Technical Bulletin

Butt Fusion Joining Procedure & Qualification Guide

1. INTRODUCTION

The procedures outlined in this document are applicable to Infra Pipes' Sclairpipe®, Gas MD, and Gas HD product lines. This procedure is based on ASTM F2620. Please refer to ASTM F2620 for more specific information about the butt fusion procedure.

2. SCOPE

This document outlines the procedures for joining polyethylene pipe by butt fusion.

The work completed in the Plastic Pipe Institute's (PPI) TR-33 confirmed that commercial stress-rates PE compounds in the form of pipe can be fused to itself (self-fusion) and to each other (cross-fusion). The stress-rated PE compounds (MDPE, HDPE) evaluated in PPI's TR-33 had the melt index cell classification values (per ASTM D3350) of '3' (<0.40 to 0.15g/10min) or '4' (<0.15g/10min) or a high load melt index 190°C (374°F)/21.6kg of 4 - 20g/10min.

3. OVERVIEW

The butt-fusion procedure, in its simplest form, consists of heating the squared ends of two pipes by holding them against a heated plate, removing the plate when the proper melt is obtained, promptly bringing the ends together, and allowing the joint to cool while maintaining the appropriate applied force.

An appropriately sized butt fusion machine is used to clamp, align, and face the pipe or fitting ends and to apply the specified fusion force.

4. REGULATIONS FOR GAS PIPE JOINING

4.1. U.S. Regulations

When used to join Infra Pipes polyethylene gas pipe and fittings, Infra Pipes fusion joining procedures are qualified in accordance with U.S. Department of Transportation Regulations 49 CFR, Part 192 § 192.283.

D.O.T. Regulations require that all people who make joints in polyethylene gas piping must be qualified under the operator's written procedures (CFR 49, Part 192, §192.285(a)).

D.O.T. Regulations require that the gas system operator must ensure that all people who make or inspect joints are qualified (CFR 49, Part 192, §192.285(d) & § 192.287).

4.2. Canadian Regulations

When used to join Infra Pipes gas pipe and fittings, Infra Pipes fusion joining procedures are qualified in accordance with Canadian Standards Association Regulations.

- CSA Regulations require that joints in polyethylene piping shall be made by personnel who are qualified in the applicable procedures. (CSA Z662, Section 12).
- CSA Regulations require that heat fusion joints shall be made in accordance with documented procedures that tests have proven. (CSA Z662, Section 12)
- CSA Regulations require that heat fusion joints shall not be made between different grades of polyethylene pipe materials, unless their compatibility is certified by the manufacturers or proven by tests. (CSA Z662, Section 12).

5. PRECAUTIONS

5.1. Static Electricity

Polyethylene plastic pipe does not readily conduct electricity. A static charge can build up on inside and outside surfaces and remain on the pipe until it discharges to a grounding device, such as a tool or a person, when they come close enough.

Discharging one part of the pipe surface will not affect other charged areas because static electricity does not readily flow from one area to another. Polyethylene pipe cannot be grounded by attaching grounding wires to it.

WARNING – Fire or Explosion – Static electricity can ignite a flammable gas or combustible dust atmosphere.

A static discharge to a person, a tool, or a grounded object close to the pipe surface can cause an electric shock or a spark that can ignite a flammable gas or combustible dust atmosphere, leading to fire or explosion.

- In gas utility applications, static electricity can be a potential safety hazard. Where a flammable gas-air mixture may be encountered, and static charges may be present, such as when repairing a leak, squeezing off an open pipe, purging, making a connection, etc., precautions to prevent electrical arcs from being struck are necessary[1]. Observe all Company (pipeline operator, utility, contractor, etc.) procedures for static electricity safety and control, including procedures for discharging static electricity and requirements for personal protection.
- Take steps to discharge static electricity from the surface of a polyethylene gas pipe. Such steps include wetting the entire exposed pipe surface with a conductive anti-static liquid or a dilute soap-and-water solution, then covering or wrapping the entire wetted, exposed pipe surface with a grounded wet burlap, conductive poly film, or wet tape conductor. The external covering should be kept wet by occasional re-wetting with an anti-static solution. The veering or tape should be suitably grounded, such as to a metal pin driven into the ground.
- Steps that discharge the outer surface do not discharge the inner surface of the pipe. Squeeze-off purging, venting, cutting, etc., can still result in a static electricity discharge. When appropriate, ground tools and remove all potential sources of ignition.
- Appropriate safety equipment should be used.
- Do not use polyethylene pipe for handling dry grain or coal where a static electricity discharge may ignite a combustible dust atmosphere and cause an explosion or fire.

