HEAT FUSION PROCEDURES

INTRODUCTION

This document provides guidelines and general practices and procedures implemented at Rahn Plastics Inc. for heat fusion of Polyethylene pipe and fittings.
Rahn Plastics Inc. is certified to ISO 9001-2015 Quality Management System that ensures all operations are to be performed in accordance with Production Process Instructions, Workmanship, Standards, Inspections and Test Instructions.
These procedures include all control conditions that must be maintained during operations including:

- Equipment specifications and environmental working conditions
- Process parameters and product characteristics that must be monitored and controlled
- Operator qualifications
- Acceptance criteria for workmanship

STANDARDS

This document makes reference, directly or implied from the identified Standards and Guidelines. Compliance requirements identified by relevant standards and/or codes:

ASTM F2620
Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings

ASTM F1056
Standard Specification for Socket Fusion Tools for Use in Socket Fusion Joining Polyethylene Pipe or Tubing and Fittings

ASTM D3350
Standard Specification for Polyethylene Plastics Pipe and Fittings Materials

ASTM D3035
Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter

These procedures are intended for heat fusion joining of PE fuel gas pipe and fittings produced in accordance with (ASTM D3261 & D2513). It also is intended for heat fusion joining of PE potable water, sewer and industrial pipe and fittings manufactured in accordance with ASTM F714, ASTM D3035, AWWA C-901 and AWWA C-906.

REFERENCE DOCUMENTS

This procedure is to be used in conjunction with PPI Handbook of Polyethylene Pipe, Chapter 9: Polyethylene Joining Procedures and the following PPI Technical Reports.

- **PPI TR-33-** Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe
- **PPI TR-41-** Generic Saddle Fusion Joining Procedure for Polyethylene Gas Piping
- **PPI TN-42-** Recommended Minimum Training Guidelines for PE Pipe Butt Fusion Joining Operators for Municipal and Industrial Projects

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THERMAL HEAT FUSION METHODS

There are three types of conventional heat fusion joints currently used in the industry; Butt, Saddle, and Socket Fusion. Additionally, electrofusion (EF) joining is available with special EF couplings and saddle fusion. The principle of heat fusion is to heat two surfaces to a designated temperature, and then fuse them together by application of a sufficient force. This force causes the melted materials to flow and mix, thereby resulting in fusion. When fused according to the pipe and/or fitting manufacturers' procedures, the joint area becomes as strong as, or stronger than, the pipe itself in both tensile and pressure properties and properly fused joints are absolutely leak proof. As soon as the joint cools to near ambient temperature, it is ready for handling.

BUTT FUSION

As per TR-33 Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe/ ASTM F2620 Standard Practice For Heat Fusion Joining of Polyethylene Pipe and Fittings

The most widely used method for joining individual lengths of PE pipe and pipe to PE fittings is by heat fusion of the pipe butt ends. This technique produces a permanent, economical and flow-efficient connection. Quality butt fusion joints are produced by using trained operators and quality butt fusion machines in good condition.

Equipment

- Pipe Cutters
- Approved Butt fusion Machine
- Stop watch
- Clean Cotton Rag
- Pyrometer
- Approved alcohol wipes

WORK INSTRUCTION-Butt Fusion

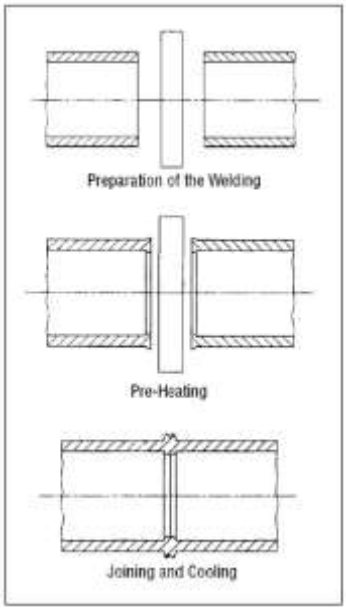
As per PPI TR-33 - Generic Butt Fusion Joining Procedure Butt Fusion Procedure Parameters the Generic Fusion Interface Pressure Range is 60-90 psi (4.14-6.21 bar) and Generic Heater Surface Temperature Range is 400 - 450°F (204-232ºC). Field-site butt fusions may be made readily by trained operators using butt fusion machines that secure and precisely align the pipe ends for the fusion process.

