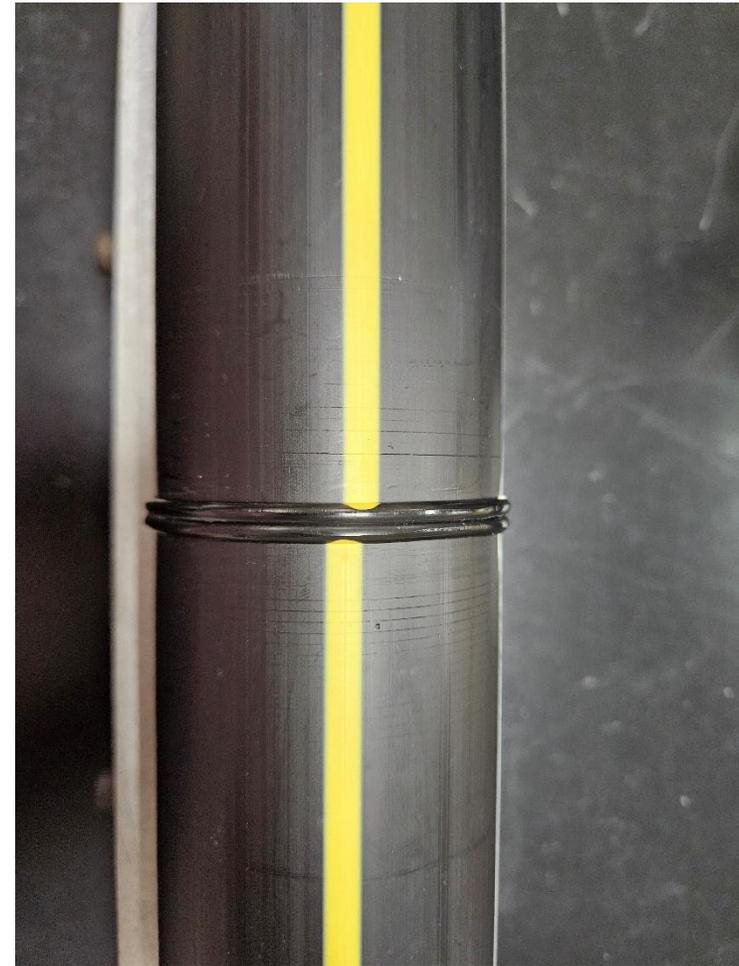


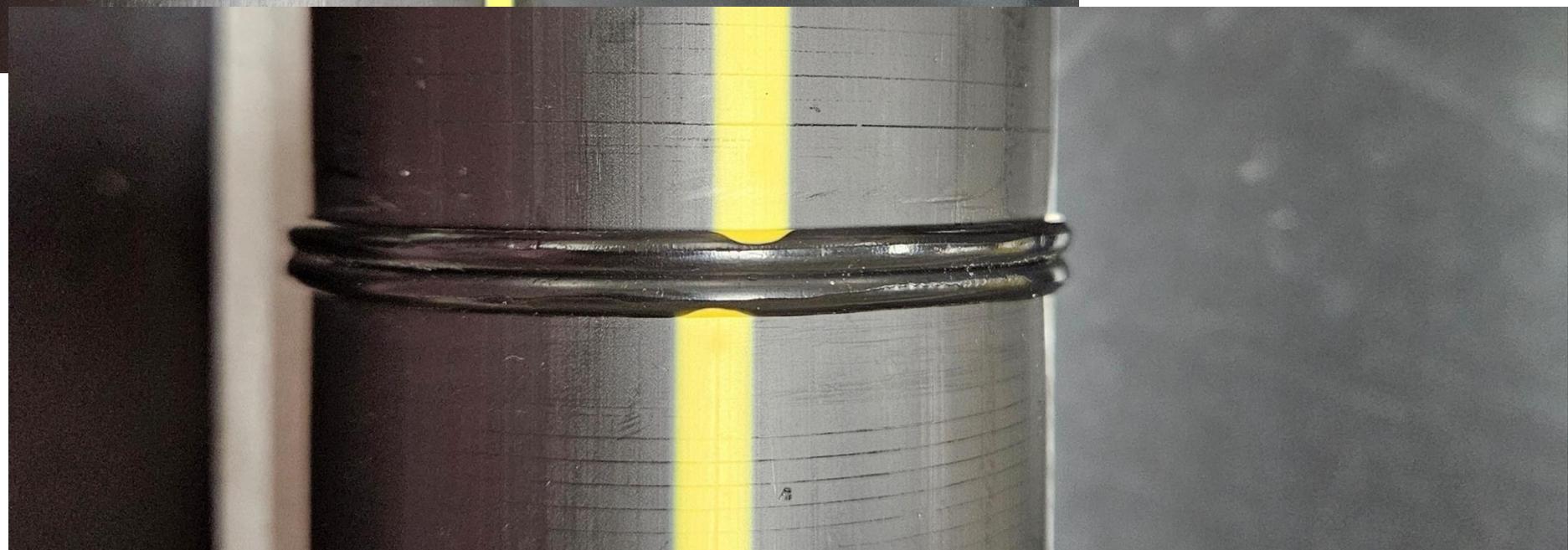
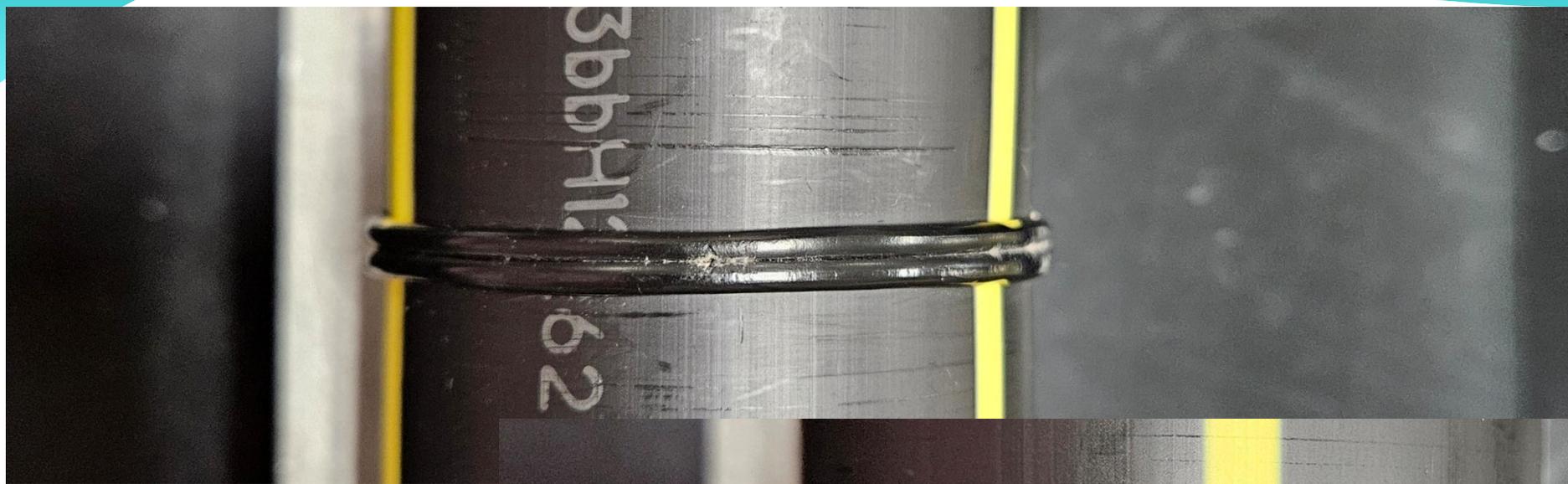












Review

Fusion

- ASTM F2620-19 is the only procedure incorporated by reference in section 192
- It will work on any pipe with a category code ending in “E”

4" IPS DR11 TEEL PIPE GAS PE2708 CDE ASTM D2513 NR W021740

- The generic process is backed up by rigorous research demonstrating success
- If properly executed, the joint should be stronger than the pipe itself
- Procedures should be followed closely to prevent bad welds





Questions