TECHNICAL REFERENCE REPORT

COMPARATIVE SUMMARY OF BUTT HEAT FUSION PROCEDURES AND GUIDELINES UTILIZED BY NORTH AMERICAN GAS DISTRIBUTION COMPANIES

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EXECUTIVE SUMMARY

A critical construction and maintenance concern involves the safety and integrity of various types of joints on plastic piping systems. By definition, thermoplastic materials are those materials that soften upon heating and re-harden upon cooling. This characteristic allows for joining thermoplastic materials by heat fusion[1] or butt fusion. Heat fusion joining uses a combination of heat and force that results in two melted surfaces flowing together to make a joint. There are several heat fusion process variables that govern the integrity of the joint including pipe surface preparation and contamination, heater (iron) temperature, applied force, and cooling times. Moreover, construction practices, equipment, and environmental factors also play a major role in the overall strength and reliability of the fusion joint.

To promote the safe joining of plastic piping materials, Title 49CFR 192.283 and 192.285 prescribe certain guidelines for developing and qualifying approved joining procedures that must be in place at each utility for their thermoplastic piping materials. To that end, extensive testing has been performed to develop and qualify approved joining procedures for PE materials utilized for gas distribution applications. In general, the responsibility of developing and qualifying approved joining procedures has rested with the gas utility companies who have either performed the required testing data as per 49CFR Part 192 requirements.

During the mid-1990's, in an effort to standardize the heat fusion procedures across the industry, the Plastics Pipe Institute (PPI) performed extensive testing based on CFR Part 192 requirements. The results of their research and the generic heat fusion procedure are summarized in the PPI TR-33 document entitled "Generic Heat Fusion Procedures for Field Joining of Polyethylene Gas Pipe". Since its initial publication, there have been notable revisions and enhancements to PPI TR-33 document. Moreover, recent on-going studies in Europe have shown that "good" strong joints can be made using parameters which are significantly different than those contained within PPI TR-33 guidelines.

To resolve these differences and in a proactive effort aimed at continuous process improvements, there was desire on the part of several leading gas utility companies (led by Southern California Gas Company - SoCal) to better understand the overall heat fusion process and the interaction of key process variables as it relates to overall joint strength. In order to accomplish the intended objectives, NYSEARCH and its members, the Operation Technology Development (OTD), and the Department of Transportation (DOT) have helped to facilitate a comprehensive program to validate (and optimize, as necessary) the potential limitations of the butt heat fusion joining parameters and establish the boundaries of the various joining process variables for PE piping systems. In addition, on the basis of the technical data, the intent of the overall program is to also establish the long term performance correlations for joints as a function of various parameters which can be used to develop and/or enhance Non Destructive Evaluation (NDE) technologies.

[1] Note: the use of the terms "heat fusion" and "butt fusion" are being used interchangeably throughout the document.

A series of tasks are being implemented in order to accomplish the overall program objectives. A critical first step towards accomplishing the overall program objectives was to trace the historical evolution of the butt heat process since its implementation in the late 1960s and cross-reference and categorize the various butt heat fusion procedures and practices currently in place at a majority of the gas utility companies throughout the United States and other industry accepted guidelines including the Plastic Pipes Institute TR-33 Guidelines.

A comprehensive review of gas industry practices, infer that strong correlations exist among various companies with respect to accepted guidelines, heat fusion and historical procedures. While the efforts to ensure standardization of the butt heat fusion procedures through the introduction of the PPI TR-33 guidelines was noble, based on the information gathered through the survey process, it is apparent that this is still not the case. The most striking differences are with respect to several heat fusion parameters and process. Specifically,

- Majority of the gas companies permit the use of a higher heater iron temperatures as compared to general manufacturer’s guidelines. The PPI TR-33 guidelines specify a heater iron temperature range between 400 – 450°F. Majority of the gas companies (11/16) responding to our survey utilize a heater iron temperature of 500°F.
- Several gas utility companies include language which specifies conditions for the interfacial pressures which may overstate the actual field joining pressures by not including specific language with respect to drag force.
- Only a limited number of the gas companies include specific language for other possible areas of concern including miter joints, handling of coiled PE pipe, and visual inspection of the joints after fabrication.

The root cause for these differences is unknown. However, it is speculated that the primary cause is as a result of “grandfathering” previously accepted fusion procedures and/or manufacturer guidelines.

This report presents a comprehensive summary of the historical perspective of heat fusion joining, review of the PPI TR-33 guidelines, and a comparative summary of the various heat fusion practices for a majority of the gas utility companies.

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OTD -	**Operations Technology Development**
PPI -	**Plastics Pipe Institute**
GRI -	**Gas Research Institute**
DOT -	**Department of Transportation**
PHMSA -	**Pipeline and Hazardous Materials Safety Administration**
CFR -	**Code of Federal Regulations**
psi -	**Unit for pressure (pound per square inch)**
mm -	**millimeter**

Section 1
Introduction and Background

By definition, thermoplastic materials are those materials that soften upon heating and re-harden upon cooling. This characteristic allows for joining thermoplastic materials by heat fusion, saddle heat fusion, and electrofusion.

