



# National Transportation Safety Board

Washington, D.C. 20594

## Safety Recommendation

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**In reply refer to:** P-98-1 through -5

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Despite the general acceptance of plastic piping as a safe and economical alternative to piping made of steel or other materials, the Safety Board notes that a number of pipeline accidents it has investigated have involved plastic piping that cracked in a brittle-like manner. For example, on October 17, 1994, an explosion and fire in Waterloo, Iowa, destroyed a building and damaged other property. Six persons died and seven were injured in the accident. The Safety Board investigation determined that natural gas had been released from a plastic service pipe that had failed in a brittle-like manner at a connection to a steel main.

The Safety Board also investigated a gas explosion that resulted in 33 deaths and 69 injuries in San Juan, Puerto Rico, in November 1996.<sup>1</sup> The Safety Board's investigation determined that the explosion resulted from ignition of propane gas that had migrated under pressure from a failed plastic pipe that displayed evidence of brittle-like circumferential cracking.

The Railroad Commission of Texas investigated a natural gas explosion and fire that resulted in one fatality in Lake Dallas, Texas, in August 1997.<sup>2</sup> A metal pipe pressing against a plastic pipe generated stress intensification that led to a brittle-like crack in the plastic pipe.

A broader Safety Board survey of the accident history of plastic piping suggested that the material may be susceptible to premature brittle-like cracking under conditions of stress intensification. No statistics exist that detail how much and from what years any plastic piping may already have been replaced; however, hundreds of thousands of miles of plastic piping have been installed, with a significant amount of it having been installed prior to the mid-1980s. Any

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<sup>1</sup>For more information, see National Transportation Safety Board Pipeline Accident Report--*San Juan Gas Company, Inc./Enron Corp., Propane Gas Explosion in San Juan, Puerto Rico, on November 21, 1996* (NTSB/PAR-97/01).

<sup>2</sup>Railroad Commission of Texas Accident Investigation No 97-AI-055, October 31, 1997

vulnerability of this material to premature failure could represent a serious potential hazard to public safety.

In an attempt to gauge the extent of brittle-like failures in plastic piping and to assess trends and causes, the Safety Board examined pipeline accident data compiled by RSPA. The examination revealed that the data were insufficient to serve as a basis for assessing the long-term performance of plastic pipe.

Lacking adequate data from RSPA, the Safety Board reviewed published technical literature and contacted more than 20 experts in gas distribution plastic piping to determine the estimated frequency of brittle-like cracks in plastic piping. The majority of the published literature and experts indicated that failure statistics would be expected to vary from one gas system operator to another based on factors such as brands and dates of manufacture of plastic piping in service, installation practices, and ground temperatures, but they indicated that brittle-like failures, as a nationwide average, may represent the second most frequent failure mode for older plastic piping, exceeded only by excavation damage.

The Safety Board asked several gas system operators about their direct experience with brittle-like cracks. Four major gas system operators reported that they had compiled failure statistics sufficient to estimate the extent of brittle-like failures. Three of those four said that brittle-like failures are the second most frequent failure mode in their plastic pipeline systems. One of these operators supplied data showing that it experienced at least 77 brittle-like failures in plastic piping in 1996 alone.

As an outgrowth of the Safety Board's investigations into the Waterloo, Iowa; San Juan, Puerto Rico; and about a dozen other accidents, and in view of indications that some plastic piping, particularly older piping, may be subject to premature failure attributable to brittle-like cracking, the Safety Board undertook a special investigation of polyethylene gas service pipe. The investigation addressed the following safety issues:<sup>3</sup>

- The vulnerability of plastic piping to premature failures due to brittle-like cracking;
- The adequacy of available guidance relating to the installation and protection of plastic piping connections to steel mains; and
- Performance monitoring of plastic pipeline systems as a way of detecting unacceptable performance in piping systems.