5.2. Electric Tool

WARNING – Fire or explosion – Electric tools or fusion equipment may not be explosion-proof and may ignite a flammable gas or flammable dust atmosphere.

DO NOT operate electrical devices that are not explosion-proof in a flammable gas or flammable dust atmosphere. When a flammable gas-air mixture may be present, observe all gas system operator (pipeline or utility company) and contractor safety procedures for the use of electric tools and equipment.

[1]See the AGA Plastic Pipe Manual For Gas Service

5.3. Protection Against Shear and Bending Loads

Protective measures such as protective sleeves and properly placed, compacted backfill are necessary at a connection where an underground polyethylene branch or service pipe is joined to a branch fitting, such as a service saddle, branch saddle, or tapping tee, on a main pipe. Protective measures are necessary for all types of plastic and non-plastic branch connections, including heat-fusion, mechanical, and electrofusion. A protective sleeve and properly placed, compacted backfill are generally used together, but whether a protective sleeve is installed, the area surrounding the connection must be embedded in a properly placed, compacted backfill to protect the polyethylene pipe against shear and bending loads.

For additional information on protection against shear and bending loads, at branch connections, and where PE pipe penetrates a structure or enters or exits a casing, see ASTM D 2774, *Underground Installation of Thermoplastic Pressure Piping*.

5.4. Liquid Hydrocarbon Permeation

When present, liquid hydrocarbons may permeate (solvate) polyethylene pipe. Liquid hydrocarbon permeation may occur when liquid hydrocarbons are present in the pipe, when soil surrounding the pipe is contaminated with liquid hydrocarbons, or when liquid hydrocarbon condensates form in gas pipelines. All types of liquid hydrocarbons (aromatic, paraffinic, etc.) have a similar effect, and the relative effect on different polyethylene pipe resins is essentially the same.

> CAUTION – Once the polyethylene pipe has been permeated with liquid hydrocarbons, heat fusion or electrofusion joining is not recommended, as the liquid hydrocarbons will leach out during heating and contaminate the joint. Liquid hydrocarbon-permeated polyethylene pipe should be joined using suitable mechanical connection methods.

Liquid hydrocarbon contamination is indicated by a rough, sandpaper-like, bubbly, or pockmarked surface when a fusion heating iron is removed from the pipe surface and may be indicated by discoloration or by a hydrocarbon fuel odour. Mechanical joining products (fittings, components, etc.) must be installed in accordance with the instructions of the mechanical joining product manufacturer. Obtain these instructions from the mechanical joining product manufacturer. The mechanical joining product manufacturer determines the capabilities of his product and its suitability for use with polyethylene pipe.

5.5. Leakage at Fusion Joints

WARNING – Correctly made fusion joints do not leak. When pressurized, leakage from a faulty fusion joint may immediately precede catastrophic separation, resulting in violent, dangerous movement of piping or parts and the release of pipeline contents under pressure. Never approach, attempt to repair, or stop leaks while the pipeline is pressurized. Always depressurize the pipeline before making corrections. Faulty fusion joints must be cut out and redone.

5.6. Handling

Polyethylene piping is a tough, robust material, but it is not immune to damage. Improper handling or abuse can damage piping, compromise system performance, and result in injury or property damage. Polyethylene piping should be unloaded and moved with proper handling and lifting equipment. Use fabric slings. Do not use chains or wire ropes. Do not roll or drop pipe off the truck or drag piping over sharp rocks or other abrasive objects. Store piping to minimize the risk of mechanical damage.