The five basic sequential steps involved in making a butt fusion joint

1-PREPARATION: Clean, clamp and align the pipe ends to be joined. The pipes must be installed in the fusion machine, and the ends cleaned with non- depositing alcohol to remove all dirt, dust, moisture, and greasy films, on both inside and outside diameter faces. With medium sand paper scratch 13mm (1/2") of external surface to allow bead to roll over.

2-FACING: The pipe ends are faced to establish clean, parallel surfaces to fit mitered angles. The ends of the pipe are faced using a rotating cutter to remove all rough ends and oxidation layers. The trimmed end faces must be clean and parallel surfaces to fit mitered angles. Check alignment of pipe ends. There should be no more than 10% of the wall thickness in misalignment to maintain full joint strength.

3-PRE-HEATING: The ends of the PE pipes are heated by contact under pressure against a heater plate. The heater plates must be clean and free from contamination. Contact is maintained until even heating is established around the pipe ends, and the contact pressure then reduced to a lower value called the heat soak pressure. Contact is then maintained until the appropriate heat soak time elapses.



4-JOINING: The heated pipe ends are then retracted and the heater plate removed. The heated PE pipe ends are then brought together and pressurised evenly to the welding pressure value. The pressure adopted in this phase depends on the pipe size. Bead sizes are to be monitored as identified in table 1. The maximum recommended time allowed for heater plate removal is indicated in Table 2.

5-COOLING: The pressure is then maintained for a period to allow the fusion process to take place, and the fused joint to cool down to ambient temperature, and hence develop full joint strength. During this cooling period the joints must remain undisturbed and under compression. Under no circumstances should the joints be sprayed with cold water. Finished fitting is removed from fusion tools once sufficient cooling time has elapsed. Allow minimum 30 minutes before rough handling

Table 1-Minimum Bead sizes

Table 3 ASTM F2620

Pipe (OD) Outside Diameter, in. (mm)	"A" Minimum Bead Size, in. (mm)
< 2.375"	1/32" (1)
≥ 2.375" (60) ≤ 3.5 (89)	1/16" (1.5)
> 3.500" (89) ≤ 8.62 (219)	3/16" (5)
> 8.625" (219) ≤ 12.75 (324)	¼" (6)
> 12.750" (324) ≤ 24 (610)	3/8" (10)
> 24.000" (610) ≤ 36 (900)	7/16" (11)
> 36.000" (900) ≤ 65 (1625)	9/16" (14)

VISUAL INSPECTION

Visually, the width of butt fusion beads should be approximately 2-2 ½ times the bead height above the pipe and the beads should be rounded and uniformly sized all around the pipe circumference. The v-groove between the beads should not be deeper than half the bead height above the pipe surface. When butt fusing to molded fittings, the fitting-side bead may display shape irregularities such as minor indentations, deflections and non-uniform bead rollover from molded part cooling and knit lines. In such cases, visual evaluation is based mainly on the size and shape of the pipe-side bead. See *Fig 1.0* for bead configuration. Visually unacceptable joints should be cut out and re-fused using the correct procedure.

Fig 1.0

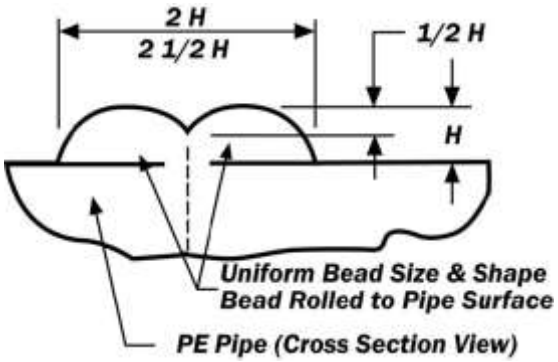


Table 2- Maximum Heater Plate Removal Times

Table 4 ASTM F2620

Pipe Wall Thickness, in	Max. Heater Removal Time, sec
0.20 to 0.36	8
>0.36 to 0.55	10
>0.55 to 1.18	15
>1.18 to 2.5	20
>2.5 to 4.5	25

