GENERIC BUTT FUSION JOINING PROCEDURE FOR FIELD JOINING OF POLYAMIDE-12 (PA12) PIPE

TR-50

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Foreword

This report was developed and published with the technical help and financial support of the members of the PPI (Plastics Pipe Institute). The members have shown their interest in quality products by assisting independent standards-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.

The purpose of this technical report is to provide important information available to PPI on a particular aspect of Polyamide-12 (PA12) pipe butt fusion to engineers, users, contractors, code officials, and other interested parties. More detailed information on its purpose and use is provided in the document itself.

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GENERIC BUTT FUSION JOINING PROCEDURE FOR FIELD JOINING OF POLYAMIDE-12 (PA12) PIPE

1.0 INTRODUCTION

To promote the safe joining of plastic piping materials, Title 49 CFR Part 192 prescribes certain requirements for developing and qualifying approved 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

Polyamide-12 (PA12) piping is approved for use in piping systems under the jurisdiction of CFR Title 49 Part 192 by reference of ASTM F2785-12 in Appendix B(I.). Thus, this PPI technical report provides a uniform joining procedure bringing greater consistency to this aspect of gas pipeline installation, facilitate the pipeline operator's efforts to qualify the procedure, reduce costs, and simplify DOT's enforcement duties.

2.0 SCOPE

In order to ensure compliance to CFR Part 192 requirements, the PA12 suppliers (Evonik Degussa and UBE Industries) have performed comprehensive testing and evaluation to establish the technical basis for generic heat fusion procedures specific to PA12 piping systems. The PA12 grades used in the test program were classified as PA42316 per ASTM F2785. The specific intent of the testing was to address the following key considerations:

- Establishing the optimum set of butt heat fusion joining parameters which lead to strong joints that can effectively perform over the intended service life;
- Verifying the ability to make strong joints over a range of pipe sizes;
- Verifying the compatibility of cross-fusion using PA12 pipe from the various manufacturers.

In order to address each of these key considerations, extensive sample fabrication and testing was performed at leading independent research institutes and McElroy manufacturing. The comprehensive results of the testing confirm the ability to make strong heat fusion joints using a range of heat fusion parameters. Annex A describes the testing program used to establish the recommended fusion condition ranges.

3.0 TESTING PROGRAM TO VALIDATE PA12 BUTT FUSION CONDITIONS

The following report presents a summary of the sample fabrications details, testing protocols, and results of the research to establish the parameter range for butt fusion of PA12 pipe. Two separate testing programs were executed; one at the Gas Technology Institute in the United States, and a second program at *Sueddeutsches Kunststoff Zentrum* (SKZ) Welding Institute in Germany. Based on these results, a generic PA12 heat fusion procedure has been established for the industry. ***It is important to note that these procedures are being presented as guidelines to help assist gas utility companies in developing and/or qualifying their own procedures for use with PA12 piping systems.*** Moreover, these procedures have also been integrated within ISO 16486 Part 2 requirements for PA12 piping systems. Additional work is on-going to integrate these procedures within ASTM and other industry accepted standards and specifications for use in the United States.

3.1. Testing Programs

Gas Technology Institute (GTI) Program

In order to comply with the relevant requirements contained within 49 CFR Part 192 requirements, the PA12 suppliers with the support of the Gas Technology Institute and McElroy Manufacturing performed comprehensive testing to establish and validate a suitable range of generic heat fusion parameters. From the onset, it was noted that previous experience with other thermoplastic materials, specifically polyethylene and polyamide 11 materials, indicates that there is a wide range for key heat fusion parameters which can influence the strength and integrity of the butt heat fusion joint.

In general, there are numerous variables which can impact the overall strength and integrity of a butt heat fusion joint, including surface preparation, heater plate temperature, interfacial pressures, and overall heating and cooling times. In order to aid the industry in developing a uniform and standardized heat fusion procedure for PE materials, the Plastics Pipe Institute, during the mid-1990's, performed extensive testing to develop a range of suitable heat fusion parameters and procedure. This procedure was issued as PPI TR-33 guidelines.

As a first step in the development of the PA12 heat fusion procedure, several PA12 heat fusion joints were made in accordance to PPI TR-33 guidelines for PE materials with the exception of using a higher heater plate temperature of 500° F. The higher heater plate temperature was specified given the higher melt point for the PA12 materials as compared to PE materials. The remaining parameters were kept the same as compared to PPI TR-33 guidelines.

Subsequently, for the PA12 materials, the following parameters were evaluated using both 2-inch IPS SDR 11 and 6-inch IPS SDR 11 PA12 pipe sizes from three of the four (3/4) PA12 suppliers including Evonik-Degussa, UBE Industries, and EMS Grivory.

- Heater Plate Temperature: 500°F ± 10°F
- Interfacial Pressure Range: 60 – 90 psi

All of the fusions were performed using the visual melt bead width guidance provided under PPI TR-33 guidelines.

