



# National Transportation Safety Board

Washington, D.C. 20594

## Pipeline Accident Brief

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Accident No.:	DCA-04-MP-006
System Type:	Natural gas distribution
Accident Type:	Leak, explosion, and fire
Location:	DuBois, Pennsylvania
Date:	August 21, 2004
Time:	About 8:54 a.m. eastern daylight time <sup>1</sup>
Owner/Operator:	National Fuel Gas Distribution Corporation
Property Damage and Losses:	\$800,000
Fatalities:	2
Injuries:	None
Material Released:	Natural gas
Pressure:	50 pounds per square inch, gauge
Failure Type:	Butt-fusion joint leak
Component Affected:	2-inch plastic main line

### The Accident

On August 21, 2004, about 8:54 a.m., a natural gas explosion destroyed a residence located at 48 Woodland Lane in DuBois, Pennsylvania. The two residents were killed in this accident. (See figure 1.)

### Postaccident Investigation

National Fuel Gas Distribution Corporation (National Fuel) probed the ground near the residence for gas leaks. Combustible gas-to-air readings were found in two areas: one area was adjacent to the affected residence, and the other area was directly over the failed pipe on the front lawn. After the explosion, National Fuel excavated the front lawn. The excavation revealed a leaking butt-fusion joint in a 2-inch-diameter plastic main line pipe. (See figure 2.)

A butt-fusion joint is made by the following process. A heater plate is inserted between two pipe ends, melting the material on each end. The heater is then removed, and the pipe ends are pushed together under applied force. The pipe ends remain under applied force as the pipe ends cool and fuse together. The butt-fusion process forces excess molten plastic onto the inside and outside of the pipe surfaces. Because both sides of the pipe are molten, two visible beads are formed on the exterior and interior of the pipe joint. (See figure 3.) When this material cools and solidifies, it is called a fusion bead.

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<sup>1</sup> All times in this brief are eastern daylight time.



**Figure 1.** Damage to 48 Woodland Lane.

National Fuel began excavating the accident site before National Transportation Safety Board investigators arrived. During the excavation, National Fuel accidentally severed the plastic pipe within a few feet of the butt-fusion joint. Because of this mishap, Safety Board investigators could not determine the undisturbed position of the pipe to assess its bending. Only a small ligament remained connected at the butt-fusion joint, making it impossible to directly test the strength of the joint.