INTERFACIAL PRESSURE

An interfacial pressure (IFP) of 60 to 90 psi (0.41 to 0.62 MPa) is used to determine the force required to butt fuse the pipe components. For manually operated fusion machines, enough force should be applied to roll the bead back to the pipe surface. A torque wrench may be use to apply the proper force. For hydraulically operated fusion machines, the fusion force can be divided by the total effective piston area of the carriage cylinders to give a hydraulic gauge reading in psi. The gauge reading is theoretical; internal and external drags are added to this figure to obtain the actual fusion pressure required by the machine. The hydraulic gauge reading is dependent upon pipe diameter, DR and machine design. Interfacial pressure and gauge reading are not the same value. To determine butt fusion joining pressure settings for hydraulic butt fusion machines *see ASTM F2620 section 8.2.2*

COLD WEATHER PROCEDURE

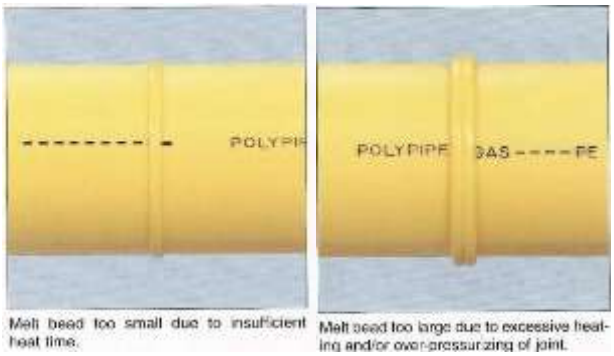
In Cold weather, the initial bead will take longer to form, due to low pipe temperature. For recommended guidelines when fusing in inclement weather, refer to the Plastics Pipe Institute, PPI Technical note TN-42: Recommended Minimum Training Guidelines for PE Pipe Butt Fusion Joining Operators for Municipal and Industrial Projects.

These guidelines apply to all applications. Additional information concerning cold weather procedures is available in ASTM F2620, Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings, Annex A1. The operator should ensure that its qualified fusion procedures take into account and are adapted for all potential inclement weather conditions in which the operator may be fusing polyethylene pipe.

Acceptable Butt Fusions

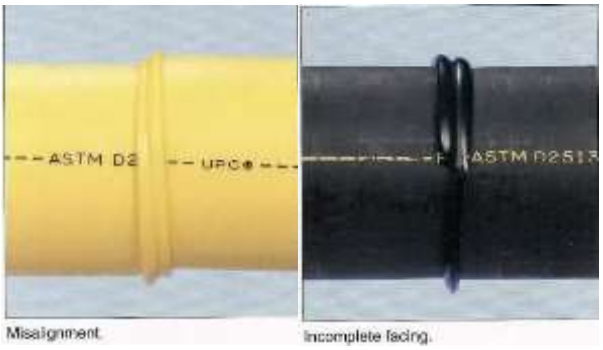
Proper alignment and double roll-back bead.

Unacceptable Butt Fusions



Melt bead too small due to insufficient heat time.

Melt bead too large due to excessive heating and/or over-pressurizing of joint.



Misalignment.

Incomplete facing.

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 pipe	➢ Misalignment ➢ Defective heating tool ➢ Worn equipment ➢ Incomplete facing
One bead larger than the other	➢ Misalignment ➢ Component slipped in clamp ➢ Worn equipment ➢ Heating iron does not move freely in the axial direction
Beads too small	➢ Insufficient heating ➢ Insufficient joining force
Beads not rolled over to surface	➢ Shallow v-groove – Insufficient heating & insufficient joining force ➢ Deep v-groove – Insufficient heating and excessive joining force
Beads too large	➢ Excessive heating time
Square type outer bead edge	➢ Pressure during heating
Rough, sandpaper-like, bubbly, or pockmarked melt bead surface	➢ Hydrocarbon (gasoline vapors, spray paint fumes, etc.) contamination

