

**General Guidelines for Butt,
Saddle, and Socket Fusion of
Unlike Polyethylene Pipes and
Fittings**

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FOREWORD

This technical note was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute. The members have shown their interest in quality products by assisting independent standard-making and user organizations in the development of standards, and also by developing reports on an industry-wide basis to help engineers, code officials, specifying groups, and users.

This technical note has been prepared to provide those responsible for the joining of polyethylene (PE) piping for fuel gas and other applications with suggested general guidelines for the heat fusion of components made from PE's that exhibit unlike (i.e., significantly different) melt flow properties. These guidelines constitute a set of basic operations that have been demonstrated by test and experience to produce satisfactory joints with commercially available materials. Upon this framework may be developed the specific procedures for the joining of a particular combination of unlike PE piping products. Each specific procedure must be acceptable to, and qualified by, the operator having legal responsibility for the performance of the piping system.

These guidelines are intended only for making heat fusion joints with unlike materials under specific conditions. It is recommended that there be no indiscriminate mixing in a PE piping system of components made from unlike materials.

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PPI intends to revise this report from time to time, in response to comments and suggestions from users of this note. Please send suggestions for improvements to PPI. Information on other publications can be obtained by contacting PPI directly or visiting the web site.

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1.0 INTRODUCTION

On occasion it may be necessary for an installer of a polyethylene (PE) piping system to heat fuse to each other piping components that are made from unlike PE materials. Recognizing this, the Plastics Pipe Institute first issued in April of 1974 Statement E, "Criteria for Joining Various Polyethylene Materials to One Another by Heat Fusion Techniques", which includes some general guidelines for this operation. Since the publishing of this statement, additional laboratory and field evaluations have been conducted by PPI members and independent testing laboratories, and new information has become available from the literature and other sources.

Upon this background have been developed the general guidelines presented in this technical note. These should be useful in establishing the procedures for the heat fusion joining of specific combinations of unlike PE materials.

In its previously issued Statement E the Plastics Pipe Institute warned that "indiscriminate mixing without consideration of inherent differences between polyethylenes can produce faulty joints subject to failure in service". PPI continues to hold to this position against indiscriminate mixing.

If the application is for butt fusion of gas distribution pipe, refer to TR - 33, "Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe". In general, if the materials to be butt fused meet ASTM D2513 and have a melt index between 0.05 and 0.25 g/10 min inclusive, the generic procedure defined in TR - 33 apply. This melt index range represents the melt index extremes of the polyethylene materials that were joined and evaluated in the development of TR-33. The procedure defined in TR-33 may apply to materials with melt indices outside of this range, but appropriate testing would be required to determine the applicability of TR-33 to these materials.

A number of PPI member manufacturers made successful fusions between the various manufacturers products using the TR-33 generic procedure then tested the fusions per DOT requirements. The manufacturers then prepared letters of endorsement that identify the combinations of products that were successfully fused using the TR-33 generic procedure, and tested under DOT requirements. The manufacturer's letters of endorsement are published in Appendix B of TR-33 for gas piping applications, and Appendix C for municipal and industrial applications. TR-33 also states, "The results further indicate that there is strong likelihood that the generic fusion procedure used in this testing (see Appendix A) could be qualified by gas pipeline operators under DOT's regulations in Part 192 for use with most of these PE piping products."

Current United States and Canadian PE 2406 and PE 3408 gas pipe materials fall in the 0.05 to 0.25 g/10 min range used in TR-33. Materials no longer commercially available, but which may be encountered in the ground for extension and/or service connections, such as Driscopipe 8000, 8600, and DuPont/Uponor Aldyl A, fall outside of the TR-33

melt index range. For fusing to materials outside of the TR-33 range, the guidelines in this Technical Note may apply and the user should contact the manufacturers of the components to be fused.

Materials that have been pre-qualified to be joined by the TR-33 generic fusion procedure are within the nominal melt index range of 0.05 to 0.25 gm/10 minutes (190°C/ 2.16 Kg), or a high load melt flow of 6 to 17 gm/10 minutes (190°C/21.6 Kg), and have a nominal base resin (non-pigmented) density range of 0.936 to 0.955 gm/cc.