The Waterloo, San Juan, and Lake Dallas accidents were only three of the most recent in a series of accidents in which brittle-like cracks in plastic piping have been implicated. In Texas in 1971, natural gas migrated into a house from a brittle-like crack at the connection of a plastic

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<sup>3</sup>For more information, see National Transportation Safety Board Pipeline Special Investigation Report--*Brittle-like Cracking in Plastic Pipe for Gas Service* (NTSB/SIR-98/01)

service line to a plastic main.<sup>4</sup> The gas ignited and exploded, destroying the house and burning one person. The investigation determined that vertical loading over the connection generated long-term stress that led to the crack.

A 1973 natural gas explosion and fire in Maryland severely damaged a house, killed three occupants, and injured a fourth.<sup>5</sup> The Safety Board's investigation revealed that a brittle-like crack occurred in a plastic pipe as a result of an occluded particle that created a stress point.

The Safety Board's investigation of a natural gas explosion and fire that resulted in three fatalities in North Carolina in 1975<sup>6</sup> determined that the gas had accumulated because a concrete drain pipe resting on a plastic service pipe had precipitated two cracks in the plastic pipe. Available documentation suggests that these cracks were brittle-like.

A 1978 natural gas accident in Arizona destroyed 1 house, extensively damaged 2 others, partially damaged 11 other homes, and resulted in 1 fatality and 5 injuries.<sup>7</sup> Available documentation indicates that the gas line crack that caused the accident was brittle-like.

A 1978 accident in Nebraska involved the same brand of plastic piping as that involved in the Waterloo accident. A crack in a plastic piping fitting resulted in an explosion that injured one person, destroyed one house, and damaged three other houses.<sup>8</sup> The Safety Board determined that inadequate support under the plastic fitting resulted in long-term stress intensification that led to the formation of a circumferential crack in the fitting. Available documentation indicates that the crack was brittle-like.

A December 1981 natural gas explosion and fire in Arizona destroyed an apartment, damaged five other apartments in the same building, damaged nearby buildings, and injured three occupants.<sup>9</sup> The Safety Board's investigation determined that assorted debris, rocks, and chunks of concrete in the excavation backfill generated stress intensification that resulted in a circumferential crack in a plastic pipe at a connection to a plastic fitting. Available documentation indicates that the crack was brittle-like.

A July 1982 natural gas explosion and fire in California destroyed a store and two residences, severely damaged nearby commercial and residential structures, and damaged

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<sup>4</sup>National Transportation Safety Board Pipeline Accident Report--*Lone Star Gas Company, Fort Worth, Texas, October 4, 1971* (NTSB/PAR-72/5).

<sup>5</sup>National Transportation Safety Board Pipeline Accident Report--*Washington Gas Light Company, Bowie, Maryland, June 23, 1973* (NTSB/PAR-74/5).

<sup>6</sup>National Transportation Safety Board Pipeline Accident Brief--"Natural Gas Corporation, Kinston, North Carolina, September 29, 1975."

<sup>7</sup>National Transportation Safety Board Pipeline Accident Brief--"Arizona Public Service Company, Phoenix, Arizona, June 30, 1978."

<sup>8</sup>National Transportation Safety Board Pipeline Accident Brief--"Northwestern Public Service, Grand Island, Nebraska, August 28, 1978."

<sup>9</sup>National Transportation Safety Board Pipeline Accident Brief--"Southwest Gas Corporation, Tucson, Arizona, December 3, 1981."

automobiles.<sup>10</sup> The Safety Board's investigation identified a longitudinal crack in a plastic pipe as the source of the gas leak that led to the explosion. Available documentation indicates that the crack was brittle-like.

A September 1983 natural gas explosion in Minnesota involved the same brand of plastic piping as that involved in the Waterloo and Nebraska accidents.<sup>11</sup> The explosion destroyed one house and damaged several others, and injured five persons. The Safety Board's investigation determined that rock impingement generated stress intensification that resulted in a crack in a plastic pipe. Available documentation indicates that the crack was brittle-like.