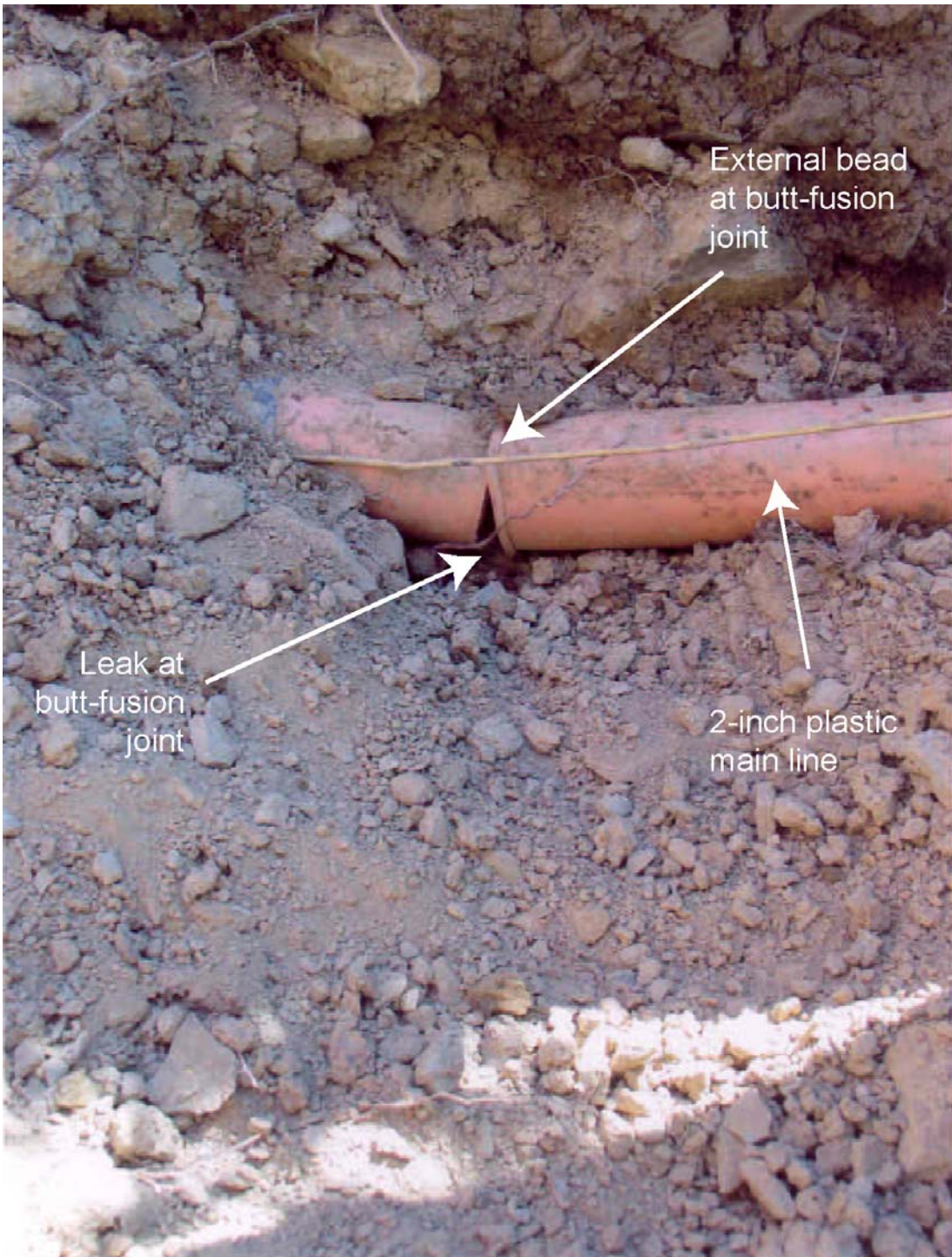
The Safety Board's examination of the butt-fusion joint linked to the explosion indicates that the bead widths were not uniform.<sup>2</sup> The bead width on one side of the butt-fusion joint ranged from 0.0535 inch to 0.1135 inch. On the other side of the joint, the bead width ranged from 0.0745 inch to 0.1060 inch. The total bead width ranged from 0.1315 inch to 0.2045 inch. The joint was found to have been visibly mitered,<sup>3</sup> having about a 2° angle. Mitering can concentrate stresses. No evidence was found indicating that the joint was significantly misaligned.<sup>4</sup>