Six specimens (like to like, e.g. Evonik pipe to Evonik pipe) were made using the upper and lower bound limits for interfacial pressure ranges and heating times with the appropriate heat fusion equipment settings as follows:

Condition 1:
- Minimum heating time / Minimum interfacial Pressure (60 sec / 60 psi)

Condition 2:
- Minimum heating time / Maximum interfacial pressure (60 sec / 90 psi)

Condition 3:
- Maximum heating time / Minimum interfacial pressure (90 sec / 60 psi)

Condition 4:
- Maximum heating time / Maximum interfacial pressure (90 sec / 90 psi)

The specimens were then tested according to the requirements contained within 49 CFR Part 192.283. Specifically, 49 CFR Part 192.283 requires either the burst pressure testing or long term sustained pressure testing and tensile strength determinations. For the PA12 butt heat fusion joints, all three tests were performed. The results were consistent with expectations – strong joints can be effectively made using these conditions. The results of the burst pressure testing and tensile strength testing demonstrated that the PA12 heat fusion joint has similar properties as compared to PA12 un-fused pipe.

Moreover, results of long term sustained pressure testing at 80° C, and 290 psig demonstrated that there were no failures for test times of at least 1000 hours. Representative test results are summarized in Table 1 below:

Table 1: Results of the testing per 49 CFR Part 192 requirements to develop qualified PA12 heat fusion procedures

Evaluation of Fusion Parameters – PA12 Pipe (Typical)					
	Control	Condition 1	Condition 2	Condition 3	Condition 4
Quick Burst Hoop Stress (Failure Mode)	6899 psi (Ductile)	7235 psi (Ductile)	7359 psi (Ductile)	7243 psi (Ductile)	7126 psi (Ductile)
Tensile at Yield	5370 psi	6072 psi	5914 psi	6017 psi	5957 psi
Elongation at Break	219%	123%	116%	121%	107%
Failure times for long term sustained pressure testing at 80°C and 290 psig (20 bars)	No Failures at times of at least 1000 hours	No Failures at times of at least 1000 hours	No Failures at times of at least 1000 hours	No Failures at times of at least 1000 hours	No Failures at times of at least 1000 hours

Given that the primary intended application for PA12 piping system is for higher pressures and larger diameters, additional tests were performed to qualify these procedures for 6-inch IPS pipe specimens. Comprehensive tests were performed on parametrically controlled fusion joints made in accordance to the previously developed PA12 joining procedures with exception of varying the interfacial pressures and heating plate temperatures. Moreover, the compatibility of cross-fusions between each of the PA12 resin suppliers' product was also investigated.

With the assistance of McElroy Manufacturing, several 6-inch PA12 butt heat fusion joints were prepared using the PA12 joining procedures. Specifically,

- 12 fusion joints were made from using the Evonik VESTAMID and UBE UBESTA PA12 materials
- 1 base material from each of the PA12 resin suppliers – pipe used as control specimens
- 3 cross fusions from different supplier materials

Four (4) coupons as shown in Figure 1 were machined from each fusion joint and subjected to McSnapper™ testing. The McSnapper™ is a high speed tensile-with-impact testing machine which combines the Tensile Impact Test ASTM D1822 and High-Speed Tensile Test ASTM D2289. Figure 2 illustrates the progression of the McSnapper™ testing apparatus.

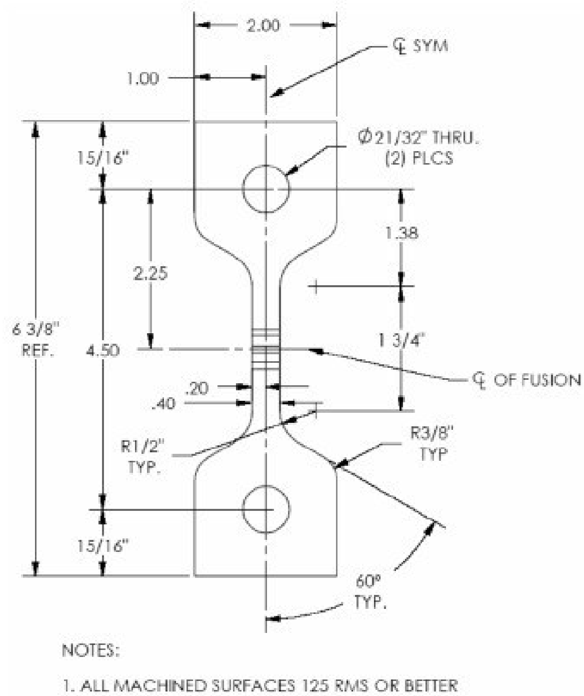

Figure 1: Schematic Illustration of test specimen used for McSnapper™ Testing

Figure 2: Typical McSnapper™ test set-up and testing progression of a typical PA12 test specimens at an average speed of 6 in/s.