5.7. Fusion in Cold Weather

In cold weather, polyethylene becomes more sensitive to impact and less flexible. Use additional care in handling. When temperatures are very cold, avoid sharp impacts such as dropping the pipe from moderate heights. Cold pipes will be harder to bend or uncoil. In inclement weather, especially in windy conditions, the fusion operation should be shielded to avoid precipitation or blowing snow and to prevent excessive heat loss from wind chill.
Information on fusion in cold weather can be found in ASTM F2620 *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*.

5.8. Key Factors for Quality Fusions

Quality fusion requires all required tools and equipment and follows all steps in the procedure in the correct sequence. The fusion procedure prepares and aligns the surfaces, heats the mating surfaces to the proper melt consistency, joins the surfaces together under pressure, and then cools the joint under pressure. Faulty fusion is caused by improper or defective equipment, omitting steps, or doing things out of sequence. Faulty fusion may be hazardous.

Training and experience provide knowledge and proficiency in what to do, what to expect, and recognizing potential problems in advance. Inadequately trained or inexperienced individuals can produce poor-quality fusions and may expose themselves or others to hazards. Federal safety regulations require that persons making joints in gas systems must be qualified in the pipeline operator's qualified fusion procedures. (See Regulations for Gas Pipe Joining)

The key factors necessary for quality fusion are:

- Fusion tools and equipment must be correct for the job, and in proper working order.

Each fusion procedure requires specific tools and equipment to be performed properly. Using poorly maintained, damaged, or incorrect tools and equipment can cause a poor fusion and may be hazardous. Use only the correct tools and equipment for the job. Do not use defective or improper tools or equipment. Follow the equipment manufacturer's maintenance procedures.

- The fusion operator must be proficient in the use of tools and equipment, and proficient in fusion procedures.

The operator should be thoroughly familiar with the tools and equipment, and their use and operation. Improper use or an incorrect operating sequence can cause a poor fusion and may be hazardous. Know how to use the equipment and follow the manufacturer's instructions.

- Pipe and fitting surfaces must be clean and properly prepared.

Dirty, contaminated, or poorly prepared surfaces that do not mate properly cannot produce a quality fusion. Clean and prepare the surfaces before joining. If contamination is reintroduced, clean the surfaces again.

- Heating tool surfaces must be clean, undamaged, and at the correct surface temperature.

Heating tool faces have non-stick coatings for quick, complete release from melted polyethylene. Dirty or contaminated heating tool faces can cause poor fusion, and damaged coatings may not release properly from the melt. Use only wooden implements, and clean, dry non-synthetic (cotton) cloths or paper towels to clean heating tool faces. Never use spray chemicals or metal tools on heating tool faces.

The specified temperature is the temperature on the surfaces that contact the pipe or fitting being joined, not the heating tool thermometer temperature. Use a pyrometer or infrared thermometer to check for uniform temperature across both component contact surfaces. (Temperature indication crayons are not preferred. If used, temperature-indicating crayons must never be applied to a surface that contacts a pipe or fitting.) Uneven temperature may indicate a faulty heater. The heater thermometer measures the internal temperature, which is usually higher than the surface temperature; however, the heating tool temperature can be verified by checking the thermometer to ensure it is maintaining the temperature. When checking surface temperature with a pyrometer or infrared thermometer, note the heating tool thermometer reading. Check the heating tool thermometer reading before each fusion to verify that the heating tool is maintaining the proper temperature. Incorrect or non-uniform temperature can cause poor fusion.

5.9. Before You Start:

- Inspect pipe lengths and fittings for unacceptable cuts, gouges, deep scratches, or other deleterious defects. Damaged products should not be used.
- Remove surface damage at pipe ends that could compromise the joining surfaces or interfere with fusion tools or equipment.
- Be sure all required tools and equipment are on site, in proper working order, and fueled up.