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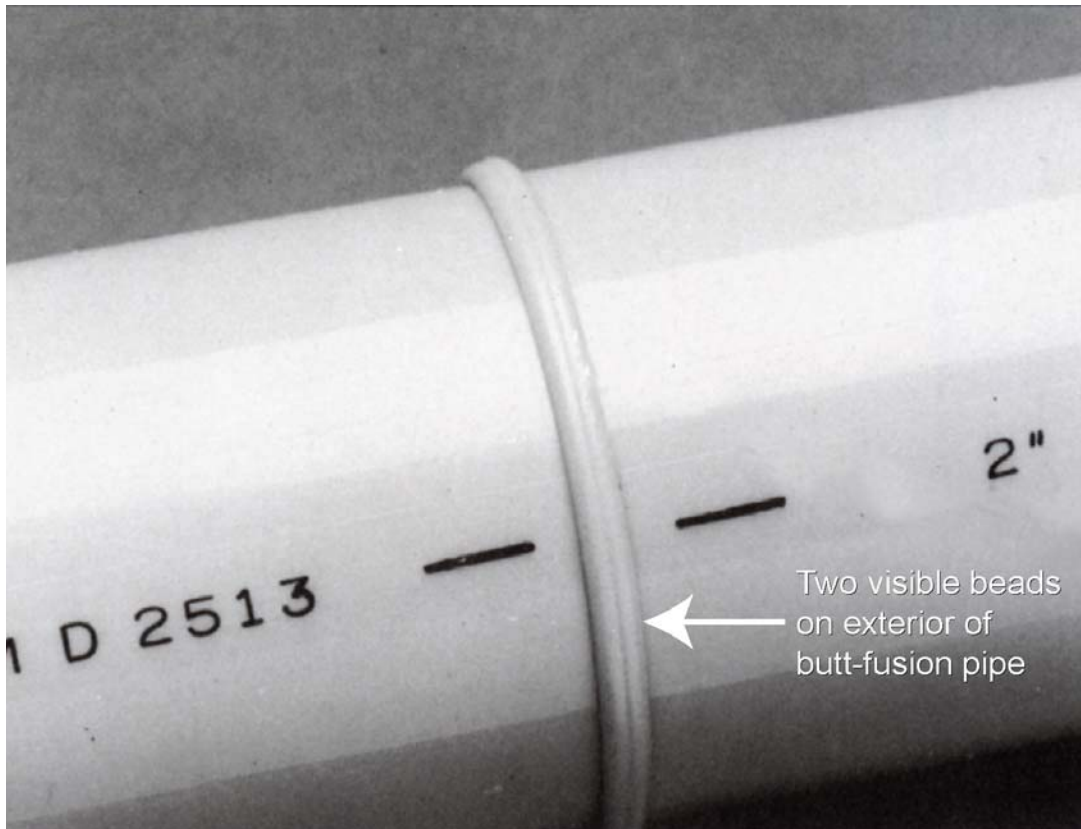
<sup>2</sup> See butt-fusion criteria discussed in the section titled *Butt-Fusion Procedures and Inspection Criteria, Preaccident*.

<sup>3</sup> *Mitered* means a butt-fusion joint that is not joined with an 180° angle from each pipe. In this report, mitering refers to a small angle made unintentionally in the field, not a large angle made intentionally as a pipe bend. A *visible miter* is a joint that has an angle detectable by the unaided eye.

<sup>4</sup> *Misaligned* means a butt-fusion joint in which the two pipes are not evenly lined up relative to each other, exhibiting a high-low disjuncture at the point of fusion.



**Figure 2.** Excavated butt-fusion joint.



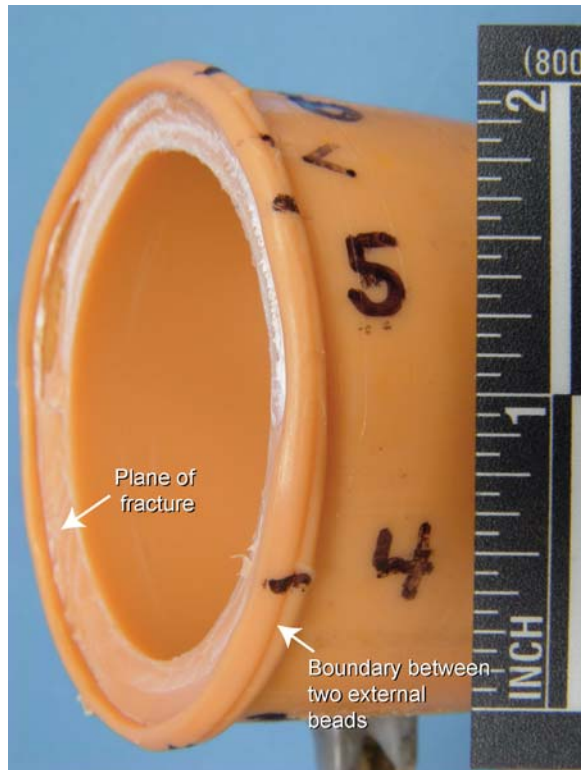
**Figure 3.** Optimal butt-fusion joint as illustrated in Uponor's Heat Fusion Installer Qualification Manual.