The results of the McSnapper™ testing on the 6-inch PA12 heat fusion joints were consistent with expectations. There was an excellent correlation between the tensile strength values of the PA12 joints as compared to PA12 pipe specimens. Figures 3 and 4 present a summary of the test data for various joints and control specimens. Detailed summary of the McSnapper™ test results are presented in Figures 3 and 4 below.

In addition to validating the performance of PA12 joints made from “like to like” PA12 pipe, additional joints were fabricated using the PA12 pipe from other suppliers’ resin, i.e. “unlike” joints or cross-fusions. The test results confirmed the ability to make strong and effective cross-fusion joints, i.e. joints made using PA12 pipes from different suppliers. It was reported that in all of the test specimens, the failures originated outside the fusion interface. The overall results demonstrated that strong effective 6-inch PA12 joints can be made using the generic PA12 joining procedures.

In addition to the McSnapper™ testing, additional long term sustained pressure testing at elevated temperatures were performed on 6-inch PA12 pipe specimens using 290 psig at 80C. The results of the testing were consistent with expectations. There were no failures in any of the PA12 heat fusion joints at test times of at least 1000 hours.

Collectively, the results of the testing (tensile impact testing and long term sustained pressure testing at elevated temperatures) amply demonstrated the ability to make strong joints using the qualified PA12 joining procedures consistent with 49 CFR Part 192 requirements.

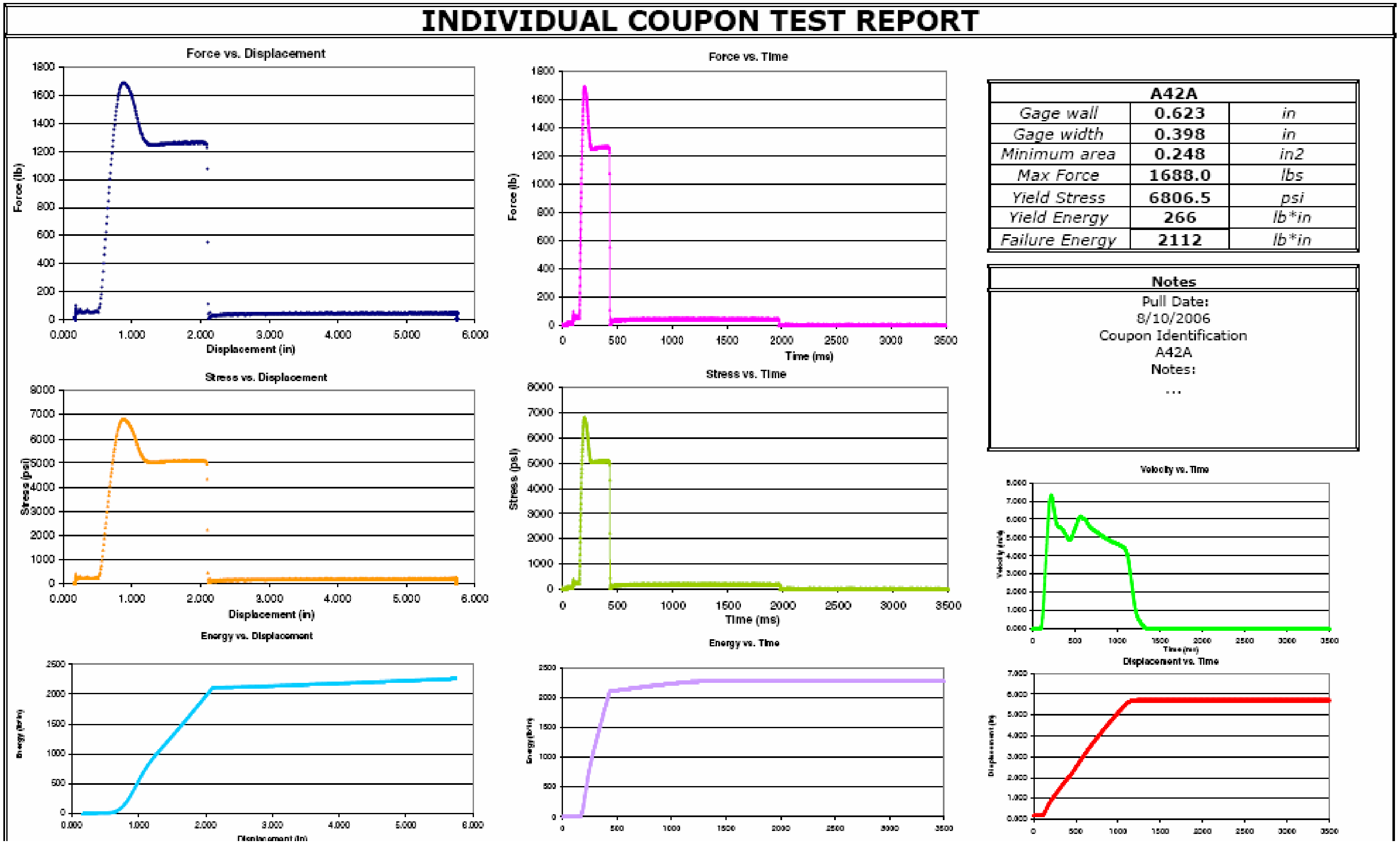

Figure 3: Illustration of test results from McSnapper testing for a typical PA12 heat fusion joint