SADDLE FUSION

As per TR-41 Generic Saddle Fusion Joining Procedure for Polyethylene Gas Piping/ ASTM F2620 Standard Practice For Heat Fusion Joining of Polyethylene Pipe and Fittings

The conventional technique to join a saddle to the side of a pipe consists of simultaneously heating both the external surface of the pipe and the matching surface of the "saddle" type fitting with concave and convex shaped heating tools until both surfaces reach proper fusion temperature. This may be accomplished by using a saddle fusion machine that has been designed for this purpose. Saddle fusion using a properly designed machine, provides the operator better alignment and force control, which is very important to fusion joint quality. The Plastics Pipe Institute recommends that saddle fusion joints be made only with a mechanical assist tool unless hand fusion is expressly allowed by the pipe and/or fitting manufacturer.

Equipment

- Approved Scraper
- Approved Heating Tool
- Heater Faces
- Saddle Fusion Machine
- Stop watch
- Clean Cotton Rag
- Pyrometer
- Approved alcohol wipes

Definitions

Initial Heat (Bead-up) - The heating step used to develop an initial melt bead on the main pipe.

Initial Heat Force (Bead-up force) - The force (pounds) applied to establish an initial melt pattern on the main pipe. The Initial Heat Force is determined by multiplying the fitting base area (sq. inches) by the initial interfacial pressure (pounds per square Inch.)

Heat Soak Force - The force (pounds) applied after an initial melt pattern is established on the main pipe. The Heat Soak Force is the minimum force (essentially zero pounds) that ensures that the fitting, heater and main stay in contact with each other.

Fusion Force -The force (pounds) applied to establish the fusion bond between the fitting and the pipe. The Fusion Force is determined by multiplying the fitting base area (square inches) by the fusion interfacial pressure (pounds per square inch).

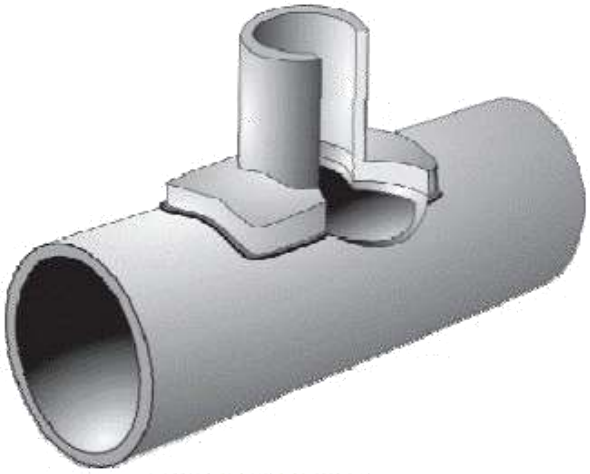
Total Heat Time - A time that starts when the heater is placed on the main pipe and initial heat force is applied and ends when the heater is removed.

Cool Time - The time required to cool the joint to approximately 120°F (49°C). The fusion force must be maintained for 5 minutes on 1 _" IPS or 10 minutes for all other main sizes, after which the saddle fusion equipment can be removed. The joint must be allowed to cool undisturbed for an additional 30 minutes before tapping the main or joining to the branch outlet.

Interfacial Area for rectangular base fittings - The major width times the major length of the saddle base, without taking into account the curvature of the base or sides, minus the area of the hole in the center of the base.

Interfacial Area for round base fittings - The radius of the saddle base squared times (3.1416), without taking into account the curvature of the base or sides, minus the area of the hole in the center of the base.