One woman was killed and her 9-month-old daughter injured in a December 1983 natural gas explosion and fire in Texas.<sup>12</sup> The Safety Board's investigation determined that the source of the gas leak was a brittle-like crack that had resulted from damage to the plastic pipe during an earlier squeezing operation to control gas flow.<sup>13</sup>

A September 1984 natural gas explosion in Arizona resulted in five fatalities, seven injuries, and two destroyed apartments.<sup>14</sup> The Safety Board's investigation determined that a reaction between a segment of plastic pipe and some liquid trapped in the pipe weakened the pipe and led to a brittle-like crack.

Excavations following the Waterloo, Iowa, accident uncovered, at a depth of about 3 feet, a 4-inch steel main.<sup>15</sup> Welded to the top of the main was a steel tapping tee. Connected to the steel tee was a 1/2-inch plastic service pipe. Markings on the plastic pipe indicated that it was a medium-density polyethylene material manufactured on June 11, 1970, in accordance with American Society for Testing and Materials (ASTM) standard D2513. The pipe had been marketed by Century Utility Products, Inc. (Century). The plastic pipe was found cracked at the end of the tee's internal stiffener and beyond the coupling nut.

The investigation determined that much of the top portion of the circumference of the pipe immediately outside the tee's internal stiffener displayed several brittle-like slow crack initiation and growth fracture sites. These slow crack fractures propagated on almost parallel planes slightly offset from each other through the wall of the pipe. As the slow cracks from different planes continued to grow and began to overlap one another, ductile tearing occurred

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<sup>10</sup>National Transportation Safety Board Pipeline Accident Brief--"Pacific Gas and Electric Company, San Andreas, California, July 8, 1982."

<sup>11</sup>National Transportation Safety Board Pipeline Accident Brief--"Northern States Power Company, Newport, Minnesota, September 19, 1983."

<sup>12</sup>National Transportation Safety Board Pipeline Accident Brief--"Lone Star Gas Company, Terrell, Texas, December 9, 1983."

<sup>13</sup>Plastic pipe is sometimes squeezed to control the flow of gas. In some cases, squeezing plastic pipe can damage it and make it more susceptible to brittle-like cracking.

<sup>14</sup>National Transportation Safety Board Pipeline Accident Report--*Arizona Public Service Company Natural Gas Explosion and Fire, Phoenix, Arizona, September 25, 1984* (NTSB/PAR-85/01).

<sup>15</sup>For more information, see Pipeline Accident Brief in appendix to National Transportation Safety Board Pipeline Special Investigation Report--*Brittle-like Cracking in Plastic Pipe for Gas Service*.

between the planes. Substantial deformation was observed in part of the fracture; however, the initiating cracks were still classified as brittle-like.

Samples recovered from the plastic service line underwent several laboratory tests under the supervision of the Safety Board. Two of these tests were meant to roughly gauge the pipe's susceptibility to brittle-like cracking. These tests were a compressed ring environmental stress crack resistance (ESCR) test in accordance with ASTM F1248 and a notch tensile test known as a PENT test that is now ASTM F1473. Lower failure times in these tests indicate a greater susceptibility to brittle-like cracking under the test conditions. The ESCR testing of 10 samples from the pipe yielded a mean failure time of 1.5 hours, and the PENT testing of 2 samples yielded failure times of 0.6 and 0.7 hours. Test values this low have been associated with materials having poor performance histories<sup>16</sup> characterized by high leakage rates at points of stress intensification due to crack initiation and slow crack growth typical of brittle-like cracking. The Safety Board has investigated two other pipelines accidents, one in Nebraska in 1978 and one in Minnesota in 1983, that involved Century piping. The Safety Board is also aware of four other accidents that it did not investigate that involved the same brand of piping.

The Century pipe involved in the Waterloo accident was made from Union Carbide's DHDA 2077 Tan resin. Although Union Carbide's laboratory data supported Union Carbide's claimed strength, the Safety Board's review of the same data showed that the material had an early ductile-to-brittle transition, indicating poor resistance to brittle-like fractures.

In the early 1970s, a Minnesota gas system operator tested a number of piping products made from DHDA 2077 Tan resin, including those marketed by Century, as part of its comprehensive specification, testing, and evaluation program. The company rejected piping made from the Union Carbide product for use in its system based on the results of sustained pressure tests. Union Carbide, in 1971, acknowledged that its DHDA 2077 Tan resin material had a lower pressure rating at 100 °F than did DuPont's polyethylene pipe material.