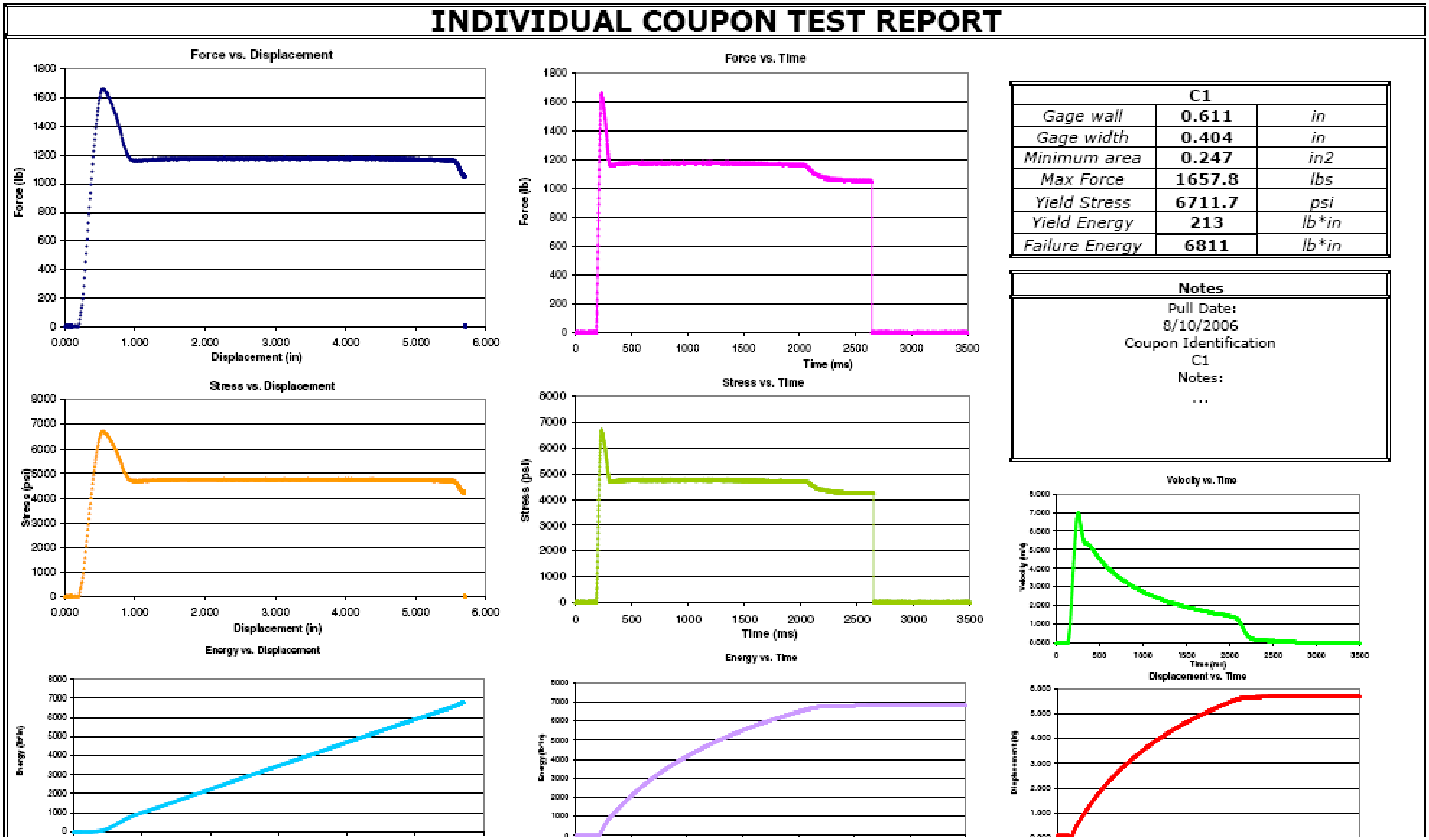

Figure 4: Illustration of test results from McSnapper testing for a typical PA12 pipe specimen

Sueddeutsches Kunststoff Zentrum (SKZ) Program

In addition to the GTI program, Evonik Degussa also commissioned an extensive research program to optimize the PA12 butt heat fusion parameters at a leading German research institute – SKZ Welding Institute. While the results of the GTI program, as previously discussed, verified the ability to make strong butt heat fusion joints using the range of interfacial pressures as specified under PPI TR-33 guidelines with a heater plate temperature of 500° F, it was noted that there are potentially significant differences in heat fusion practices throughout the world. Specifically, in Europe and elsewhere, a general industry practice is to utilize lower interfacial pressures as compared to the higher interfacial pressures specified in the United States. As a result, additional parametrically controlled tests were performed.