2.0 HEAT FUSION JOINING AND EVALUATION OF JOINTS

In the heat fusion joining process, joining of the two components occurs by melting two aligned interfaces; merging the melts, and solidifying the unified melt by cooling under pressure. A fundamental factor for the efficient merger of the two materials is the development, in the interfaces to be joined, of melts that are uniform. Another factor is for the merger to take place evenly and under positive pressure over the entire interface. Parameters affecting melt quality are heating temperature, heating time, fusion pressure, polymer melt flow behavior, ambient temperature, and wind conditions. The melt flow behavior of polyethylene may differ significantly from one material to another according to polymer structure characteristics such as the degree of branching, molecular weight and molecular weight distribution. An indicator of the comparative melt flow behavior of polyethylene materials is the Melt Index as determined in accordance with ASTM D 1238, "Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer"¹. ASTM D 3350, "Standard Specification for Polyethylene Plastic Pipe and Fittings Materials", includes Melt Index as a classification criterion.

When heat fusing similar materials, the development of uniform melts may readily be accomplished with currently available equipment. This is a little more difficult when fusing materials that have different melting characteristics. One technique intended to compensate for this difference and produce uniform melt qualities in different materials is to heat both materials under the same thermal driving force (i.e., heater temperature) but start the heating of the higher melt viscosity (lower Melt Index - see Note 1) material earlier than that of the lower melt viscosity (higher Melt Index) material so that both materials simultaneously emerge from the heating tool with relatively uniform depth of melt. This technique, which usually employs a heat shield, is used by some installers of PE piping, and has been the subject of an evaluation by PPI. Results obtained indicate that this heat fusion technique yields satisfactory joints.

The operator joining piping components made of unlike PE materials should consider that requirements on fused joints imposed by the regulations of the Department of

¹ The Melt Index per ASTM D-1238 is a measure of the amount of molten material that extrudes during a given period of time through a die of specified diameter and length and under prescribed conditions of temperature and extrusion pressures. Materials of higher melt viscosity extrude more slowly and exhibit, therefore, lower Melt Indexes.

Transportation are essentially quality control tests keyed on the performance characteristics of monolithic joints that have been validated by both long term successful experience and long term pressure testing in accordance with ASTM D 2837, 'Standard Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials'. A similarly extensive background of information is not available for combinations of fusions of mixed PE's. The operator is, therefore, advised to not only rely on quality control type tests for evaluating mixed joints, but to also consider their longer term pressure testing performance which is a more reliable indicator of ultimate joint quality.

3.0 PPI EVALUATION OF FUSION OF UNLIKE PE PIPING COMPONENTS

PPI member producers of PE pipe and fittings and of the materials from which they are made have been evaluating various methods for the heat fusion joining of unlike PE components. This work has led to the development of the guidelines herein presented. By using these guidelines, socket, butt, and saddle fusions of many combinations of piping components made from the following materials have been produced:

Pipe and Fittings Materials Evaluated		
Coded Materials	Material Classification ²	
Tested	By ASTM D 2513	By D 3350-02a
A	PE 2306	PE 214333
B	PE 3406	PE 335433
C	PE 2306	PE 234333
D	PE 3408/3406	PE 355434
E	PE 2306	PE 234333
F	PE 3408/3406	PE 345434

The resultant joints have been evaluated for compliance to the 73.4°F burst pressure and sustained (1,000 hours) pressure requirements imposed by ASTM D 2513, "Standard Specification for Thermoplastic Gas Pressure Piping Systems" on the less demanding component. The short-term test was conducted in accordance with ASTM D 1599, "Standard Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings"; the sustained pressure test in accordance with ASTM D 1598, "Standard Test Method for Time-to-Failure of Plastic Pipe under Constant Internal Pressure". A large number of specimens containing heat fusions of the above materials in various pipe diameters and wall thicknesses, and fittings types and sizes, have been evaluated by these tests. In every case the requirements of ASTM D 2513 for the less demanding component have been satisfied.

² In both of the shown classification systems the second digit codes the Melt Index Category. The lower the value of the Melt Index the more viscous is the melt at a given melt temperature. The system of ASTM D-3350 covers more Melt Index categories and is, therefore, more useful for making comparisons of the melt flow properties of PE materials.

The following are recommendations for basic operations that need to be complemented by the addition of detailed requirements reflecting melt characteristics and other properties of the specific materials being joined.