- The pipe and fitting surfaces where tools and equipment are fitted must be clean and dry. Use clean, dry, non-synthetic (cotton) cloths or paper towels to remove dirt, snow, water, and other contamination. Refer to ASTM F2620 for more guidance on proper cleaning of PE.
- Shield heated fusion equipment and surfaces from inclement weather and winds. A temporary shelter over the fusion equipment and the fusion operation may be required.
- Relieve tension in the line before making connections.
- When joining coiled pipe, making an S-curve between pipe coils can relieve tension. In some cases, it may be necessary to allow the pipe to equalize to the temperature of its surroundings. Allow pulled-in pipes to relax for several hours to recover from tensile stresses.
- Pipes must be correctly aligned before making connections.

  WARNING – Impact Hazard – Do not bend pipe into alignment against open butt fusion clamps. The pipe may spring out, causing injury or damage. Pipe must be aligned before placing it into the butt fusion equipment.

6. BUTT FUSION

6.1. Set-Up Parameters

Heating Tool Surface Temperature: 425°F ± 25°F (218°C ± 14°C)

Heating tool surfaces must reach the temperature indicated above before fusion begins. Prior to starting, all points on both heating tool surfaces that will contact the pipe or fitting ends must be within the prescribed temperature range.

A pyrometer or other surface-temperature measuring device shall be used before the first joint of the day and periodically throughout the day to ensure the heating tool face is at the proper temperature.

When the properly heated mating surfaces are brought together, the force required to make the joint is the force needed to roll the fusion-melt beads onto the pipe surface. This is determined visually.

The formula to calculate the hydraulic pressure for a hydraulic butt fusion machine, or the applied force (measured using a torque wrench) for a manual machine, is:

$$\mathrm{HP} = \frac{0.785 \times \left(\mathrm{OD}^2 - \mathrm{ID}^2\right) \times \mathrm{IP}}{\mathrm{PA}} + \mathrm{DP}$$

OD = Outside Diameter (in)

ID = Inside Diameter (in)

IP = Interfacial Pressure (psi)

PA = Piston Cross-sectional Area (in2)

DP = Drag Pressure (psi)

Drag pressure is the force required to move the carriage. Add this pressure to the theoretical fusion joining pressure to get the actual machine gauge pressure to set.

Refer to ASTM F2620, Table 2, for butt fusion machine setup parameters.

The maximum OD high-low misalignment allowed in the butt fusion procedure is to be less than 10% of the pipe's minimum wall thickness. It is also allowable to fuse pipes of unequal dimension ratios if the two pipes differ by no more than one standard DR increment. However, fusing two different DRs requires that the misalignment be less than 10% of the minimum wall thickness of the thinner-walled pipe.

6.2. Procedure

6.2.1. Secure

Clean the inside and outside of the component (pipe or fitting) ends by wiping with a clean, dry, lint-free cloth or paper towel. Remove all foreign matter. Align the components with the machine, place them in the clamps, and then close the clamps. Do not force pipes into alignment against open fusion machine clamps. (When working with coiled pipe, if possible, "S" the pipes on each side of the machine to compensate for coil curvature and make it easier to join.) Component ends should protrude past the clamps enough so that facing will be complete. Bring the ends together and check high-low alignment. Adjust alignment as necessary by tightening the high side down.

6.2.2. Face

Place the facing tool between the component ends, and face them to establish smooth, clean, parallel mating surfaces. Complete facing produces continuous circumferential shavings from both ends. Fusion equipment operators should check to confirm that the circumferential shavings are continuous. Face until there is a minimal distance between the fixed and movable clamps. Some machines have facing stops. If stops are present, face down to the stops. Remove the facing tool and clear all shavings and pipe chips from the component ends. Do not touch the component ends with your hands after facing.

6.2.3. Align

Bring the component ends together, check alignment, and check for slippage against fusion pressure. Look for complete contact at all points along both ends, with no detectable gaps, and for the outside diameters to be in high-low alignment (except for the misalignment permitted in section 6.1). If necessary, adjust the high side by tightening the high side clamp. Do not loosen the low-side clamp, as components may slip during fusion. Re-face if high-low alignment is adjusted.