In the SKZ study, a range of heater plate temperatures were evaluated from 200° C – 260° C (392° F – 500° F) using different interfacial pressure ranging from 0.3 N/mm^2 to 0.6 N/mm^2 (44 psi to 87 psi) and varying heating times. The results of the testing also confirmed the ability to make strong joints over a wide range of butt heat fusion parameters as specified in the generic PA12 heat fusion procedure. Moreover, the results further confirmed that there is a smaller and more well-defined range of parameters within the generic heat fusion parameters can be used which will not only produce strong joints but will also lead to more visually acceptable joints.

In general, polyamides tend to absorb moisture to varying degrees. PA12, based on its inherent chemical characteristics, tends to absorb the lowest amount of moisture of the various commercially available polyamides. During the application of heat in the joining process, the absorbed water tends to evaporate. Subsequently, the final bead appearance tends to be different as compared to polyethylene. This is illustrated in Figure 5 which shows the pipe interface following the completion of the specified heating time to produce the required melt bead. As one increases the heater plate temperature, it is observed that there is a corresponding effect on the bead appearance. However, as the testing results demonstrate, at lower heater plate temperatures around 240° C (465° F) and the appropriate interfacial pressures, strong joints can be made with a relatively better visual appearance. It is important to emphasize that anecdotal experience throughout the world indicates that the final visual bead appearance is merely aesthetic and has no correlation to joint strength.

To further illustrate that the bead appearance of the PA12 does not correlate with the strength of the overall joint across the joint interface, additional microscopic analysis was performed which shows that there is continuity of the polymer across the interface and that there are no voids and/or other discontinuities. This is illustrated in Figure 6 below.