At the same location where the external bead width was thinnest, the bead was distorted. The external bead on one side of the joint was larger than the bead on the other side. The boundary between the two beads was indistinct. The internal bead was also distorted, with the bead on one side of the joint higher than the other side. On one side of the joint, the internal bead had numerous pockmarks.<sup>5</sup> On the other side, small globules of plastic adhered to the bead, which is consistent with material being pulled from one bead and deposited on the other bead when the joint was made.

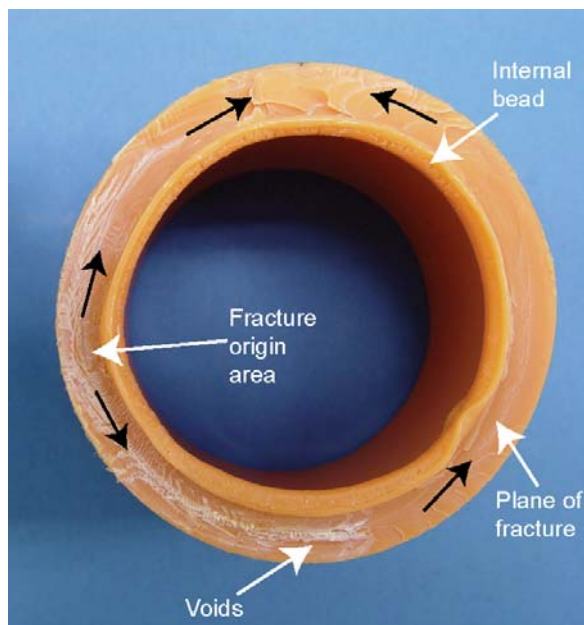
The fracture between the two pipe ends closely followed the plane of the center of the butt-fusion joint. (See figure 4.) The external bead remained attached to one piece of the pipe, and the internal bead remained attached to the other piece of the pipe. (See figure 5.)

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<sup>5</sup> *Pockmarks* may indicate a less than optimal butt fusion.



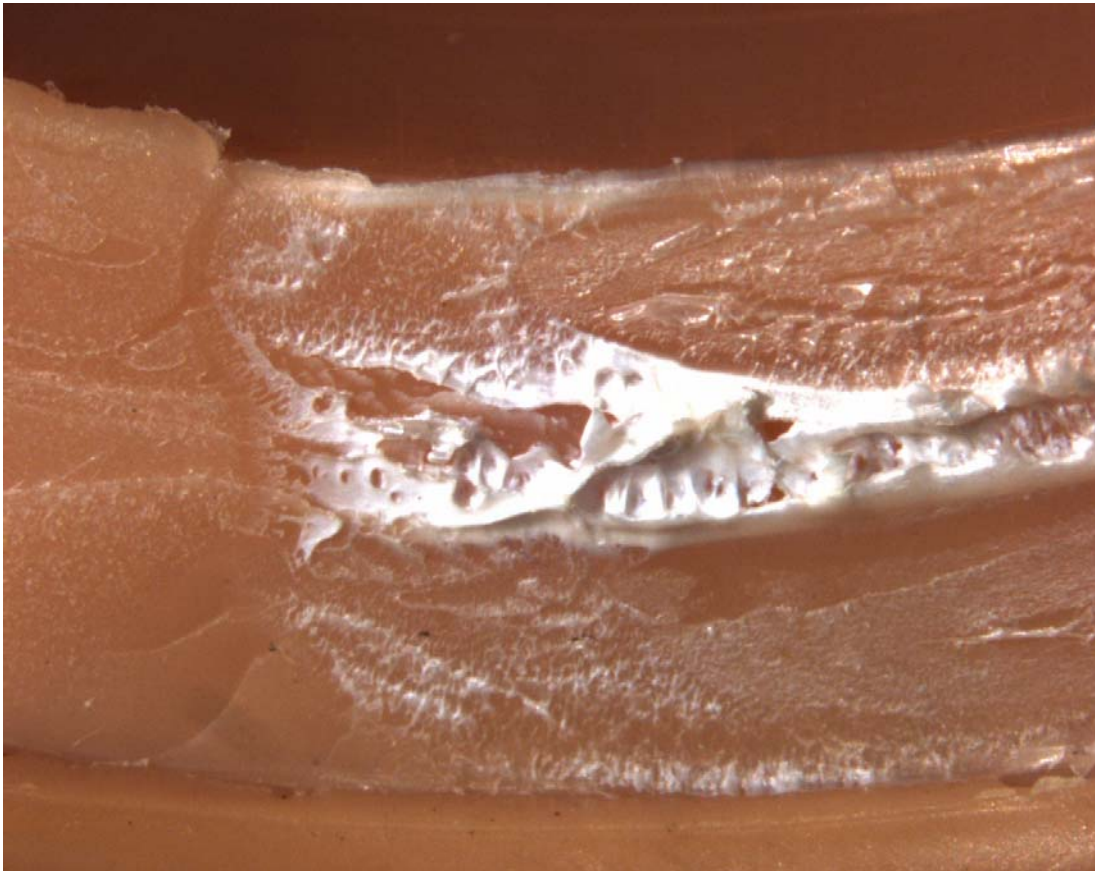
**Figure 4.** Fractured end showing external bead and plane of fracture at center of butt-fusion joint.