Heat fusion joining uses a combination of heat and force that results in two melted surfaces flowing together to make a joint. Based on the results of testing and evaluation on the part of the pipe/resin suppliers, Gas Research Institute (GRI), and other industry organizations, it has been demonstrated that several variables can influence the integrity of the joint including pipe end preparation, heater (iron) temperature and surface condition, applied force, and heating/cooling times.

Typically, heat fusion joining consists of the following:

1. Securely fasten the pipe components to be joined in the appropriate fusion equipment
2. Clean, Face, and Align the pipe ends
3. Set the heating iron temperature up to the prescribed joining temperature
4. Melt the pipe interface
5. Join the two profiles together
6. Hold under pressure

In general, to promote the safe joining of plastic piping materials, Title 49CFR Part 192 prescribes certain requirements for developing and qualifying joining procedures that must be in place at each utility for use with their plastic piping materials. Specifically,

- Each joint must be made in accordance with written procedures that have been proven by test or experience to produce strong leak tight joints – CFR Part 192, §192.273
- Written procedures for various types of joints must be qualified by subjecting them to various required tests – CFR Part 192, §192.283
- All persons making joints must be qualified under the operators written procedures - CFR Part 192, §192.285
- Gas system operators must ensure that all persons who make or inspect joints are qualified - CFR Part 192, §192.285 and §192.287

In order to qualify and approve a joining procedure, joints made in accordance with written procedures must be subjected to various required tests. Per CFR Part 192.283 (a) and (c) requirements, butt heat fusion joints must be subjected to tensile test and either the quick burst test or long term sustained pressure testing. Provided that the results of the testing are positive, the procedure is then qualified for use in gas distribution applications.

During the mid-1990s, at the request of the DOT, PPI and its member companies performed research to develop a single standardized generic butt heat fusion procedure for the industry. The results of their research and the generic heat fusion procedure are summarized in the PPI TR-33 document entitled "Generic Heat Fusion Procedures for Field Joining of Polyethylene Gas Pipe". These procedures have been accepted by some gas utility companies as their "qualified" heat fusion procedures. It is important to note that the PPI TR-33 procedure is intended for PE materials made in accordance to ASTM D2513 requirements, excluding the Uponor Aldyl-A MDPE and Driscopipe D8000 HDPE.

In general, PPI TR-33[2] outlines the following parameters and procedure for PE gas pipe:

Butt Fusion Procedure Parameters:
Generic Fusion Interfacial Pressure Range: 60-90 psi (4.14 – 6.21 bar)
Generic Heater Surface Temperature Range: 400 – 450°F (204 – 232C)

To ensure that joints made in accordance to the aforementioned parameters and procedure produce strong quality joints, PPI and its member companies performed testing on 2-inch and 8-inch pipes from various pipe manufacturers. In addition, PPI also investigated the integrity of cross-fusion joints made between the various manufacturers. Based on the results of the testing, all of the major North American PE pipe suppliers issued letters of support for the procedures and butt fusion parameters contained within PPI TR-33.

While the overall heat fusion procedures contained within the PPI TR-33 guidelines have served the natural gas industry well, additional research and work being performed in Europe demonstrates that the overall heat fusion procedure can be significantly modified and still produce strong joints.

In a proactive effort to better understand the overall heat fusion process and implement continuous process improvements, several leading gas utility companies (led by Southern California Gas Company – SoCal) and the Department of Transportation have supported a comprehensive program to investigate various heat fusion parameters and characterize their impact on the long term performance of butt heat fusion joints by varying each parameter. In order to accomplish the intended program objectives, a critical first task was to determine the historical evolution of the heat fusion process since the introduction of PE piping for gas distribution applications and to determine the various ranges of parameters being used by gas distribution companies presently.

The following sections of this report present information related to the historical evolution of the heat fusion procedures, results of a comprehensive review of heat fusion procedures used by gas utility companies, and the relationship to the PPI TR-33 guidelines.

[2] The following is an abbreviated version of the PPI TR-33 procedures. Interested readers are referred to the actual document which is available from the Plastics Pipe Institute for more detailed information.

Section 2
Historical Perspective

Since the introduction of plastic materials for gas distribution applications during the 1960's, heat fusion joining has been a preferred method for connecting plastic piping segments. At present, there are thousands of heat fusion joints in service today which are performing safely.