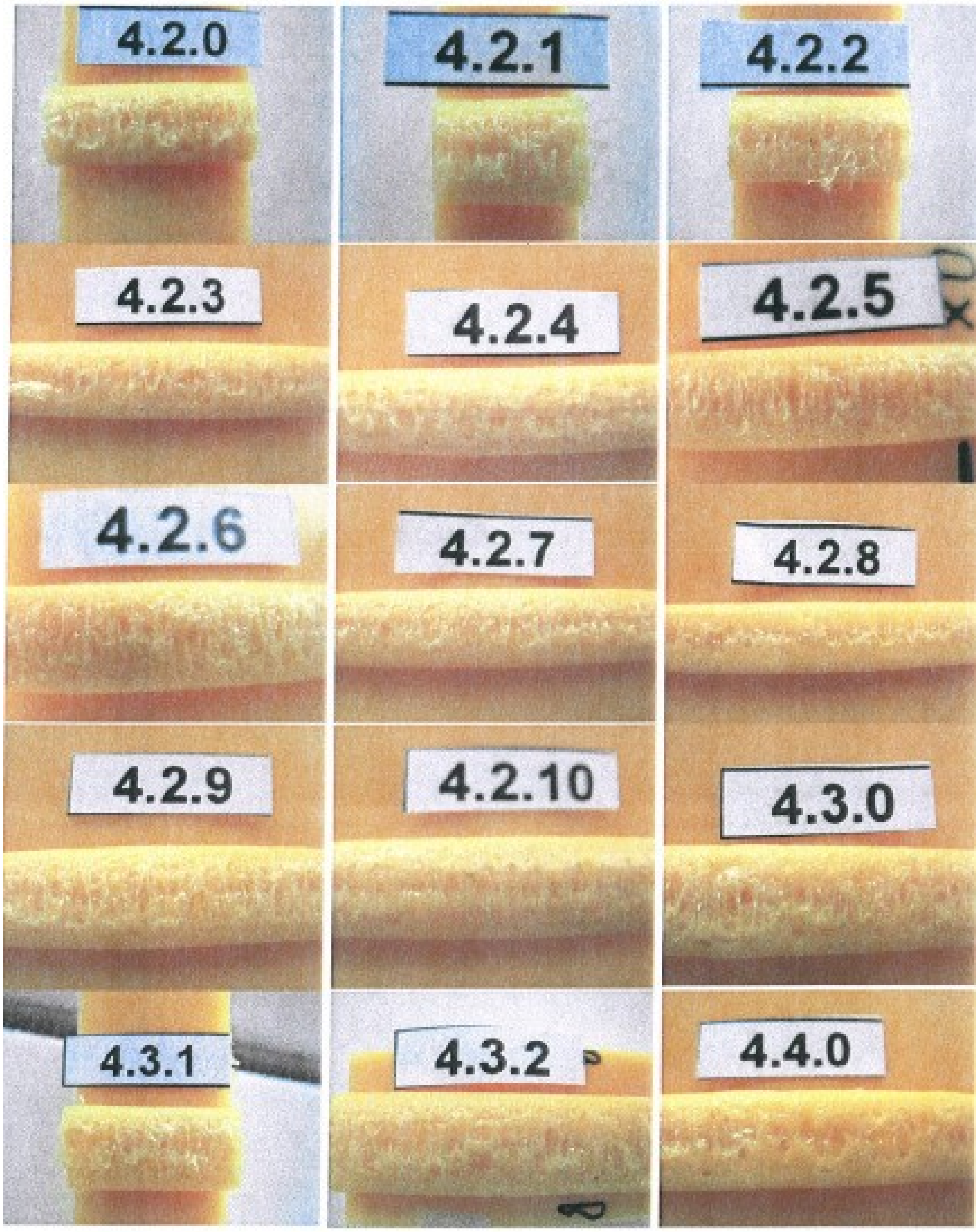

Figure 5: PA12 melt bead appearance over a range of temperatures used in the study.

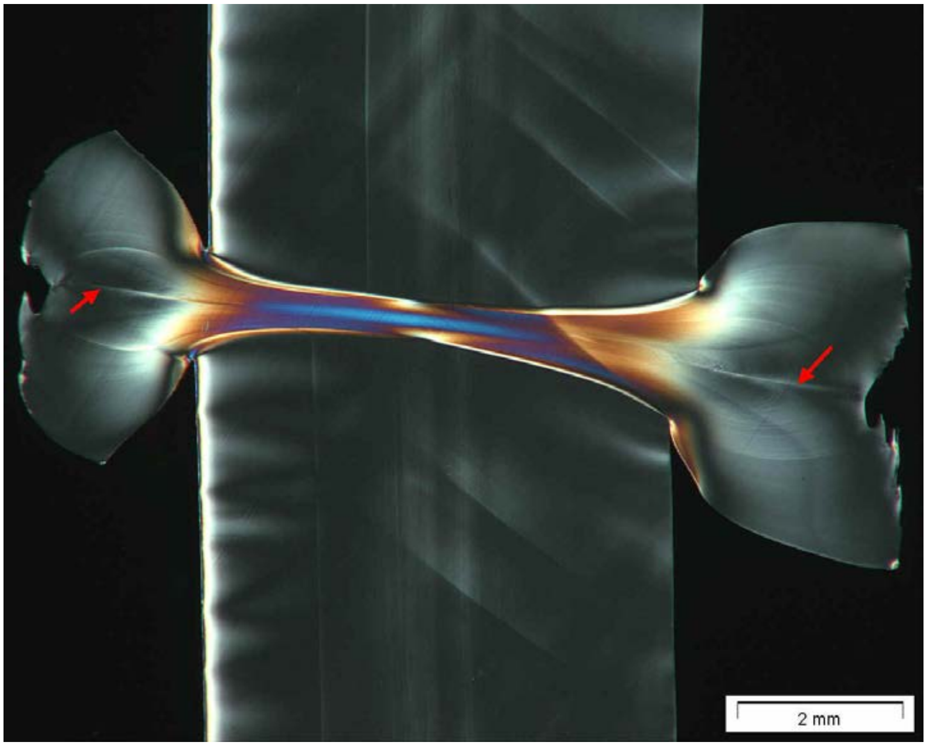

Figure 6: Representative transmitted light micrograph of typical PA12 heat fusion joint (Note: There are no discontinuities or voids across the joint interface)

3.2. <u>Conclusion and Recommendations</u>

The cumulative results of both the GTI and SKZ study indicate that a suitable heat fusion procedure for PA12 materials has been developed on the basis of the required testing per 49 CFR Part 192 requirements which can produce strong PA12 butt heat fusion joints. The PA12 pipes supplied from the different pipe suppliers for the purposes of this program meet ASTM F2785 requirements and are suitable for gas distribution applications. Based on the available information and the results of the testing, there is a strong likelihood that that the generic heat fusion procedure for PA12 can be qualified by gas distribution companies under DOT's regulations in 49 CFR Part 192 for use with PA12 gas piping products.

ANNEX A

Generic Butt Fusion Procedure for Polyamide 12 (PA12) Pipe

The following butt fusion procedures are intended for use with polyamide 12 (PA12) pipe. Critical parameters in the butt fusion process are heater plate surface temperature, heat soak time, interfacial pressure during initial contact of the molten pipe ends and during cooling and cooling time. The heat soak time and cooling time parameters vary as a function of pipe size and wall thickness. The pipe should be held under pressure until it is sufficiently cool enough to touch with bare hands.

NOTE: This procedure was developed in typical industrial shop ambient conditions. At low ambient temperatures, inclement weather, windy conditions, etc., appropriate actions should be taken to shield the fusion equipment and pipe being fused. The temperatures might have to be adjusted in very cold conditions. If temperatures are adjusted test fusions shall be made and tested to qualify the modified conditions.