The developer of a procedure designed to fuse two specific unlike materials is responsible for ensuring that the resultant joints qualify to all applicable code and regulatory requirements. It is not to be assumed that the use of these basic recommended operations automatically ensures the qualification, or compliance, of the resultant joint to any standard or code requirement.

4.0 SUGGESTED GUIDELINES FOR THE JOINING OF UNLIKE MATERIALS

4.1 Guidelines for Socket Fusion

4.1.1 Joining Conditions:

- (1) Heater surface temperature: $500 \pm 10^\circ\text{F}$.
- (2) Heating times for pipe and fitting as recommended by the manufacturer of each component.

4.1.2 Guidelines:

- (1) Attach the proper size heater adapters and bring the temperature of the heating surface to $500 \pm 10^\circ\text{F}$. Be sure that the heating surfaces are clean and free of water, dirt, or plastic.
- (2) Cut the pipe end squarely and remove any burrs.
- (3) Clean the pipe end and the fitting, both inside and outside, by wiping with a clean, lint free cloth.
- (4) Place the 'cold ring' clamp³ around the pipe at the location determined by the depth gauge.
- (5) Using even pressure, bring the preheated tool into full contact with the outside surface of the end of the pipe and the inside surface of the socket in such a time sequence that the recommended heating time for each component is satisfied.⁴ The lead time for the component with the longer heating time should be predetermined by subtracting the shorter from the longer heating times. If the recommended heating times are within 10 percent of each other, the longer time may be used for both components. As with socket fusion of like components, the fusion time count down begins when pipe and fitting are fully inserted.

³ The 'cold ring' clamp is a fixture placed on the pipe that limits pipe heating to only a specific section.

⁴ Heating times required to achieve proper melt conditions may be affected by ambient working conditions such as temperature and wind. Appropriate compensation for these may be required and should be considered. Some manufacturers provide helpful guidelines.

- (6) At the completion of the heating cycle, simultaneously pull, with a snap action, pipe and fitting from the heater. Quickly check visually to confirm that there is complete melt around the entire pipe and fitting socket surfaces. If satisfactory, immediately insert the pipe squarely and fully into the socket. Hold or block the fresh joint in place until the mating surfaces have solidified. If an incomplete melt pattern is observed, the joint is not to be completed. A new joint should then be made with slightly longer heating times

4.2 Guidelines for Butt Fusion

4.2.1 Joining Conditions:

- (1) Set the heater surface temperature at the higher of the two values that are recommended by the manufacturers of the piping components that are to be joined to each other. Temperatures in the range of 340 to 450°F tend to be preferred for butt fusion of pipes made from materials with melt index cell categories, as defined in ASTM D 3350, of from 1 through 4. Temperatures from 450 to 500°F are commonly used with PE's of the melt index cell category 5 and sometimes category 4.
- (2) Heating times for each of the two components to be joined are per the recommendation of the manufacturer of each component. In cases for which the times are either not specified or given for the selected fusion temperature, the heating times are those required to attain the specified visual melt conditions recommended by the component suppliers.

4.2.2 Guidelines:

- (1) Bring the heating surfaces to the proper temperature.
- (2) Clean the inside and outside of the components to be joined (both pipes, or pipe and fitting) by wiping with a clean, lint free cloth. Remove all foreign matter.
- (3) Clamp the components in the machine. Check alignment of the ends and adjust as needed. Face off the ends.
- (4) Remove the facing device and clean away cuttings from inside and outside the pipe. Bring the piping components together and check for alignment, gap, and ovality. Adjust as required. The ends of the piping components should meet squarely around their entire circumference.
- (5) Push the ends to be joined against the heater in such time sequence that the recommended heating time for each component is satisfied. This may be accomplished by placing at the beginning of the heating cycle an insulator sheet between the heating tool and the component with the shorter

recommended heating time. This insulator is removed when the component with the longer recommended heating time has been heating just long enough so that the balance of the heating time will allow both components to simultaneously achieve both recommended heating times, or should be predetermined by subtracting the shorter from the longer heating time (see Note 4). If the recommended heating times are within 10 percent of each other, the average of the two may be used for both components. This can also be accomplished visually. To ensure proper and full contact is made between the components and the heater, the initial contact should be under moderate pressure. After holding this pressure very briefly, it should be released without breaking contact. Continue to hold the components in place without movement while an even bead of molten polyethylene develops around the components as a result of thermal expansion.