**Figure 5.** View of fracture surface on one piece of pipe. Pipe is oriented as it was found. Fracture origin was at 9 o'clock position as shown. Unlabeled arrows indicate crack propagation directions.

The fracture surfaces at the butt-fusion joint were examined using optical microscopy and an environmental scanning electron microscope. The fracture surface exhibited voids where the internal and external beads were distorted. (See figure 6.) Fracture surface features indicated that the crack initiated near the center of the pipe wall within the butt-fusion joint, followed by a slow progressive crack growth.<sup>6</sup> Ductile ribbons of plastic pipe material present at the inner and outer edges of the fracture surface indicated that the crack did not initiate at the notches<sup>7</sup> of either the internal or external beads.

Studies of butt-fusion joints subjected to elevated temperature and high pressure indicate that a fracture occurring in the butt-fusion area will normally start on the pipe wall surface at the notch of the internal bead or, if bending is involved, the fracture would be expected to start at the outer pipe wall surface. However, the initiation of the fracture in the accident pipe near the center of the pipe wall is consistent with inadequate fusion of the joint.



**Figure 6.** Voids in central portion of fracture surface.

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<sup>6</sup> See National Transportation Safety Board *Brittle-like Cracking in Plastic Pipe for Gas Service*, Special Investigation Report NTSB/SIR-98/01 (Washington, DC: NTSB, 1998), for additional information regarding progressive crack growth.

<sup>7</sup> As the bead rolls back, a *notch* is formed between the bead and the wall of the pipe. Stress concentration increases in the area of the notch.

The butt-fusion joint that joined the two coiled plastic pipes<sup>8</sup> involved in this accident was made on January 10, 1996, using a machine called the McElroy 14, which is manufactured by McElroy Manufacturing, Inc. (McElroy). The two plastic pipes were manufactured in different years. One pipe was manufactured on May 16, 1995; the other was manufactured on October 5, 1994. Uponor Aldyl Company (Uponor) manufactured both medium-density<sup>9</sup> pipes. According to written certifications from Uponor, the pipe met the requirements of ASTM D-2513, “Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings.” Laboratory testing of the accident pipe determined that the dimensions, density, and melt index were within Uponor’s production specifications.

## **Butt-Fusion Procedures and Inspection Criteria**

### ***Preaccident***

Uponor had a butt-fusion joining procedure, adopted in December 1991, for its pipe product. Uponor qualified its joining procedure in accordance with Title 49 *Code of Federal Regulations* (CFR) 192.283.<sup>10</sup> As a service to National Fuel and other pipeline companies, Uponor provided its procedure.

National Fuel had its own procedure for making butt-fusion joints. The butt-fusion joining procedures for National Fuel and Uponor were similar. The National Fuel butt-fusion procedure was adopted in February 1993. National Fuel made butt-fusion joints using a variety of machines. The company inspected and certified its butt-fusion machines in accordance with its procedures.