Fitting Label - The initial heat force, heat soak force and the fusion force may be listed in the lower right hand corner of the fitting label for all saddle fusion fittings (depending upon the manufacturer, This will eliminate the need to calculate the fusion forces in the field. (Example: 180/0/90)



Standard Saddle Fusion Joint

The temperature of the heater adapter fusion surfaces must be 500°±10°F. (Table 2)

Table 2: Generic Saddle Fusion Parameters

Heater Adapter Surface Temperature	500°±10°F
Initial Interfacial Pressure	60±6 psi
Heat Soak Interfacial Pressure	0 psi
Total Heating Time on Main—1 _" IPS Pressure Main	15 seconds max
Fusion Interfacial Pressure	30±3 psi
Total Heating Time on Main--2" IPS Pressure Main	25-35 seconds max.
Total Heating Time on non-pressure 1 _" IPS, 2" IPS mains, and on pressure or non-pressure 3" IPS and larger mains	Look for a 1/16" bead around the fitting base

WORK INSTRUCTION-Saddle Fusion

There are five basic sequential steps that are commonly used to create a saddle fusion joint;

1-PREPARATION: This procedure requires the use of a Saddle Fusion Tool. This tool must be capable of holding and supporting the main, rounding the main for good alignment between the pipe and fitting, holding the fitting, and applying and indicating the proper force during the fusion process.

2-INSTALL FUSION TOOL: Install the Saddle Fusion Tool on the main. The tool should be centered over a clean, dry location where the fitting will be fused. Secure the tool to the main. Abrade the main, where the fitting will be joined. The abraded area must be larger than the area covered by the fitting base. After abrading, brush residue away with a clean, dry cloth. Abrade the fusion surface of the fitting. Insert the fitting in the Saddle Fusion Tool loosely.

3-PRESSURE APPLICATION: Using the Saddle Fusion Tool, move the fitting base against the main pipe and apply approximately 100 pounds-force to seat the fitting. Secure the fitting in the Saddle Fusion Tool.

4-HEATING: The heater must be fitted with the correct heater adapters. As per ASTM F2620 Standard Practice For Heat Fusion Joining of Polyethylene Pipe and Fittings

Place the heating tool on the main centered beneath the fitting base. Immediately move the fitting against the heater faces, apply the Initial Heat Force (see fitting label), and start the heat time. Apply the Initial Heat Force until melt is first observed on the crown of the pipe main (Initial Heat is the term used to describe the initial heating (bead-up) step to develop a melt bead on the main pipe and usually is 3-5 seconds) and then reduce the force to the Heat Soak Force (Bead-up force) (Table 2). Maintain the Heat Soak Force until the Total Heat Time is complete. At the end of the Total Heat Time, remove the fitting from the heater and the heater from the main with a quick snapping action. Quickly check for an even melt pattern on the pipe main and fitting heated surfaces (no unheated areas).

5-FUSION and COOLING: Whether or not the melt patterns are satisfactory, press the fitting onto the main pipe very quickly (within 3 seconds) after removing the heater and apply the Fusion Force (see the fitting label). Maintain the Fusion Force on the assembly for 5 minutes on 1 _" IPS and for 10 minutes on all larger sizes, after which the saddle fusion equipment may be removed. (Fusion Force adjustment may be required during Cool Time, but never reduce the Fusion Force during cooling.) (Table 2) Cool the assembly for an additional 30 minutes before rough handling or tapping the main.

COLD WEATHER PROCEDURE

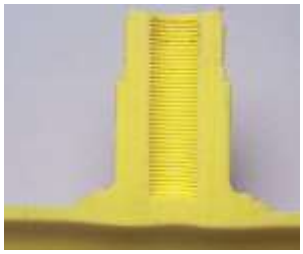
These procedures are based on tests conducted under controlled ambient temperature conditions. Environmental conditions on a job site could affect heating and cooling times. Regardless of job site conditions or ambient temperature, the prescribed heating tool temperature is required. Do not increase or decrease the heating tool temperature. Refer to ASTM F2620 Annex A1. Cold Weather Procedures for further information.

VISUAL INSPECTION

The fusion bead is to be inspected around the entire base of the fitting at the main pipe. The fusion bead should be of uniform size and should have a "three-bead" shape, which is characteristic of this type of fusion. Melt beads must be free of gaps or voids. The first bead is the fitting base melt bead. The second or outermost bead is the result of the heater tool face on the main pipe. The third bead, or center bead, is the main pipe melt bead. All beads should be of uniform size with the first and third being approximately the same and the second generally being smaller.