- (6) At the end of the heating cycle move the pipe component ends away from the heater, remove the heater and immediately bring the ends together with sufficient force to develop an interface pressure that will form a uniform bead around the entire circumference of the joint and that is found to produce acceptable joint strength characteristics.
- (7) Hold the assembly under fusion force (pressure) until the joint has solidified. (Guidelines for the cooling time of the different materials are often available from the pipe component supplier).
- (8) Visually inspect the joint. If a heat shield was used, both beads should be approximately the same size. If a heat shield was not used, the bead on the higher melt flow material should be slightly larger than that on the lower melt flow material

4.3 Guidelines for Saddle Fusion

4.3.1 Joining Conditions:

- (1) Heater surface temperature set at $500 \pm 10^{\circ}\text{F}$.
- (2) Heating times for pipe and fitting as recommended by the manufacturer of each component. In cases for which the heating times are neither specified nor given for the selected fusion temperature, the heating time should be that required to attain a specified visual melt condition.

4.3.2 Guidelines:

- (1) Attach the proper heating adapters and bring the temperature of the heating surface to $500 \pm 10^{\circ}\text{F}$. Be sure that the heater adapters are clean and free of water, dirt, or plastic
- (2) Install mechanical assist tool with pipe rounding capability.

- (3) Roughen and clean the concave surface of the fitting base and the mating convex surface of the pipe. The use of emery or garnet cloth of 50 to 60 grit is recommended to remove all contamination from the pipe surface. It is essential to completely remove the outer pipe surface without altering the contour. All mating surfaces should be kept clean.
- (4) Bring the heater into full and firm contact with the pipe and the fitting base in such time sequence that the recommended heating time for each component is satisfied. This may be accomplished by placing at the beginning of the heating cycle a flexible insulator between the heater and the component with the shorter recommended heating time. This insulator is removed when the component with the longer recommended heating has been heating for such lead time that will result in both components simultaneously reaching the required melt condition. The necessary lead time should be predetermined by subtracting the shorter from the longer heating times ⁵ (see Notes 4 and 5). If the recommended heating times are within 10 percent of each other, the average of the two may be used for both components. During the heating cycle, comply with the force recommendation of the component suppliers. When the insulator is used and the force is relaxed to permit its removal, the force should be carefully reimposed to the same level.
- (5) At the completion of the heating cycle remove the heater, quickly check the heated pipe and fitting surfaces to ensure the presence of proper melt patterns, and if satisfactory, immediately place the fitting on the pipe with sufficient force to effect fusion. Normally this results in the appearance of a light roll or third bead which forms between the melts established on the pipe and fitting during the heating cycle. Hold the fitting in place until the mating surfaces have cooled and solidified. If an incomplete melt pattern is observed, the joint should be completed, and after cooling, the outlet removed to prevent its use. A new connection at another location on the pipe should be made under an adjusted heating cycle.

5.0 OTHER DOCUMENTS FOR REFERENCE

For information on specific piping components it is suggested that piping component supplier instruction manuals be consulted.

⁵ When fusing a saddle fitting onto a pipe that is under pressure, it is important that the proper melt surface condition be obtained quickly without excessive heat penetration into the pipe wall. Otherwise, the pipe may rupture at that point from internal pressure. In respect to this precaution it should be noted that the time required to obtain an adequate melt pattern when using a serrated concave heating tool tends to be significantly shorter than that when using a smooth faced tool.

PPI TR-33, **“Generic Butt Fusion Joining Procedure For Field Joining of Polyethylene Pipe**
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PPI TR-41, **“Generic Saddle Fusion Joining Procedure for Polyethylene Gas Piping”**

PPI Statement S, “Caution Statement on Heat Fusion Methods of Polyethylene Pipe and/or Fittings of similar Colors”

PPI Statement T, “Caution Statement on Saddle (Sidewall) Heat Fusion without Use of Mechanical Assist Tooling”

PPI Handbook of Polyethylene Pipe, Chapter 9, “Polyethylene Joining Procedures”

PPI TN-20, “Special Precautions for Fusing Saddle Fittings to Live PE Fuel Gas Mains Pressurized on the Basis of a 0.40 Design Factor.”

ASTM F 2620, “Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings”

Department of Transportation, Pipeline Safety Regulations, Part 192 “Transportation of Natural and Other Gas by Pipeline: Minimum Federal safety Standards”