In order to better understand the evolution of the heat fusion procedures throughout the past decades, a comprehensive literature search was performed and various discussions were held with gas utility companies. Unfortunately, there is very limited historical information that is available in both the public domain and within gas utility companies with respect to the butt heat fusion procedures. One public source of historical information was found on the Performance Pipe[3] website which contains the heat fusion procedures for both the Driscopipe materials and Plexco Pipe materials (medium density and high density materials). It is important to note that no statements can be made with respect to the "age" of this information as no date was printed on the documents and the commercial trade names being presented in this report may or may not be presently sold.

Driscopipe 6500 Materials

The Driscopipe 6500 material is/was[4] a high molecular weight medium density PE material. In general, the overall heat fusion procedure specified with the use of this material is the same as that which is being used presently; however, there are some notable exceptions.

1. The overall surface preparation technique and process is essentially the same.
2. The [heater iron][5] surface temperature is 375°F – 400°F. A note is included which states that "Surface temperature of 500°F is optional, but extreme care must be exercised to avoid overmelt, overpressure, and cold fusions."
3. There are no statements with respect to heating times, visual indications of acceptable melt bead widths, applicable pipe sizes, potential for cross-fusions with other grades of PE materials.
4. The use of a pyrometer or templistick is recommended to ensure proper temperatures for the heat iron.

Driscopipe 8100 Materials

The Driscopipe 8100 material is a very high molecular weight high density PE material. In general, the overall heat fusion process with this particular material is essentially the same as that which is being used presently.

1. The overall surface preparation technique and process is essentially the same.

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[3] Performance Pipe is the commercial name of the company formed during the merger between Driscopipe (Phillips Petroleum Company) and Plexco Pipe (Chevron Company).

[4] It is unknown if this material is in use or presently being sold under a different tradename

[5] The term "heater iron" has been inferred by the author as the published information is ambiguous whether the specified temperature is for the PE material surface or heater iron surface.

2. The [heater iron][6] surface temperature is 475°F – 500°F.
3. While there are no statements with respect to heating times and applied interfacial pressures, there are visual references for the bead size as a function of pipe diameter during melt.
4. There are no statements with respect to the potential for cross-fusions with other grades of PE materials.
5. The use of a pyrometer or templistick is recommended to ensure proper temperatures for the heat iron.

Plexco YellowPipe™ PE2406

The Plexco YellowPipe is/was[7] a medium density material. In general, the overall heat fusion process with this particular material is essentially the same as that which is being used presently.

1. The overall surface preparation technique and process is essentially the same.
2. There are two specified "heater iron" temperatures which are specified: 440°F±10°F and 500°F±10°F.
3. For each of the specified heat iron temperature, there are associated heating times which are specified as a function of pipe size.
4. A cooling time is also specified as a function of pipe size.
5. There is no guidance provided with respect to interfacial pressures; however, approximate bead size values are presented as a function of pipe size.
6. Additional guidance is provided with respect to rough handling of the pipes after the heat fusion process.

Plexco PE3408 YellowStripe and PE3408 EHMW

Both the PE3408 YellowStrip and PE3408 EHMW are/were high molecular weight high density PE materials supplied by Plexco. The procedures for these respective materials are very similar to their PE2406 materials discussed previously.

1. The overall surface preparation technique and process is essentially the same.
2. There are two specified "heater iron" temperatures which are specified: 440F±10F and 500°F±10°F.
3. For each of the specified heat iron temperature, there are associated heating times which are specified as a function of pipe size.
4. A cooling time is also specified as a function of pipe size.
5. There is no guidance provided with respect to interfacial pressures; however, approximate bead size values are presented as a function of pipe size.
6. Additional guidance is provided with respect to rough handling of the pipes after the heat fusion process.

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[6] The term "heater iron" has been inferred by the author as the published information is ambiguous whether the specified temperature is for the PE material surface or heater iron surface.
[7] It is unknown if this material is in use or presently being sold under a different tradename

Section 3
Plastics Pipe Institute TR-33 Guidelines

From the preceding discussions, it is clear that, historically speaking, there were differences in the overall heat fusion procedures / parameters between various pipe manufacturers for their respective PE materials. While the overall heat fusion process was essentially similar, there was an array of information relative to specific joining parameters, e.g. the specified heater iron temperature for the PE2406 materials.

In an effort to harmonize the heat fusion procedures by the various PE pipe manufacturers, during the mid-1990s, PPI and its member companies performed research to develop a single standardized generic butt heat fusion procedure for the industry. The results of the research and the generic heat fusion procedure have been summarized in the PPI TR-33 document.