Uponor published a set of key visual inspection criteria for identifying an acceptable butt-fusion joint. These criteria were in effect in 1996 at the time the fusion joint involved in the accident was made. As stated in Uponor’s inspection criteria (adjacent to photographs of butt-joint fusions), key visual criteria for a good-quality fusion included the following:

- Uniform bead development on both pipe ends
- Bead rolled back to pipe
- No misalignment between pipe ends

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<sup>8</sup> Butt fusion of coiled pipe is considered more difficult than fusion of straight pipe because the residual curvature makes it difficult to obtain an optimal alignment and reduce mitering. Proper procedures and equipment and extra care are necessary if high-quality joints are to be consistently produced.

<sup>9</sup> *Medium density* is characterized in ASTM D-2513. ASTM is now known as ASTM International, one of the largest voluntary standards development organizations in the world. ASTM was originally an abbreviation for American Society for Testing and Materials.

<sup>10</sup> Title 49 CFR 192.283 is issued by the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration in Part 192, “Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards;” Subpart F, “Joining of Materials Other Than by Welding;” Section 192.283, “Plastic pipe: Qualifying joining procedures.”

In addition, the Uponor procedure stated that joints not meeting these visual criteria had to be remade before being placed into service. The Uponor procedure further stated, “If the pipe ends are not aligned, adjust them in the shells and . . . [start over].” This procedure did not address mitering.

National Fuel essentially used Uponor’s inspection criteria. As part of its procedure for making a butt-fusion joint, National Fuel required the fuser<sup>11</sup> to inspect the completed joint for conformity with its criteria. National Fuel’s procedure also stated, “If there is any reason to believe a butt fusion is defective, it shall be removed and replaced.”

Safety Board investigators interviewed two current and two retired National Fuel employees familiar with National Fuel’s fusion procedures and training at the time when the subject butt-fusion joint was made. The four interviewees included two master trainers who conducted initial qualification training and two foremen who requalified personnel in the field based on instructions from the master trainers. The interviewees stated that National Fuel had verbal instructions in effect in 1996 advising its fusers not to allow a visual miter; however, this guidance was not found in its written operating procedures.

The butt-fusion joint linked to the explosion was made with a 500-foot length of 2-inch coiled pipe that was butt fused to a previously installed 2-inch coiled pipe using the McElroy 14. According to the National Fuel butt-fusion procedure, the fusion required the fuser to apply 15 to 20 foot-pounds with the machine, which would have resulted in a joining force on the pipe ends of 165 to 215 pounds. A 500-foot roll of 2-inch plastic pipe weighs approximately 315 pounds. Depending on the placement of the pipe roll, the drag caused by the weight of the pipe roll could have been negligible or significant. The written procedures of Uponor, National Fuel, and McElroy did not account for drag force;<sup>12</sup> however, McElroy’s onsite training program provided instructions to fusers so that they could determine in the field the drag force for a butt-fusion joint. Among the four National Fuel interviewees, there was variation in the level of knowledge regarding drag force and the need to compensate for its effects.

## **Current**

Since the accident, the PWPoly Corporation has acquired Uponor. The combined businesses of PWPoly Corporation and Uponor operate under the name USPoly Company (USPoly). Today, USPoly continues to manufacture medium-density pipe, but it no longer manufactures the type of pipe involved in this accident.

USPoly’s March 5, 2000, pipe joining procedure addresses the methods for joining coiled pipe using butt fusion and recommends that drag force be determined on a case-by-case basis. Its procedure requires that the completed joint be inspected and prescribes that any joint not meeting

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<sup>11</sup> A *fuser* is a person who makes fusion joints.