Midwest Gas, the Waterloo, Iowa, gas operator at the time of the explosion and fire, had experienced at least three other significant failures involving Century pipe. The most recent failures, occurring between 1992 and 1994, prompted the company to collect samples of the Century material for independent laboratory testing. Samples were being gathered for testing at the time of the Waterloo accident. The subsequent laboratory report indicated that the Century piping had poor resistance to slow crack growth.

Midwest Gas's subsequent analysis of the company's leakage history concluded that its installations with Century piping had failure rates significantly higher than those with piping

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<sup>16</sup>Uralil, F. S., et al., *The Development of Improved Plastic Piping Materials and Systems for Fuel Gas Distribution—Effects of Loads on the Structural and Fracture Behavior of Polyolefin Gas Piping*, Gas Research Institute Topical Report, 1/75 - 6/80, NTIS No. PB82-180654, GRI Report No. 80/0045, 1981; Hulbert, L. E., Cassady, M. J., Leis, B. N., Skidmore, A., *Field Failure Reference Catalog for Polyethylene Gas Piping, Addendum No. 1*, Gas Research Institute Report No. 84/0235 2, 1989; and Brown, N. and Lu, X., "Controlling the Quality of PE Gas Piping Systems by Controlling the Quality of the Resin," *Proceedings, Thirteenth International Plastic Fuel Gas Pipe Symposium*, pp. 327-338, American Gas Association, Gas Research Institute, Battelle Columbus Laboratories, 1993

from other manufacturers. Midwest Gas had received warnings from two pipe fitting manufacturers against use of their products with Century pipe because of Century pipe's susceptibility to brittle-like cracking. The current operating company in the Waterloo, Iowa, area, MidAmerican Energy, has, since the accident, replaced all the identified Century piping in its gas pipeline system.

The Safety Board concluded that plastic pipe extruded by Century Utility Products, Inc., and made from Union Carbide's DHDA 2077 Tan resin has poor resistance to brittle-like cracking under stress intensification, and this characteristic contributed to the Waterloo, Iowa, accident.

While Century piping has been identified specifically as being subject to brittle-like cracking (slow crack growth), evidence suggests that much of the early polyethylene piping may be more susceptible to such cracking than originally thought and thus may also be subject to premature failure.

The procedure used in the United States to rate the strength of plastic pipe, which was developed in the early 1960s, involved subjecting test piping to different stress values and recording how much time elapsed before the piping ruptured. The stress rupture data of the samples were then plotted, and a best-fit straight line was derived to represent the material's decline in rupture resistance as its time under stress increased.

To meet the requirements of the procedure, at least one tested sample had to be able to withstand stress rupture testing until at least 10,000 hours, or slightly more than 1 year. The straight line that was plotted to describe the data for this material was extrapolated out by a factor of 10, to 100,000 hours (about 11 years). The point at which the sloping straight line intersected the 100,000-hour point indicated the appropriate hydrostatic design basis for this material.

A key assumption characterized the assignment of a hydrostatic design basis under the procedure: The procedure assumed that the gradual decline in the strength of plastic piping material as it was subjected to stress over time would continue to be described by a straight line. In the early 1960s, the industry had little long-term experience with plastic piping, and a straight line seemed to represent the response of the material to laboratory stress testing. With little other information on which to base strength estimations, the straight-line assumption appeared valid. This procedure and assumption for rating the strength were incorporated into industry and government requirements.

As experience grew with plastic piping materials and as better testing methods were developed, however, the straight-line assumptions of the procedure came to be challenged. Elevated-temperature testing indicated that polyethylene piping can exhibit a decline in strength that does not follow the straight-line assumption, but instead shows a downturn. The difference between the actual (falloff) and projected (straight line) strengths became even more pronounced as the lines were extrapolated beyond 100,000 hours.