In general, PPI TR-33[8] outlines the following parameters and procedure for PE gas pipe:

Butt Fusion Procedure Parameters:
Generic Fusion Interfacial Pressure Range: 60-90 psi (4.14 – 6.21 bar)
Generic Heater Surface Temperature Range: 400°F – 450°F (204°C – 232°C)

Butt Fusion Procedure:

1. Cleaning and Securing: Once installed within the heat fusion joining equipment, the pipe ends must be cleaned to ensure that all foreign matter has been removed from the joining surface. The pipe ends are then placed in the joining equipment and brought together to ensure proper alignment.
2. Facing: A facing tool is then placed between the pipe ends to establish a smooth, clean, and parallel mating surface.
3. Align: Once the pipe ends have been faced, the pipe ends are brought together and checked for high-low alignment. At this point, any required adjustments are made as necessary by adjusting the clamping jaws until the outside diameters of the pipe ends match. If any adjustments are made, the pipe ends must be re-faced and cleaned to ensure a smooth clean surface.
4. Melt: The heating tool is placed between the pipe ends. A pyrometer or other surface temperature-measuring device should be used to ensure the proper temperature of the heating tool. The pipe ends are then brought into contact with the heating tool at the prescribed temperature. The ends are held against the heating tool without any force until the pipe melts. When the proper melt bead size is formed, the ends are quickly separated and the heating tool is removed. It is important to note, the overall process is based on a visual appearance of the melt bead, which is dependent on the pipe size. For 2-inch pipe size, a bead size of approximately 1/16” should be present and for larger sizes, e.g. 8-inch, a bead

[8] The following is an abbreviated summary of the PPI TR-33 procedures. Interested readers are referred to the actual document which is available from the Plastics Pipe Institute for more detailed information.

size of approximately 1/8” – 3/16” should be present before removing the heater iron.

5. Join: Immediately after removing the heating tool, in a continuous motion bring the molten pipe ends together and apply the correct joining force. The fusion force is determined by multiplying the interfacial pressure (60-90 psi) by the cross sectional area of the pipe end
6. Hold: Once the pipe ends are brought together under the specified force, the applied joining force is maintained against the pipe ends until the joint is cool to the touch. It is recommended that that joint be allowed to cool for an additional 30 minutes prior to any rough handling or installation.

To ensure that joints made in accordance to the aforementioned parameters and procedure produce strong quality joints, PPI and its member companies performed comprehensive tensile testing on 2-inch and 8-inch pipes from various pipe manufacturers. In addition, PPI also investigated the integrity of cross-fusion joints made between the various manufacturers. Based on the results of the testing, many of the PPI member companies (PE pipe suppliers) issued letters of support for the procedures contained within PPI TR-33.

Since its inception, the PPI TR-33 has also been continuously revised and improved to provide additional information and guidance as new information has been gathered. As a result, the use of the term “current” or any reference to PPI TR-33 guidelines is for the most recent of the TR-33/2006 document available via the Plastics Pipe Institute’s website.

Based on a review of the PPI TR-33 guidelines and a comparison to the heat fusion procedures from Driscopipe and Plexco pipe discussed in the previous section, certain high level observations can be inferred:

1. The heater iron specified currently with the PPI TR-33 guidelines (400°F – 450°F) is for both medium density and high density materials. In one regard, the lower end of the PPI TR-33 temperature range is greater than the specified low end of the Driscopipe 6500 material (375°F). On the other hand, the higher end of the PPI TR-33 range of 450°F is lower than the previously specified value of 500°F.
2. Unlike previous guidelines and procedures supplied by the respective pipe manufacturers, the current PPI TR-33 guidelines present an interfacial pressure range along with approximate quantitative visual indicator for acceptable melt bead widths.
3. The PPI TR-33 guidelines and accompanying letters of support from various pipe manufacturers support cross-fusions between the various grades of PE materials.
4. Additional references and statements have been added to the current PPI TR-33 guidelines to reference procedures and parameters used in Europe and elsewhere, e.g. interfacial pressure ranges.

5. Additional statements have been added to the current PPI TR-33 guidelines with respect to miter joints and consideration for the drag force which was not included in the historical documentation.

Section 4
Survey of Industry Heat Fusion Procedures and Practices

Having understood the historical evolution of the overall heat fusion process and procedures and the PPI TR-33/2006 Generic Heat Fusion guidelines, the next step was to obtain information related to the heat fusion process and procedures currently being utilized by leading gas utility companies throughout a cross-section of the United States. As a result, a comprehensive survey was provided to various sponsoring gas utility companies to solicit information related to their heat fusion procedures and practices and additional useful information. The objective was to ascertain commonalities/differences, if any, amongst various gas utility companies, correlations between gas companys' procedures and the PPI TR-33 guidelines, and performance histories and trends of heat fusion joints in-service. The intent was to use this information in order to help establish the initial set of heat fusion parameters for further evaluation. The following sections presents a comprehensive review of the information provided by the gas utility companies and high level observations.

4.1 Survey Overview

A survey was sent to 24 sponsoring gas utility companies. A total of 18 out of 24 companies responded to the survey - seventeen (17) companies provided their actual heat fusion procedures for review – Note: 2 companies share a single procedure; therefore, 16 unique procedures were reviewed.