<sup>12</sup> The fusion of a long or heavy segment of pipe is different from the fusion of two small segments of plastic pipe. *Drag force* is the force required to move the pipe to be joined. If this drag force is not added before applying the joining force, the proper joining force may not be applied.

visual inspection criteria be remade. The USPoly procedure does not address mitering. USPoly's key visual inspection criteria for its medium-density pipe product include the following:

- Complete and uniform beads
- Bead rolled back to pipe
- Alignment

The Plastics Pipe Institute (PPI) is the major trade association representing the plastics piping industry. The PPI publishes universal fusion procedures that are widely accepted throughout the pipeline industry. PPI's current butt-fusion joint procedure, published in late 2005, recommends that the drag force be determined on a case-by-case basis. The PPI procedure does not address the joining of coiled pipe or the avoidance of mitering. The PPI procedure includes an illustration of a properly made butt-fusion joint, but it does not specifically address inspecting the finished joint.

In November 2000, McElroy, the manufacturer of the McElroy 14, established butt-fusion procedures that recommend determining drag force on a case-by-case basis. In addition, McElroy specifies using PPI's fusion procedures or the pipe manufacturer's procedures for certain fusion parameters, such as joining force and holding time.

ASTM D-2657, "Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings," contains a general butt-fusion joint procedure. The ASTM procedure requires the use of PPI or pipe-manufacturer procedures to specify the fusion parameters. The ASTM procedure further prescribes inspecting the finished joint in accordance with recommended appearance guidelines. The ASTM procedure also addresses calculating and using a drag force.

National Fuel's current butt-fusion procedure,<sup>13</sup> published in May 2005, addresses joining coiled pipe. This procedure adds a predetermined fixed drag force for some fusion machines. As a part of its operating procedure, National Fuel requires the fuser to inspect the completed butt-fusion joint. This visual examination of the butt fusion includes proper alignment, no miter, complete bead rollover, relatively uniform beads, and proper bead width. National Fuel's current procedure states, "If there is any reason to believe the butt fusion is defective, it shall be removed and replaced." A butt-fusion joint made by a fuser in the field is subject to inspection by a foreman. Since January 1, 2000, National Fuel's Quality Assurance/Quality Control department has been performing periodic field audits that sometimes include inspections of butt fusions, depending upon the subject of the audit. The fusers have been required to use a permanent marker to write their employee identification number on their butt -fusion joints since January 2001.

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<sup>13</sup> National Fuel's current policy does not permit two segments of coiled pipe to be butt fused; however, a straight pipe can be butt fused to coiled pipe.

## **Qualification of Fusion Personnel**

### ***Preaccident***

Title 49 CFR 192.285 required that all personnel making plastic pipe joints be qualified under the applicable joining procedure. To qualify, the applicant had to have appropriate training or experience using the procedure and had to produce at least one joint using it. These joints were visually examined and mechanically tested by one of several approved methods, which included pressure testing, tensile testing, and cutting the joint into a minimum of three strips and bending them to failure. This testing was required for qualification and requalification.

Two qualified fusers were on the National Fuel work crew that installed the 2-inch plastic pipe on January 10, 1996. One of these fusers signed a form indicating that he had made the butt-fusion joint where the failure occurred. He also signed the chart of the final pressure test before this pipeline segment was placed in service.

According to National Fuel records, both work crew fusers passed their original plastic pipe butt-fusion qualification tests. Both work crew fusers requalified in 1994, 1995, and 1996. During their requalification tests, they used a variety of butt-fusion machines, including the McElroy 14. Their requalification testing was performed in accordance with 49 CFR 192.285. Their requalification records indicate that they received a review of procedures. The fusers were not given a written examination, and records did not reflect whether they were requalified using coiled or straight pipe. Neither crew fuser, according to National Fuel records, had a documented failed joint.

### ***Current***

In its fuser qualification plan, National Fuel has two levels of training and qualification: initial qualification and requalification. New employees who produce plastic fusions and fitting installations are required to take an initial training course. The course reviews the National Fuel procedures, best practices for plastic material installation, and fusion and mechanical coupling installation. Individuals performing plastic joining are requalified on an annual basis. Both the initial and requalification programs include instructional videos, reviews of updated or changed operating procedures, and changes in materials or products. Both a written test and a practical exam are given. The trainee must be able to differentiate between acceptable and unacceptable fusions. The trainee is required to make test joints that may or may not be made from coiled pipe. These joints are visually examined by the trainer and then evaluated by mechanical testing. To qualify an individual for the inspection of fused plastic pipe, National Fuel requires the individual to pass either a written or an oral examination and to understand how to determine that a joint meets National Fuel's acceptance criteria. On March 8, 2004, two Pennsylvania Public Utility Commission (PUC) inspectors audited National Fuel's program. No issue regarding National Fuel's butt-fusion operator qualifications was identified in the audit report.