6.2.4. Melt

Verify that the heating tool is maintaining the correct temperature. Place the heating tool between the component ends, then move the ends against it. The initial contact should be under moderate pressure (known as contact pressure) to ensure full contact. Hold contact pressure for a very brief moment, then lower to drag pressure without breaking contact. Contact pressure must be relieved at the first indication of melt completely around the pipe ends. Procedures for releasing the pressure in the hydraulic cylinder that creates interfacial pressure vary by manufacturer. Review the equipment manufacturer's recommended procedure to ensure that only drag pressure is applied during the soak cycle. Hold the ends against the heating tool using only drag pressure. Beads of melted polyethylene will form at the component ends against the heating tool. When the proper melt bead size is formed (see Table 1), quickly separate the ends and remove the heating tool.

During heating, the melt bead will expand out flush to the heating tool surface or may curl slightly away from the surface. If the melt bead curls significantly away from the heating tool surface, it may indicate unacceptable pressure during heating.

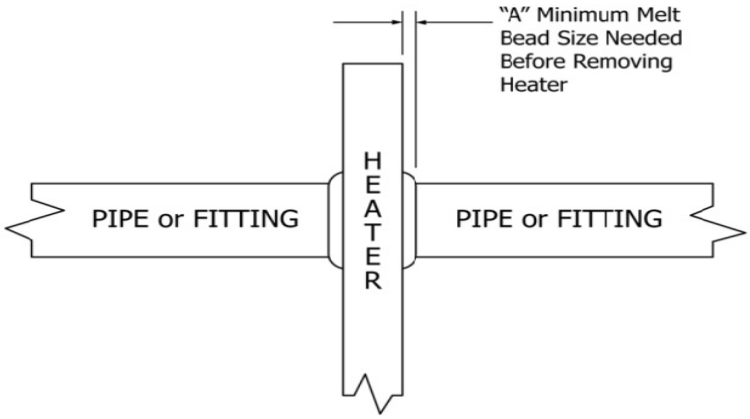

Figure 1: Minimum Bead Size 'A' Determined by Table 1

Table 1: Melt Bead Sizes for Corresponding Pipe Sizes

Pipe Outside Diameter (OD) (inch)	"A" Minimum Bead Size (inch). Measured from the heater plate
<2.37 (60mm)	1/32 (1mm)
≥ 2.37 (60mm) ≤ 3.5 (89mm)	1/16 (1.5mm)
> 3.5 (89mm) ≤ 8.62 (219mm)	3/16 (5mm)
> 8.62 (219mm) ≤ 12.75 (324mm)	1/4 (6mm)
> 12.75 (324mm) ≤ 24 (610mm)	3/8 (10mm)
> 24 (610mm) ≤ 36 (900mm)	7/16 (11mm)
> 36 (900) ≤ 65 (1625mm)	9/16 (14mm)

6.2.5. Join

Immediately after heating tool removal. Quickly inspect the melted ends, which should be flat, smooth, and completely melted. If the melt surfaces are acceptable, immediately and in a continuous motion, bring the ends together and apply the correct joining pressure. Do not slam. Where the equipment permits, ramping up to the joining pressure is desirable. Apply enough joining pressure to roll both melt beads over to the pipe surface.

A concave melted surface is unacceptable (Figure 2); it indicates pressure during heating. Do not continue. Allow the component to cool and start over. The correct joining pressure will form a double bead that is rolled over to the surface on both ends.

Figure 2 - Unacceptable Concave Melt Appearance

6.2.6. Hold

Hold the joining pressure against the ends until the joint is cool. The joint is cool enough for gentle handling when the double bead is cool to the touch. Cool for about 30 – 90 seconds per inch of pipe diameter. Do not try to shorten the cooling time by applying water, wet cloths, or the like. Avoid pulling, installation, pressure testing, and rough handling for at least an additional 30 minutes[1]. Heavier-walled pipes require longer cooling times.

6.2.7 Inspect

Visually inspect and compare the joint against the butt fusion bead inspection acceptance guideline in Figure 3. The v-groove between the beads should not be deeper than half the bead height above the pipe surface.