Acceptable Saddle Fusion

Proper alignment, force and melt
Proper pipe surface preparation



No gap or voids at fusion interface

Unacceptable Saddle Fusions

Insufficient melt & misaligned

Bead above base of fitting

Saddle Fusion Bead Troubleshooting Guide

Observed Condition	Possible Cause
Non-uniform bead size around fitting base	➢ Misalignment ➢ Defective heating tool ➢ Fitting not secured in heating tool ➢ Heating temperature not within specified range
One bead larger than the other	➢ Misalignment ➢ Heating temperature not within specified range ➢ Fitting slipped in clamp ➢ Defective or worn equipment
Beads too small	➢ Insufficient heating ➢ Insufficient joining force
Beads too large	➢ Excessive heating time ➢ Excessive joining force
Absence of third bead, or third bead widely separated from center bead	➢ Incorrect pipe main heating tool ➢ Insufficient joining force
Pressurized main blowout (beside base or through fitting base)	➢ Excessive heating ➢ Heating temperature not within specified range ➢ Incorrect heating tool faces ➢ Excessive time to start heating or in joining the fitting to the main pipe after heating time cycle
Rough, sandpaper-like, bubbly, or pockmarked melt bead surface	➢ Hydrocarbon (gasoline vapors, spray paint fumes, etc.) contamination

SOCKET FUSION

As per Chapter 9 PE Pipe Joining Procedures/ ASTM F2620 Standard Practice For Heat Fusion Joining of Polyethylene Pipe and Fittings

This technique consists of simultaneously heating both the external surface of the pipe end and the internal surface of the socket fitting until the material reaches the recommended fusion temperature, inspecting the melt pattern, inserting the pipe end into the socket, and holding it in place until the joint cools. Figure 2.0 illustrates a typical socket fusion joint. Mechanical equipment is available to hold both the pipe and the fitting and should be used for sizes larger than 2" CTS to help attain the increased force required and to assist in alignment. Most pipe manufacturers have detailed written procedures to follow. The majority refer to ASTM F 2620.

Figure 2.0 Standard Socket Fusion Joint

Follow these general steps when performing socket fusion:

- Thoroughly clean the end of the pipe and the matching inside surface of the fitting
- Square and prepare the pipe end
- Heat the parts
- Join the parts
- Allow to cool

Equipment

- Pipe Cutter
- Chamfering Tool
- Heater Face
- Depth Gauge
- Cold Rings
- Stop watch
- Clean Cotton Rag
- Pyrometer
- Approved alcohol wipes

EQUIPMENT SELECTION

Select the proper size tool faces and heat the tools to the fusion temperature recommended for the material to be joined. As per ASTM F2620 Heating tool faces are produced to Specification ASTM F1056 dimensions, and are coated with a non-stick material to keep melted pipe and fitting material from sticking to the face.

WORK INSTRUCTION-Socket Fusion

As per ASTM F2620 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings the Heater Surface Temperature Range is 490°F to 510°F (254 to 266°C) for socket fusions.

The four basic sequential steps involved in making a socket fusion joint

1-PREPARATION: Cut the end of the pipe square. Chamfer the pipe end for sizes 1¼"-inch diameter and larger. (Chamfering of smaller pipe sizes is acceptable and sometimes specified in the instructions.) Remove scraps, burrs, shavings, oil, or dirt from the surfaces to be joined. Clamp the cold ring on the pipe at the proper position, using the integral depth gauge pins or a separate (thimble type) depth gauge. The cold ring will assist in re- rounding the pipe and provide a stopping point for proper insertion of the pipe into the heating tool and coupling during the fusion process.

2-HEATING: Check the heater temperature. Periodically verify the proper surface temperature using a pyrometer or other surface temperature measuring device. If temperature indicating markers are used, do not use them on a surface that will come in contact with the pipe or fitting. Bring the hot clean tool faces into contact with the outside surface of the end of the pipe and with the inside surface of the socket fitting, in accordance with pipe and fitting manufacturers' instructions.