## **Additional Fusions Removed from DuBois**

The Pennsylvania PUC supervised the excavation and visual inspection of an additional 40 joints from an area in the vicinity of the accident that were made in either 1994 or 1996. Inspectors from the Pennsylvania PUC removed 24 of the joints and submitted them to the Safety Board for laboratory analysis.

Of the 24 joints examined at the Safety Board's Materials Laboratory, 5 were made from straight pipe, and 19 were made from coiled pipe. The five joints made from straight pipe were found to have sufficiently uniform beads, complete bead rollover, no visible miter, and proper alignment.

About half of the 19 joints made from coiled pipe had visible variation in bead width, but all were relatively uniform. All of the 19 joints had complete bead rollover. The 19 joints had miter angles that were greater than those on the straight pipe joints; the miter angles for the joints made from coiled pipe ranged from 0.7° to 4.2°. The average angle of the miter for the 19 joints was 2.08°. Thirteen of the 19 joints made from coiled pipe had a misalignment in excess of that allowed by National Fuel and Uponor. Two joints had an area that separated in the joint during tensile testing. These two joints had regions of poor bonding in the fusion area; one of the joints exhibited voids similar to those observed on the fracture surface of the accident joint.

Records to identify a specific fuser with any of the 24 joints examined by the Safety Board's Materials Laboratory were unavailable. National Fuel records show that in 1994 there were nine qualified fusers and in 1996 there were seven qualified fusers who could make butt-fusion joints in the DuBois Service Center area.

## **Gas System Performance Monitoring**

Federal regulations (49 CFR 192.613 and 192.617) require that gas pipeline system operators have procedures in place for monitoring the performance of their gas systems. These procedures must cover surveillance of gas system failures and leakage history, analysis of failures, submission of failed samples for laboratory examination (to determine the causes of failure), and minimizing the possibility of future recurrences. National Fuel has reported that it is revising its surveillance and analysis program to address the integrity of butt-fusion joints.

## **Probable Cause**

The National Transportation Safety Board determines that the probable cause of the leak, explosion, and fire in DuBois, Pennsylvania, on August 21, 2004, was the fracture of a defective butt-fusion joint and the failure of the National Fuel Gas Distribution Corporation to have an adequate program to inspect butt-fusion joints and replace those joints not meeting its inspection criteria.

## **Recommendations**

As a result of its investigation of the August 21, 2004, DuBois, Pennsylvania, pipeline accident, the National Transportation Safety Board makes the following safety recommendations:

### **To the Pennsylvania Public Utility Commission:**

Require an analysis of the integrity of butt-fusion joints in National Fuel Gas Distribution Corporation's gas distribution system and replacement of those joints that are determined to have unacceptable characteristics. (P-06-1)

### **To National Fuel Gas Distribution Corporation:**

Revise your butt-fusion procedures for plastic pipe to include a requirement for determining drag force in the field for each butt-fusion joint. (P-06-2)

Revise your initial qualification and requalification procedures for plastic gas pipe to ensure fusers produce test joints made from coiled pipe with characteristics similar to those experienced in the field. (P-06-3)

### **To USPoly Company:**

Revise your butt-fusion procedures to include a requirement for the avoidance of mitering in plastic gas pipe joints. (P-06-4)

### **To the Plastics Pipe Institute:**

Revise your butt-fusion joining procedure for plastic gas pipe to (1) stress the importance of inspecting the finished joint, (2) include guidance on the joining of coiled pipe, and (3) include a requirement for the avoidance of mitering. (P-06-5)

**BY THE NATIONAL TRANSPORTATION SAFETY BOARD**

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**Adopted: May 31, 2006**