The combination of more durable modern plastic piping materials and more realistic strength testing has rendered the strength ratings of modern plastic piping much more reliable.

Unfortunately, much of the early plastic piping was sold and installed with expectations of strength and long-term performance that, because they were based on questionable assumptions about long-term performance, may not have been valid. This is borne out by data from a variety of sources. The history of strength rating requirements, a review of the piping properties and literature, and observations of several experts with extensive experience in plastic piping, all suggest that much of the polyethylene pipe, depending upon the brands, manufactured from the 1960s through the early 1980s fails at lower stresses and after less time than originally projected. *The Safety Board therefore concluded that the procedure used in the United States to rate the strength of plastic pipe may have overrated the strength and resistance to brittle-like cracking of much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s.*

Another important assumption of the design protocol for plastic pipe involved the ductility of the materials. It was assumed, based on short-term tests, that plastic piping had long-term ductile properties. Ductile material, by bending, expanding, or flexing, can redistribute stress concentrations better than can brittle material, such as cast iron. Notable from results of tests performed under the strength-rating procedure was that those short-term stress ruptures in the testing process tended to be characterized by substantial material deformation in the area of the rupture. This deformation described a material with obvious ductile properties. However, it was shown that, as time-to-failure increased in stress rupture tests, failures in several materials occurred as slit failures that, because they were not accompanied by substantial deformation, were more typical of brittle-like failures. These slit or brittle-like failures were characterized by crack initiation and slow crack growth. The procedure used to rate the strength of plastic pipe did not distinguish between ductile fractures and slit fractures and assumed that both types of failures would be described by the same straight line.

The assumption of ductility of plastic piping had important safety ramifications. For example, a number of experts believed it was safe to design plastic piping installations based on stresses primarily generated by internal pressure and to give less consideration to stress intensification generated by external loading. Ductile material reduces stress intensification by localized yielding, or deformation.

As noted previously, laboratory data supported the strength rating assigned to DHDA 2077 Tan resin by the process used at the time to rate strength; nevertheless, the material showed evidence of early ductile-to-brittle transition. The fact that the process used to measure the long-term durability of piping materials did not reveal the susceptibility to premature brittle-like cracking of the DHDA 2077 Tan material highlights the weaknesses of the process in use at the time. More significantly, it calls into question the durability of other early materials that were rated using the same process and that remain in service today. This concern is heightened by the fact that, in addition to the Waterloo accident involving Century pipe and DHDA 2077 Tan resin, other accidents investigated or documented by the Safety Board have demonstrated that brittle-like cracking occurs in other older plastic piping as well.

All available evidence indicates that polyethylene piping's resistance to brittle-like cracking has improved significantly through the years. Several experts in gas distribution plastic

pipings have told the Safety Board that a majority of the polyethylene piping manufactured in the 1960s and early 1970s had poor resistance to brittle-like cracking, while only a minority of that manufactured by the early 1980s could be so characterized.<sup>17</sup> Several gas system operators have told the Safety Board that they are aware of no instances of brittle-like cracking with their own modern polyethylene piping installations.

Premature brittle cracking in plastic piping is a complex phenomenon. Without clear and straightforward communication to pipeline operators about brands of piping and conditions that increase the likelihood of brittle cracking, many pipeline operators may not have the knowledge to make good decisions affecting public safety. Some of these key decisions include how often to conduct leak surveys and whether to repair or replace portions of pipeline systems.

Frequently, piping manufacturers, because they can receive feedback from a number of customers, are the first to learn of systemic problems with their products. For small operators, contact with a manufacturer may be the major source of outside communication about poorly performing products. Unfortunately, while manufacturers have a high degree of technical expertise regarding their products, they may also tend to aggressively publicize the best performance characteristics of their products while only reluctantly acknowledging weaknesses. The Safety Board is aware of only a very few cases in which manufacturers of resin or pipe have formally notified the gas industry of materials having poor resistance to brittle cracking.