Butt Fusion Procedure Parameters:

- Interface Pressure Range[1]: 60 – 90 psi
- Heater Surface Temperature Range: 460° F – 500° F

Butt Fusion Procedures:

The principle of heat fusion is to heat two surfaces to a designated temperature, 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 proper procedures, the joint area becomes as strong as or stronger than the pipe itself in both tensile and pressure properties.

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 seven steps involved in making a butt fusion joint are:

1. Clean the pipe ends
2. Securely fasten the components to be joined
3. Face the pipe ends
4. Align the pipe profile
5. Melt the pipe interfaces without pressure
6. Join the two profiles together
7. Hold under pressure until cool

[1] Interfacial pressure is NOT the same as the gauge pressure. The interfacial pressure is used to determine the joining pressure setting on hydraulic machines when joining specific pipe diameters and DR values. These values will vary based on the heat fusion equipment supplied by various manufacturers.

1. **Clean:** Clean the inside and outside of the pipe to be joined by wiping with a clean lint free cloth. Remove all foreign matter.
2. **Secure:** Clamp the components in the machine. Check alignment of the ends and adjust as needed.
3. **Face:** The pipe ends must be faced to establish clean, parallel mating surfaces. Most, if not all, equipment manufacturers have incorporated the rotating planer block design in their facers to accomplish this goal. Facing is continued until a minimal distance exists between the fixed and movable jaws of the machine and the facer is locked firmly and squarely between the jaw bushings. This operation provides for a perfectly square face, perpendicular to the pipe centerline on each pipe end and with no detectable gap.
4. **Align:** Remove any pipe chips from the facing operation and any foreign matter with a clean, untreated, lint-free cotton cloth. The pipe profiles must be rounded and aligned with each other to minimize mismatch (high-low) of the pipe walls. This can be accomplished by adjusting clamping jaws until the outside diameters of the pipe ends match. The jaws must not be loosened or the pipe may slip during fusion.
5. **Melt:** Heating tools that simultaneously heat both pipe ends are used to accomplish this operation. These heating tools are normally furnished with thermometers to measure internal heater temperature so the operator can monitor the temperature before each joint is made. However, the thermometer can be used only as a general indicator because there is some heat loss from internal to external surfaces, depending on factors such as ambient temperatures and wind conditions. A pyrometer or other surface temperature-measuring device should be used periodically to insure proper temperature of the heating tool face. Additionally, heating tools are usually equipped with suspension and alignment guides that center them on the pipe ends. The heater faces that come into contact with the pipe should be clean, oil-free and coated with a permanent nonstick coating as recommended by the manufacturer to prevent molten plastic from sticking to the metallic heater surfaces. Remaining molten plastic can interfere with fusion quality and must be removed according to the tool manufacturer's instructions.

   Plug in the heater and bring the surface temperatures up to the specified temperature range. Install the heater in the butt fusion machine and bring the pipe ends into full contact with the heater. To ensure that full and proper contact is made between the pipe ends and the heater, the initial contact should be just sufficient to ensure good contact between the pipe end and the heater surface. After holding the pressure for no more than a few seconds, it should be released without breaking contact. Continue to hold the components in place, without force, while a bead of molten polyamide develops between the heater and the pipe ends. When the proper bead size is formed against the heater surfaces, the heater should be removed. The bead size is dependent on the pipe size. See Table A1 below for approximate melt bead sizes.

Table A 1: Recommended acceptable melt bead sizes for different pipe diameters.

Pipe Size	Approximate Melt Bead Size
1 ¼" and smaller (40mm and smaller)	1/32" – 1/16" (1-2 mm)
Above 1 ¼" through 3" (above 40 mm-90mm)	About 1/16" (2 mm)
Above 3" through 8" (above 90mm – 225mm)	1/8"-3/16" (3-5mm)

6. **Joining:** After the melt bead size is within the approximate range shown in Table A1, the heater tool is quickly removed and the molten pipe ends are brought together with sufficient force to form a fusion bead at the joint location. The fusion force is determined by multiplying the interfacial pressure by the pipe wall area.

   For manually operated fusion machines, a torque wrench may be used to accurately apply the proper force. For manual machines without force reading capability of a torque wrench, the correct fusion joining force is the force required to form a uniform bead during joining. 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 units of hydraulic pressure. The gauge reading is theoretical; the internal and external drag need to be added to this figure to obtain the actual fusion pressure required by the machine.

7. **Hold:** The molten joint must be held immobile under pressure until cooled adequately to develop strength. Allowing proper times under pressure for cooling prior to removal from the clamps of the machine is important in achieving joint integrity. The fusion force should be held between the pipe ends until the surface of the bead is cool to the touch.

   Pulling, installation, or rough handling of the pipe should be avoided until the joint cools to ambient temperature (roughly an additional 30 minutes).

Visual Inspection

Visually mitered (angled, off-set) joints (Figure A1) should be cut out and re-fused (straight or coiled pipe).