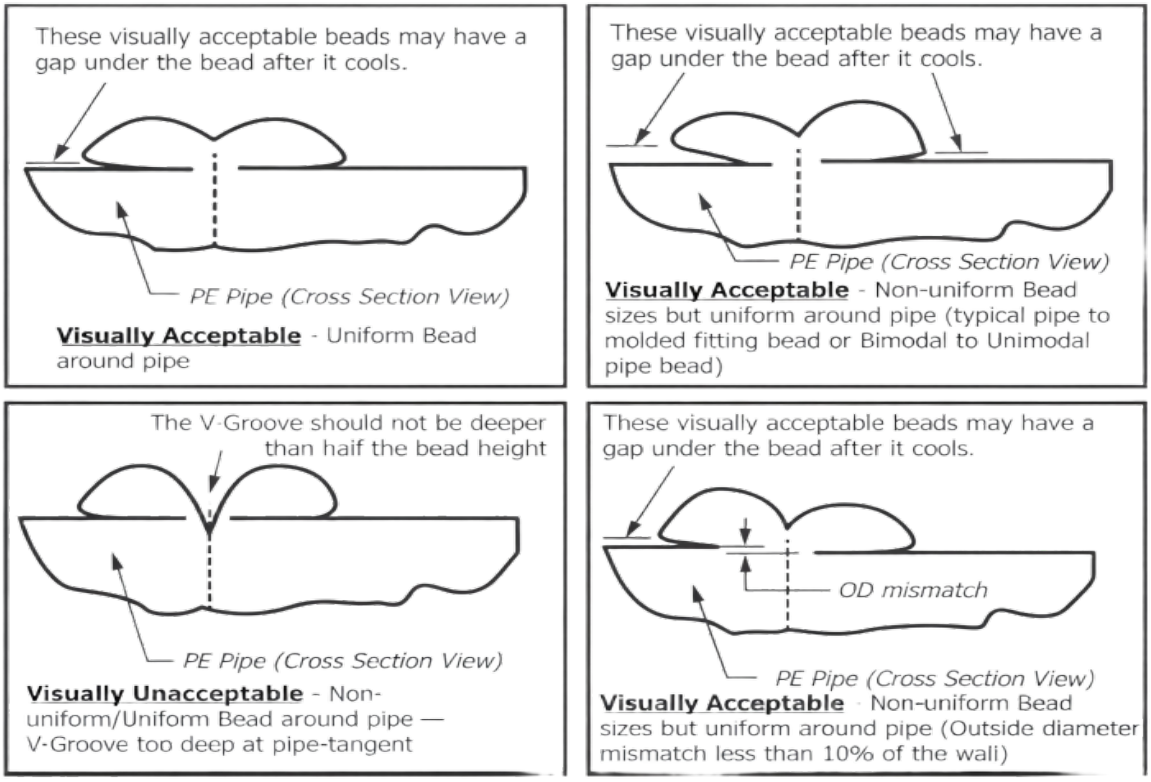

Figure 3 - Outside Diameter Butt Fusion Bead Guidelines as per ASTM F2620

- When butt fusing to molded fittings, the fitting's side bead may have an irregular appearance. This is acceptable provided the pipe side bead is correct.
- It is not necessary for the internal bead to roll over to the inside surface of the pipe.
- When butt-fusing dissimilar polyethylene pipes, the melt bead size may vary due to differences in melt index. This is acceptable provided the melted bead is sufficiently large.

[1]Allow the pipe to cool to ambient temperature for the pipe to be used in directional drilling applications or pipe otherwise subject to high tensile loads.