Thus, although reputable manufacturers commonly provide essential technical assistance and serve as partners to pipeline operators, operators are still responsible for evaluating and determining which products are most likely to maintain the integrity of their pipeline systems. Furthermore, perhaps because the possibility of premature failure of plastic piping due to brittle-like cracking has not been fully appreciated within the industry and the scope of the potential problem has not been fully measured, the Federal Government has not provided information on this issue to gas system operators. The Safety Board concluded that gas pipeline operators have had insufficient notification that much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s may be susceptible to brittle-like cracking and therefore may not have implemented adequate pipeline surveillance and replacement programs for their older piping.

In the view of the Safety Board, manufacturers of resin and pipe should do more to notify pipeline operators about the poor brittle-crack resistance of some of their past products. The Plastics Pipe Institute (PPI) is the manufacturers' organization that covers most of the major resin and pipe producers, many of whom have manufactured resin and pipe for several years. The Safety Board therefore recommended that the PPI advise its members to notify pipeline system operators if any of their piping products, or materials used in the manufacture of piping products, currently in service for natural gas or other hazardous materials indicate poor resistance to brittle-like failure.

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<sup>17</sup>A number of these experts considered material to have poor resistance to brittle-like cracking if the material was shown to have brittle-like fractures in stress rupture testing at 73 °F before 100,000 hours.

Based on evidence examined by the Safety Board, the premature transition of plastic piping from ductile failures to brittle failures appears to have little observable adverse impact on the serviceability of plastic piping except in those instances in which undamaged piping is subjected to stress intensification generated by external forces. Unfortunately, stress intensification, which can take many forms, has been found in a number of gas piping systems. Rock impingement, soil settlement, and excess pipe bending are among the potential sources of stress intensification, and the combination of piping with poor resistance to brittle-like cracking and external forces can lead to significant rates of failures. These failures can, in turn, lead to serious accidents. The Safety Board therefore concluded that much of the plastic pipe manufactured and used for gas service from the 1960s through the early 1980s may be susceptible to premature brittle-like failures when subjected to stress intensification, and these failures represent a potential public safety hazard.

Examples of conditions that can generate stress intensification include differential earth settlement, particularly at connections with more rigidly anchored fittings; excessive bending as a result of installation configurations, especially at fittings; and point contact with rocks or other objects. The Safety Board special investigation determined that much of the available guidance to gas system operators for limiting stress intensification at plastic pipeline connections to steel mains is inadequate or ambiguous. Based on its review of this guidance and on the history of the plastic pipeline accidents it has investigated, the Safety Board concluded that, because guidance covering the installation of plastic piping is inadequate for limiting stress intensification at plastic service connections to steel mains, many of these connections may have been installed without adequate protection from shear and bending forces.

Subsequent to the Waterloo accident, personnel from the Iowa Department of Commerce, after discussions with OPS personnel, stated that the Waterloo installation was not in violation of 49 CFR 192.361, which specifies minimum pipeline safety standards for the installation of gas service piping. They further stated that, while they agree that the installation of protective sleeves at pipeline connections is prudent, a specific requirement to install protective sleeves is beyond the scope of Part 192 and is inconsistent with the regulation's performance orientation.

The Transportation Safety Institute (TSI) conducts training classes for Federal and State pipeline inspectors. TSI instructors advise class participants that many of the performance-oriented regulations within Part 192 can only be found to be violated if the gas system fails in a way that demonstrates that the regulation was not followed. The TSI acknowledges the difficulty of identifying violations under paragraph 192.361(d). A TSI instructor told the Safety Board that, in the case of the failed pipe at Waterloo, the installation could not be faulted under Part 192 because of the length of time (23 years) between the installation date and the failure date.