In order to ensure a statistically representative sampling, the survey was sent to large, medium, and small companies (large companies representing over 5000 miles of plastics piping versus small representing companies with less than 1000 miles of plastics piping, and medium companies representing systems between 1000-5000 miles). The survey was completed by 8 large companies, 6 medium, and 4 small companies.

The survey also solicited additional information other than just heat fusion procedures to ascertain peripheral information which may be of interest or could otherwise facilitate a greater understanding of their practices. This included:

- Choice of materials being used and sizes
- Inspection methodologies
- Joint failure detection
- Probable causes of joint failure
- Company specific heat fusion procedures

4.2 Survey Results - General

Based on the survey responses, the data were analyzed to observe any meaningful trends. Some high level observations from the various sections of the survey include the following:

1. The majority of the companies utilize medium density PE materials.
2. The range of pipe sizes include 2-inch IPS through 8-inch IPS with 2-inch accounting for 50% to potentially over 80% of the PE systems.
3. Over the years, gas utility companies have installed pipes from several manufacturers including Plexco, Driscopipe, KWH, and Polypipe. Historically, Driscopipe PE materials have been the most widely used PE pipe material.
4. The McElroy heat fusion equipment is the most commonly used. Other manufacturers also mentioned include Rigid, Connectra, and TDW.
5. Two (2) out of the seventeen (2/17) are using the McElroy Ultramac (Ultrasonic testing tool) in a limited manner – operator training and qualification and to better understand potential issues related to joints in the field.
6. Twelve (12) out eighteen companies (12/18) have reported joint failures. Follow-up discussions with the remaining six companies indicate that these companies have also experienced joint failures; however, owing to scarcity of specific data (frequency/type/cause), they chose not to respond.
    a. The overall data from the various gas utility companies indicates that the frequency of joint failures is relatively small. Majority of the failures that were reported with any level of increased frequency was on older generation PE piping systems. For modern PE materials, the average frequency of failures was 10 joint failures (reported as "leaks") over a 5 year time period.
    b. Majority of companies reported that the majority of the joint failures were discovered during the pressure testing and/or during routine leak surveys.
7. The consensus feedback from the gas utility companies with respect to the primary cause of field failures was due to deviations from the qualified procedures – additional details to be provided in the sections to follow.

Survey Results – Comparison of Gas Company Practices

In addition to gathering the aforementioned information, a comprehensive review of the heat fusion procedures from each of the gas utility companies was performed to better understand the commonalities/differences and correlations, if any, with PPI TR-33 guidelines.

As previously mentioned, the integrity of butt heat fusion joints is a function of several parameters including pipe size and SDR values, pipe ends surface preparation, heater (iron) temperature, applied interfacial pressure, dwell time, and heating/cooling times. Each company's procedures were analyzed with respect to each of these key technical points. The results are presented in Tables 1-4 below. Company names have been withheld due to confidentiality requirements.

As expected, there are significant similarities and small scale differences among the heat fusion procedures used by various gas utility companies throughout the United States. Detailed discussions with respect to the each company's heat fusion practice and the PPI TR-33 guidelines are presented in the section to follow.

ID	Heater Iron Temperature (F)	Interfacial Pressure (Psi)	Heating Time (sec)	Cool Down prior to Rough Handling (min.)	Bead Size (in.)	Equipment	Comments
1	400 – 500	Range of specified pressures based on pipe size and equipment	Range of times depending on pipe size – visual emphasized	30 min.	Consistent with PPI TR-33	McElroy	
2.	400 – 500	60 ft-lbs and hold for 90sec	55 – 60 sec	15 – 60 min.	Not Specified	McElroy, TDW, Connectra, Uponor	▪ No statements were included with respect to applicable pipe sizes
3.	500	Range of specified pressures based on pipe size and equipment	Range of times depending on pipe size – visual emphasized	30 min.	Consistent with PPI TR-33	McElroy, Uponor	• Guidance to account for drag when using hydraulic equipment. • Only pyrometer permitted as temperature measurement device
4.	475 – 500	Range of specified pressures based on pipe size and equipment	None Specified	30 min	Unknown – References made to manufacturers procedures	McElroy	• Pyrometer and templistick permitted as temperature measurement

Table 1: Comparative summary of the heat fusion practices employed by various gas utility companies

							device
ID	**Heater Iron Temperature (F)**	**Interfacial Pressure (Psi)**	**Heating Time (sec)**	**Cool Down prior to Rough Handling (min.)**	**Bead Size (in.)**	**Equipment**	**Comments**
5	400 – 450	60 – 90	Visual emphasized	30 min.	Consistent with PPI TR-33	McElroy	• Do not permit butt heat fusion with 1-1/4” pipe sizes
6	490 – 500	NA	NA	NA	NA	NA	
7	440	Range of specified pressures based on pipe size and equipment	Range of times depending on pipe size – visual emphasized	30 min.	Consistent with PPI TR-33	McElroy	• Guidance to account for drag when using hydraulic equipment. • Pyrometer, templistick, and infrared thermometer permitted as temperature measurement device • DO NOT permit cross fusion of MDPE and HDPE materials
8	500	Specified pressures based on pipe size	Range of times depending on pipe size – visual	30 min	Consistent with PPI TR-33	McElroy	