Table 2 - Butt Fusion Bead Troubleshooting Guide

Observed Condition	Possible Cause
Excessive double bead width	Overheating; Excessive joining force
Double bead v-groove too deep	Excessive joining force; Insufficient heating; Pressure during heating
Flat top on bead	Excessive joining force; Overheating
Non-uniform bead size around the pipe	Misalignment; Defective heating tool; Worn Equipment; Incomplete facing
One bead larger than the other	Misalignment; Component slipped in clamp; Worn equipment; Defective heating tool; Incomplete facing dissimilar material - see note above
Beads too small	Insufficient equipment; Insufficient joining force
Beads not rolled over to surface	Shallow v-groove - Insufficient heating & insufficient joining force. Deep v-groove - Insufficient heating & excessive joining force
Beads too large	Excessive heating time
Square-ish outer bead edge	Pressure during heating
Rough, sandpaper-like, bubbly, or pockmarked mealt bead surface	Hydrocarbon contamination

6.3. Butt Fusion Qualifying Procedure

6.3.1.

Prepare a sample joint. Pipes on either side of the joint should be at least 6" (150 mm) or 15 times the wall thickness in length. Observe the joining process to determine that the correct procedure is being followed.

6.3.2.

Visually inspect the sample joint and compare it to a sample or picture of an acceptable joint.

6.3.3.

Allow the sample to cool completely for at least 1 hour.

6.3.4.

Cut the sample joint lengthwise along the pipe into at least three straps that are at least 1" (25 mm) or 1.5 wall thicknesses wide.

6.3.5.

Visually inspect the cut surface at the joint and compare it to a sample or picture of an acceptable joint. There should be no gaps, voids, misalignment, or unbonded areas.

6.3.6.

Bend the straps until the ends of the straps touch. The test strap must be free of cracks and separations within the fusion joint zone.

6.3.7.

If flaws are observed in the joint, compare the appearance with pictures of unacceptable joints. Prepare a new sample joint using the correct joining procedure and repeat the qualifying procedure.