3-JOINING: Simultaneously remove the pipe and fitting from the tool using a quick "snap" action. Inspect the melt pattern for uniformity and immediately insert the pipe squarely and fully into the socket of the fitting until the fitting contacts the cold ring. Do not twist the pipe or fitting during or after the insertion, as is the practice with some joining methods for other pipe materials.

4-COOLING: Hold or block the pipe in place so that the pipe cannot come out of the joint while the mating surfaces are cooling. These cooling times are listed in TABLE 1 Socket Fusion Time Cycles from ASTM F2620

ASTM F2620 TABLE 1 Socket Fusion Time Cycles

PIPE SIZE	PE 2708		PE 4710	
	HEATING TIME (Sec)	COOLING TIME (Sec)	HEATING TIME (Sec)	COOLING TIME (Sec)
½" CTS	6-7	30	6-10	30
¾" CTS	6-7	30	6-10	30
1" CTS	9-10	30	9-16	30
1 ¼" CTS	10-12	30	10-16	30
½" IPS	6-7	30	6-10	30
¾" IPS	8-10	30	8-14	30
1" IPS	10-12	30	15-17	30
1 ¼" IPS	12-14	45	18-21	60
1 ½" IPS	14-17	45	20-23	60
2" IPS	16-19	45	24-28	60
3" IPS	20-24	60	2832	75
4" IPS	24-29	60	32-37	75

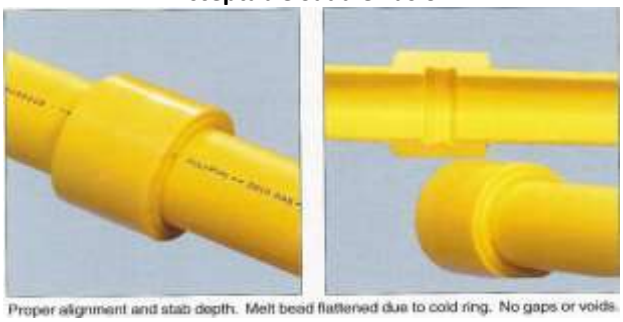
COLD WEATHER PROCEDURE

These procedures are based on tests conducted under controlled ambient temperature conditions. Environmental conditions on a job site could affect heating and cooling times. Regardless of job site conditions or ambient temperature, the prescribed heating tool temperature is required. Do not increase or decrease the heating tool temperature. Refer to ASTM F2620 Annex A1. Cold Weather Procedures for further information.

VISUAL INSPECTION

After completing the specified cooling and waiting time, remove the cold ring clamp and the socket fitting holder. Inspect the joint. A good joint will have a uniform melt ring that is flat against the socket fitting and perpendicular to the pipe. There should be no gaps, voids or un-bonded areas between the fitting and the pipe.

Acceptable Saddle Fusion



Proper alignment and stab depth. Melt bead flattened due to cold ring. No gaps or voids.

Unacceptable Saddle Fusions

Short stab depth caused by failure to use a depth gauge.

Excessive stab depth caused by failure to use a cold ring.

Socket Fusion Bead Troubleshooting Guide

Observed Condition	Possible Cause
No cold-ring impression in socket fitting	➢ Depth gauge not used ➢ Cold ring not used or set at incorrect depth ➢ Insufficient heat time
Gaps or voids around pipe at socket fitting edge	➢ Pipe or fitting not inserted or removed straight from heater face ➢ Joining together at an angle ➢ Twisting while joining pipe and fitting ➢ Cold ring not used or set at incorrect depth
Voids in fusion bond area together	
Wrinkled or collapsed pipe or tubing end	➢ Incorrect heating sequence –Push the pipe or tubing into the heater after the fitting (Inserting the tubing first heats the tubing too long) ➢ Cold ring set too deep ➢ Cold ring not used
Un-bonded area on pipe or tubing at end of pipe or tubing	➢ Cold ring set too deep ➢ Cold ring not used
Socket melt extends past end of pipe or tubing	➢ Cold ring set too shallow
Rough, sandpaper-like, bubbly, or pockmarked melt bead surface	➢ Hydrocarbon contamination