Table 2: Comparative summary of the heat fusion practices employed by various gas utility companies

ID	Heater Iron Temperature (F)	Interfacial Pressure (Psi)	Heating Time (sec)	Cool Down prior to Rough Handling (min.)	Bead Size (in.)	Equipment	Comments
		and equipment	emphasized				
9	500	Specified pressures based on pipe size and equipment	Range of times depending on pipe size – visual emphasized	30 min	Consistent with PPI TR-33	McElroy	• Guidance to account for drag when using hydraulic equipment. • Dwell time specified – No greater than 3 secs. • DO NOT permit cross fusion of MDPE and HDPE materials
10	475 – 525	NA	NA	NA	NA	NA	
11	440	75 psi for hydraulic equipment	Range of times depending on pipe size – visual emphasized	30 min.	Consistent with PPI TR-33	McElroy	
12	440	Specified pressures based on pipe size and equipment	Range of times depending on pipe size – visual emphasized	30 min	Consistent with PPI TR-33	McElroy	
13	440 and 500	Manufacturers guidance for	Range of time depending on iron	30 min	Consistent with PPI TR-33	McElroy	

Table 3: Comparative summary of the heat fusion practices employed by various gas utility companies

		larger pipe	temperature				
ID	Heater Iron Temperature (F)	Interfacial Pressure (Psi)	Heating Time (sec)	Cool Down prior to Rough Handling (min.)	Bead Size (in.)	Equipment	Comments
14	500	Manufacturers guidance	Manufacturers guidance	Manufacturers guidance	Manufacturers guidance	McElroy	Only for 4”
15	400 – 500	60 – 90	Range of times depending on pipe size – visual emphasized	30 min.	Consistent with PPI TR-33	McElroy	
16	440	75±15	Range of times depending on pipe size – visual emphasized	30 min.	Consistent with PPI TR-33	McElroy	

Table 4: Comparative summary of the heat fusion practices employed by various gas utility companies

Section 5
Discussion

As previously discussed, since its inception, the PPI TR-33 guidelines have been integrated within many gas utility companies' own heat fusion policies and practices. The following section presents a comparative summary of the PPI TR-33 guidelines and the heat fusion procedures which were provided by various gas utility companies, as presented in preceding section. The discussions follow the central points from the TR-33 document.

Secure:
The TR-33 guidelines require that the pipe shall be cleaned on both the inside and outside surface by using a clean lint-free cloth. The pipe should then be clamped in the machine and checked to ensure proper alignment. There is no discernable difference between the TR-33 guidelines and the various companies' heat fusion procedures. All of the gas companies take significant care to effectively emphasize this key technical consideration.

Face / Align
The TR-33 guidelines require that the pipe ends must be faced to establish clean, parallel mating surfaces. Operators are instructed to visually inspect that the faces are square, perpendicular to the pipe centerline with no detectable gap. There is no discernable difference between the TR-33 guidelines and the various companies' heat fusion procedures.

Melt
Once aligned and secured in the heat fusion equipment, the TR-33 guidelines require heating both pipe ends simultaneously. The TR-33 guidelines provide additional guidance and tools to insure proper temperature of the heater iron plate which comes into contact with the pipe ends. A pyrometer or "other surface temperature-measuring" device is recommended.

The TR-33 guidelines prescribe the temperature range of 400-450F (204-232C). There is no quantitative guidance which is provided with respect to contact pressure during the heating. The TR-33 guidelines prescribe approximate melt bead sizes, as shown in Table 5 below – Note, the table has been intentionally truncated at 12-inch pipe sizes:

Pipe Size	Approximate Bead Size
1-1/4" and smaller	1/32" – 1/16" (1-2mm)
1-1/4" through 3"	About 1/16" (2mm)
3" through 8"	1/8" – 3/16" (3-5mm)
8" through 12"	3/16" – ¼" (5-6mm)

Table 5: Approximate melt bead size during heating cycle per PPI TR-33

There are two points of emphasis.

- First, eleven (11) out of the sixteen gas utility companies' procedures specify heater iron temperatures which are greater than the temperature range specified in the PPI TR-33 guidelines. This difference may potentially be attributed to “grandfathering” of previous procedures for high density materials – see historical procedures from Driscopipe and Plexco.

- Second, there is no discernable difference between the TR-33 guidelines and the various companies’ heat fusion procedures with respect to the approximate melt bead size as a function of pipe size. All of the responding companies prescribe the same melt bead width range as compared to PPI TR-33 guidelines and historical references.