RSPA acknowledges that the regulation that requires gas service lines to be installed so as to minimize anticipated piping strain and external loading lacks performance measurement criteria. The Safety Board pointed out in a previous accident investigation report<sup>18</sup> that, although

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<sup>18</sup>National Transportation Safety Board Pipeline Accident Report, *Kansas Power and Light Company Natural Gas Pipeline Accidents, September 16, 1988 to March 29, 1989* (NTSB/PAR-90/03).

the OPS considers many of its pipeline safety regulations to be performance-oriented requirements, many are no more than general statements of required actions that do not establish any criteria against which the adequacy of the actions taken can be evaluated. The Safety Board has further stated that regulations that do not contain measurable standards for performance make it difficult to determine compliance with the requirement. The Safety Board therefore previously recommended that RSPA:

Evaluate each of its pipeline safety regulations to identify those that do not contain explicit objectives and criteria against which accomplishment of the objective can be measured; to the extent practical, revise those that are so identified. (P-90-15)

As a result of this safety recommendation, the OPS asked the National Association of Pipeline Safety Representatives liaison committee to review the 20 regulations deemed to be the least enforceable due to lack of clarity. The Safety Board has encouraged RSPA to make such a review a periodic effort so that all of the regulations, not just the specified 20, are continually clarified. The last correspondence to the Safety Board from the OPS regarding this recommendation was on March 8, 1993, and the recommendation has remained classified "Open—Acceptable Response." In an October 31, 1997, letter to the OPS, the Safety Board inquired as to the status of 28 open safety recommendations to RSPA, including P-90-15. The OPS has not yet provided a written response for P-90-15. The Safety Board will continue to follow the progress and urge completion of this recommendation.

Federal regulations require that gas pipeline system operators have in place an ongoing program to monitor the performance of their piping systems. Before the Waterloo accident, Midwest Gas developed only a limited capability for monitoring and analyzing the condition of its gas system. For example, the company did not statistically correlate failure rates to the amounts of installed pipe or components provided by specific manufacturers. The design of the program meant that the relatively few areas with high failure rates (for example, those with Century pipe) were aggregated with and therefore masked by the large number of plastic piping installations that had low failure rates. Thus, the Midwest Gas surveillance program did not reveal the high failure rates associated with Century pipe. Only after the accident did Midwest Gas identify the Century pipe within its pipeline system as having high failure rates, even though the company could have collected and processed the same type of data and reached the same determination before the accident. If Midwest Gas had further correlated its data to years of installation, it may have also been able to examine the effects of its changing installation methods or changes in performance with different manufacturers through the years.

The Safety Board concluded that, before the Waterloo accident, the systems used by Midwest Gas Company for tracking, identifying, and statistically characterizing plastic piping failures did not permit an effective analysis of system failures and leakage history. The Safety Board further concluded that if, before the Waterloo accident, Midwest Gas had had an effective surveillance program that tracked and identified the high leakage rates associated with Century piping when subjected to stress intensification, the company could have implemented a

replacement program for the pipe and may have replaced the failed service connection before the accident.

Since the accident, MidAmerican Energy has revised its systems, adding parameters to provide the company with added capability to sort failures. However, MidAmerican Energy has not chosen parameters that will allow an adequate analysis of its plastic piping system failures and leakage history. For example, the generic "improper installation" is a parameter to be linked to leaks; however, no parameters have been added for the presence, lack, improper design, or improper placement of a protective sleeve. And no parameters have been added to link leaks to squeeze locations, improper joining, or items to differentiate between insufficient support and excessive installed bending. The Safety Board therefore concluded that MidAmerican Energy's current systems for tracking, identifying, and statistically characterizing plastic piping failures do not enable an effective analysis of system failures and leakage history.

In a previous accident investigation report,<sup>19</sup> the Safety Board pointed out that many operators had not established procedures to comply with Federal regulations requiring surveillance and investigation of failures. The Safety Board recommended that RSPA:

Emphasize, as a part of OPS inspections and during training and state monitoring programs, the actions expected of gas operators to comply with the continuing surveillance and failure investigation, including laboratory examination requirements. (P-90-14)

In a letter to the Safety Board, RSPA responded that the TSI had increased emphasis on gas surveillance and failure investigation in the operations block of its industry seminars held across the country. The letter stated that the TSI would incorporate a discussion of accident analysis into a new hazardous liquids seminar that was to be presented for the first time in FY 1992. Additionally, RSPA noted that it planned to place additional emphasis on continuing surveillance and failure investigation requirements in its new inspection forms at the time of the next revision. Based on this response, the Safety Board classified Safety Recommendation P-90-14 "Closed—Acceptable Action."