Coiled pipe may leave a bend in some pipe size that must be addressed in the preparation of the butt heat fusion process. There are several ways to address this situation.

1. Straighten and re-round coiled pipe before the butt fusion process
2. If there is still curvature present, install the pipe ends in the machine in an “S” configuration with the print lines approximately 180° apart in order to help gain proper alignment and help produce a straight joint. See Figure A2 below.
3. If there is still a curvature present, another option would be to install a straight piece of pipe between the two coiled pipes.

Every effort should be made to make the joint perpendicular to the axis of the pipe.

Figure A 1: Visually unacceptable mitered joint.

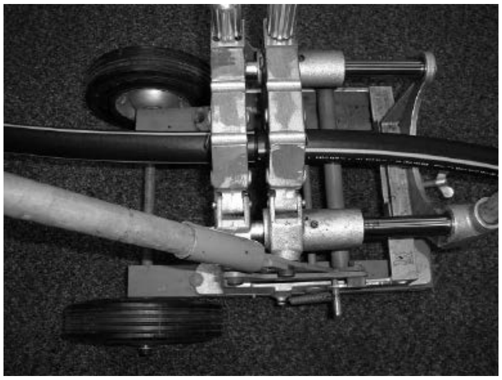

Figure A 2: Coiled pipe with residual curvature correctly positioned in the butt fusion machine.

Figures A3 and A4 show visually acceptable fusion beads.

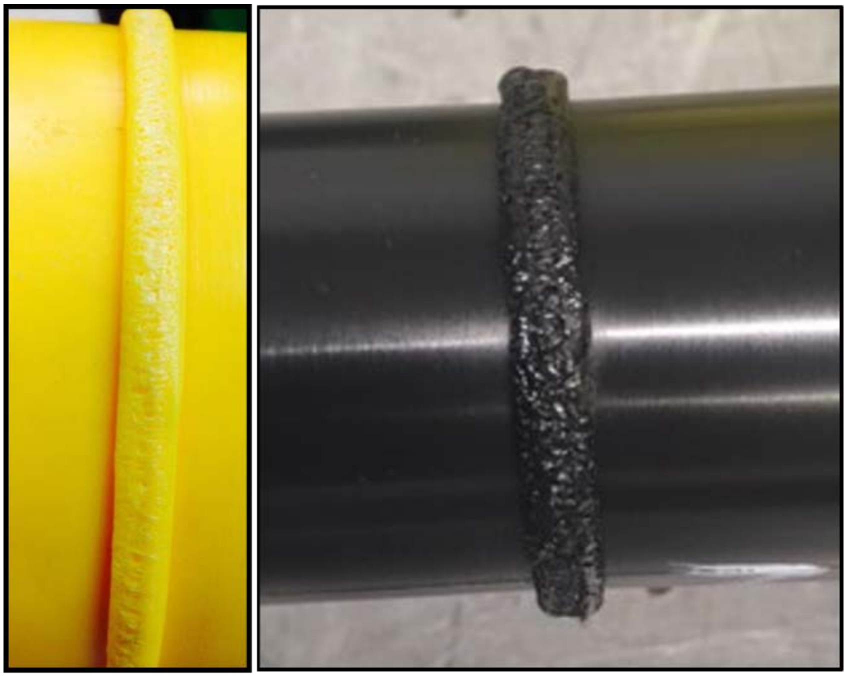

Figure A 3: Visually acceptable PA12 fusions

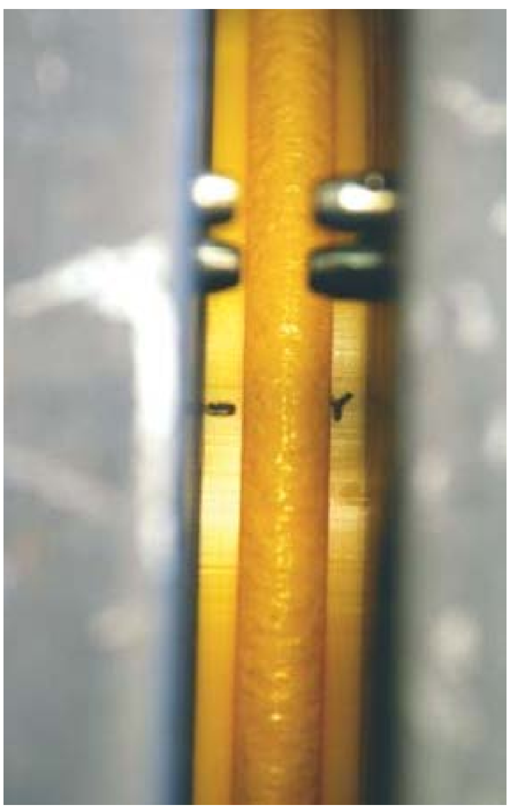

Figure A 4: Acceptable external bead while in the fusion machine.