Joining

The TR-33 guidelines state that once the desired melt has been obtained, the heater iron should be removed and molten pipe ends should be brought together with “sufficient fusion force to form a double rollback bead against the pipe wall.” The TR-33 guidelines prescribe an interfacial pressure of 60-90 psi.

Given the differences among the various heat fusion equipments that are utilized in the field, no additional quantitative guidance is provided within PPI TR-33. However, cautionary statements to account for differences in the fusion pressures as a function of manual versus hydraulic equipment are provided.

For manual equipment, TR-33 states that a torque wrench may be used to apply the proper force. For hydraulic butt heat fusion machines, “the fusion force can be divided by the total effective piston area of the carriage cylinders to give a hydraulic gauge reading.” However, this reading is theoretical and additional consideration should be taken into account for both the internal and external drag.

Of the 16 company practices (17 companies total – two companies use same procedure) which were reviewed, four out of the sixteen (4/16) directly prescribe the interfacial pressure range as specified within PPI TR-33 guidelines with no modification. Ten out of the sixteen (10/16) actually prescribe various hydraulic gauge pressure reading as a function of pipe size and heat fusion equipment. However, of these ten companies, only three out of the ten (3/10) actually include cautionary statements to ensure that the internal and external drag force encountered in the field is added to the published hydraulic readings cited in their respective company’s procedures.

Hold

The TR-33 guidelines instruct the operator to maintain the joint under the fusion force until the joint has “cooled adequately to develop strength… The fusion force should be held between the pipe ends for approximately 30-90 seconds per inch of pipe diameter or until the surface of the melt bead is cool to touch … Avoid pulling, installation, or rough handling for an additional 30 minutes.”

There is no discernable difference between the TR-33 guidelines and the various companies’ heat fusion procedures. Of the 16 company procedures which were reviewed, 14 out of the 16 company maintain similar guidelines. In general, gas utility companies are on the high side with respect to the hold time – See Table above.

Visually Inspect
The PPI TR-33 guidelines further state that upon completion of the joining process, the operator should visually inspect and compare the joint against the manufacturer's recommended appearance guidelines. TR-33 states that "the width of the butt heat fusion beads should be approximately 2 to 2-1/2 times the bead height above the pipe and the beads should be rounded and uniformly sized around the pipe circumference." – as shown in Figure 1 below.

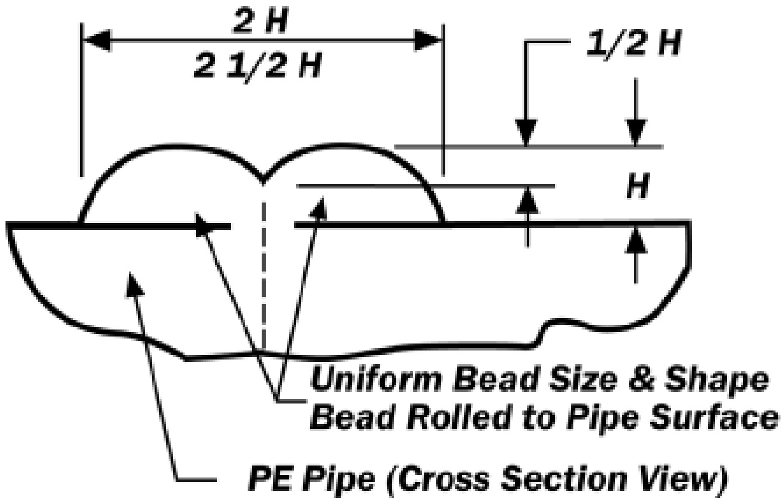

Figure 1: Illustrative example of a properly made butt fusion joint (Courtesy of Plastic Pipe Institute TR-33 Guidelines)

The TR-33 guidelines also prescribe additional cautionary guidance to remove and cut-out mitered (angled, off-set) joints, as illustrated in Figure 2 below.

Figure 2: Illustrative example of a visually unacceptable mitered joint (Courtesy of Plastic Pipe Institute TR-33 Guidelines)

Finally, TR-33 offers additional guidance with respect to proper handling of coiled pipe including, as shown in Figure 3:

1. straighten and re-round coiled pipe butt heat fusion process
2. install pipe ends in the machine in an "S" configuration with the print lines approximately 180 degrees apart
3. install a straight piece of pipe between two coiled pipes