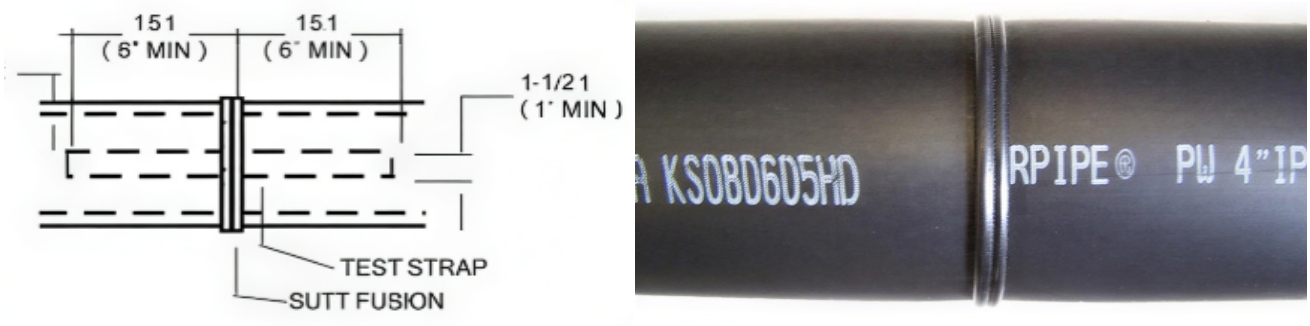

Figure 4 - Acceptable Appearance

6.4. Acceptable Fusions

- Proper double roll back bead
- Proper alignment

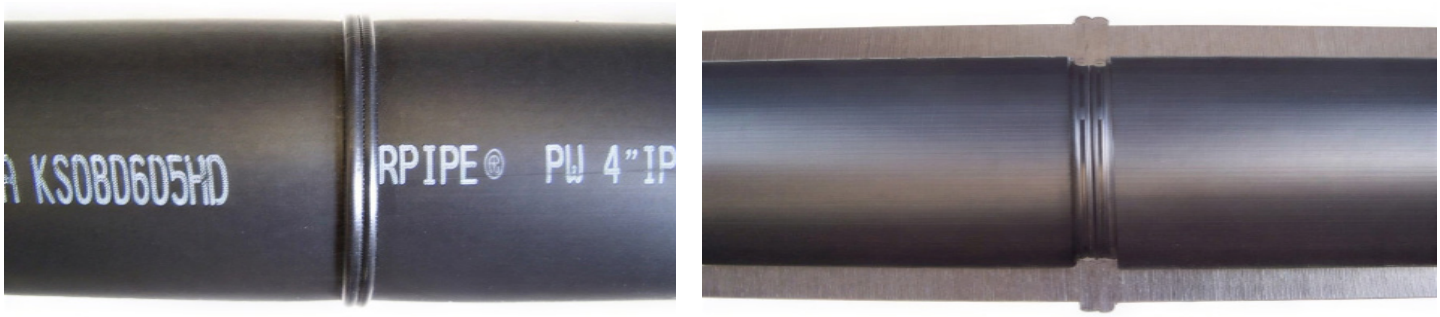

Figure 5 - Acceptable Fusions

6.5. Unacceptable Fusions

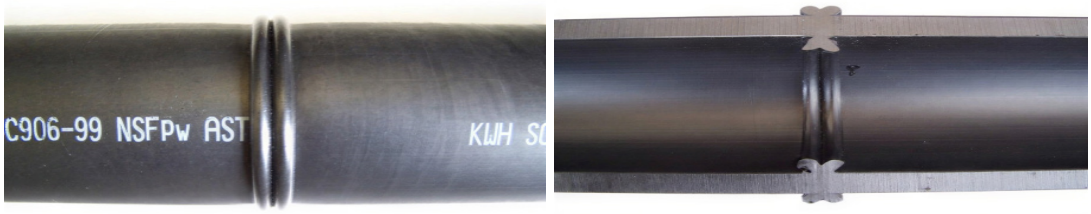

Figure 6 - Excessive heat time or too much applied pressure (melt bead too large)

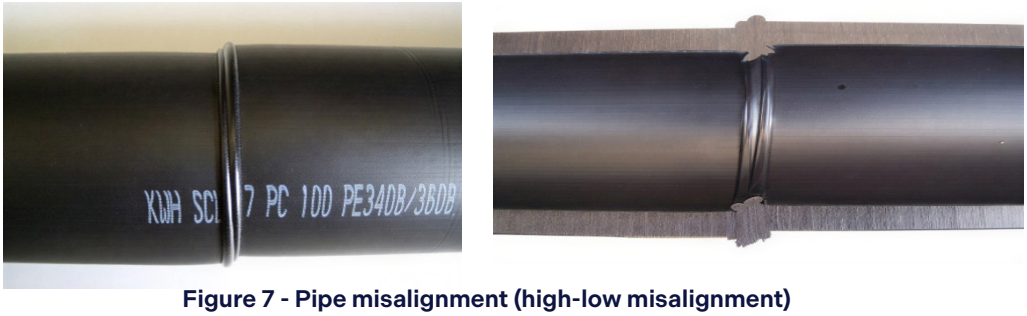

Figure 7 - Pipe misalignment (high-low misalignment)

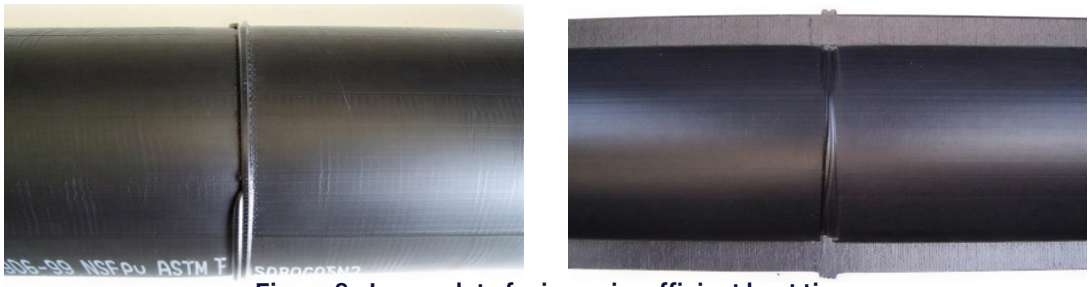

Figure 8 - Incomplete facing or insufficient heat time

Figure 9 - Pipe angled in the fusing unit