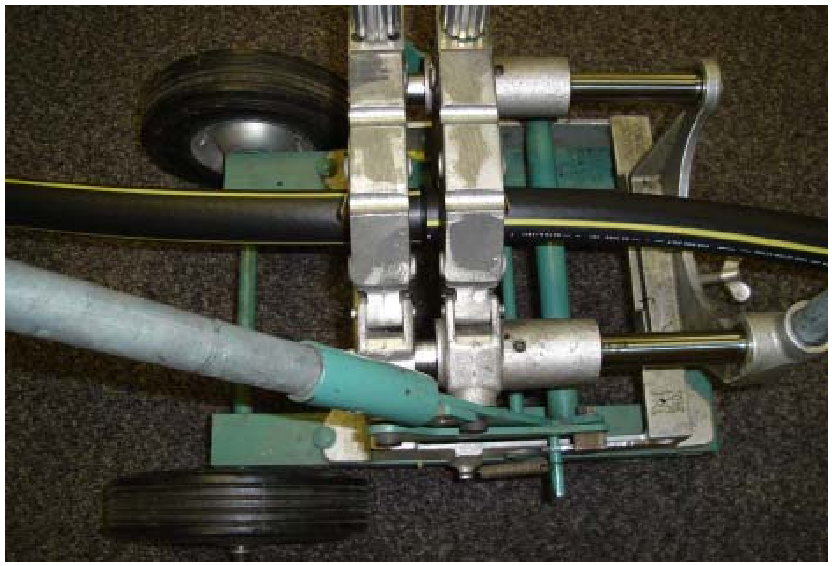

Figure 3: Illustrative example of alignment of coiled pipe ends (Courtesy of Plastic Pipe Institute TR-33 Guidelines)

Of the sixteen gas utility company procedures, no company includes verbiage with respect to the visual indication of an acceptable joint. Four (4) out of the sixteen (4/16) companies include cautionary statements to instruct their crews and contractors to cut out potential mitered joints. Four (4) out of sixteen (4/16) companies specifically include statements on dealing with joining coiled pipe ends.

Cross-fusions

There is no formal guidance within the actual TR-33 procedures with respect to permitting the cross-fusion of medium density PE materials and high density PE materials. However, based on the letters of support from various pipe manufacturers, the manufacturers do certify that it is possible to cross-fuse MDPE and HDPE materials with the use of TR-33 procedures.

Regardless, of the sixteen companies, four (4) companies explicitly include verbiage which DO NOT permit cross-fusions. Twelve (12) companies offer no guidance (allowing or disallowing) with respect to this point. Based on the available information, this is possibly attributed to the fact that these companies only utilize one particular grade of PE pipe.

Section 6
Summary and Conclusions

In general, the overall heat fusion joining process consists of the following:

1. Securely fasten the pipe components to be joined in the appropriate fusion equipment
2. Clean, Face, and Align the pipe ends
3. Set the heating iron temperature up to the prescribed joining temperature
4. Melt the pipe interface
5. Join the two profiles together
6. Hold under pressure

In a proactive effort aimed at continuous process improvements, there was desire on the part of several leading gas utility companies (led by Southern California Gas Company - SoCal) to better understand the overall heat fusion process and the interaction of key process variables as it relates to overall joint strength. In order to accomplish the intended objectives, NYSEARCH and its members, the Operation Technology Development (OTD), and the Department of Transportation (DOT) have helped to facilitate a comprehensive program to validate (and optimize, as necessary) the butt heat fusion joining parameters and establish the boundaries of the various joining process variables for PE piping systems. In addition, on the basis of the technical data, the intent of the overall program is to also establish the long term performance correlations for joints as a function of various parameters which can be used to develop and/or enhance Non Destructive Evaluation (NDE) technologies.

A critical first step towards accomplishing the overall program objectives was to identify and categorize the various butt heat fusion procedures and practices being employed by a majority of the gas utility companies throughout the United States. In addition to comparing the practices among the various gas utility companies, additional correlations were made with respect to the Generic Heat Fusion procedures established by PPI in its TR-33 document.

A comprehensive survey was sent to 24 sponsoring gas utility companies representing a broad range of size. A total of 18 out of 24 companies responded to the survey - seventeen (17) companies provided their actual heat fusion procedures for review. The results of the survey and comparative analysis among the various gas utility companies and correlations to TR-33 guidelines were consistent with expectations.

There are strong similarities among the various gas companies with respect to the overall heat fusion process – cleanliness, melt, cool down prior to rough handling. However, there are notable exceptions with respect to certain parameters including the heater iron temperature and interfacial pressure ranges as discussed in the preceding sections. The exact reasons for the differences are not clear. Probable causes could be due to the grade of PE materials which are approved and/or "grandfathering" in previous company procedures.

However, based on the gathered information, it can be reasonably inferred that a majority of the gas utility companies employ the use of the PPI TR-33 guidelines with some small scale modifications based on company specific preferences. The most notable exception is the use of a significantly higher heater iron temperature as compared to the upper bound limit specified within the TR-33 guidelines.

REFERENCES:

1. Anon., Pipeline Safety Regulations, U.S. Department of Transportation, Pipeline Hazardous Materials Safety Administration, June 2004.

2. Plastics Pipe Institute, TR-33 Guidelines, "Generic Heat Fusion Procedures for Field Joining of Polyethylene Gas Pipe", 2006.