Despite the RSPA response to this safety recommendation, for a variety of reasons—including the inadequate performance monitoring programs found at Midwest Gas/MidAmerican Energy, the susceptibility to brittle cracking of much of the polyethylene piping installed through the early 1980s, deficiencies noted in gas industry communications regarding poorly performing brands of polyethylene piping, and differences noted in the performance of different types and brands of polyethylene piping—RSPA may need to do more. Gas system operators may need to be advised once again of the importance of complying with Federal requirements for piping system surveillance and analyses. As is the case with older piping, an effective plastic pipeline surveillance program would be based on factors such as piping manufacturer, installation date, pipe diameter, operating pressure, leak history, geographical location, modes of failure (such as bending,

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<sup>19</sup>National Transportation Safety Board Pipeline Accident Report--*Kansas Power and Light Company Natural Gas Pipeline Accidents, September 16, 1988, to March 29, 1989.*

inadequate support, rock impingement, or improper joining), location of failure (such as at the main to service or at pipe squeeze locations), and other factors such as the presence, absence, or misapplication of a sleeve. An effective program would also evaluate past piping and components installed, as well as past installation practices, to provide a basis for the replacement, in a planned, timely manner, of plastic piping systems that indicate unacceptable performance.

The expressed purpose of RSPA's *Guidance Manual for Operators of Small Natural Gas Systems* is to assist nontechnically trained persons who operate small gas systems. However, the manual provides no caution against bending close to a plastic service connection to a steel main. The manual recommends following manufacturers' instructions and indicates that a properly designed sleeve should be used at this connection, which would address designing the sleeve with the proper diameter and length. However, none of the steel tapping tee manufacturers has recommended precautions to limit stresses at the service to main connection; therefore, nontechnically trained persons may not realize the importance of determining these parameters.

The National Transportation Safety Board therefore makes the following safety recommendations to the Research and Special Programs Administration:

Notify pipeline system operators who have installed polyethylene gas piping extruded by Century Utility Products, Inc., from Union Carbide Corporation DHDA 2077 Tan resin of the piping's poor brittle-crack resistance. Require these operators to develop a plan to closely monitor the performance of this piping and to identify and replace, in a timely manner, any of the piping that indicates poor performance based on such evaluation factors as installation, operating, and environmental conditions; piping failure characteristics; and leak history. (P-98-1)

Determine the extent of the susceptibility to premature brittle-like cracking of older plastic piping (beyond that piping marketed by Century Utility Products, Inc.) that remains in use for gas service nationwide. Inform gas system operators of the findings and require them to closely monitor the performance of the older plastic piping and to identify and replace, in a timely manner, any of the piping that indicates poor performance based on such evaluation factors as installation, operating, and environmental conditions; piping failure characteristics; and leak history. (P-98-2)

Immediately notify those States and territories with gas pipeline safety programs of the susceptibility to premature brittle-like cracking of much of the plastic piping manufactured from the 1960s through the early 1980s and of the actions that the Research and Special Programs Administration will require of gas system operators to monitor and replace piping that indicates unacceptable performance. (P-98-3)

In cooperation with the manufacturers of products used in the transportation of gases or liquids regulated by the Office of Pipeline Safety, develop a mechanism by which the Office of Pipeline Safety will receive copies of all safety-related notices, bulletins, and other communications regarding any defect, unintended

deviation from design specification, or failure to meet expected performance of any piping or piping product that is now in use or that may be expected to be in use for the transport of hazardous materials. (P-98-4)

Revise the *Guidance Manual for Operators of Small Natural Gas Systems* to include more complete guidance for the proper installation of plastic service pipe connections to steel mains. The guidance should address pipe bending limits and should emphasize that a protective sleeve, in order to be effective, must be of the proper length and inner diameter for the particular connection and must be positioned properly. (P-98-5)

Also, the National Transportation Safety Board issued Safety Recommendations P-98-6 to the Gas Research Institute; P-98-7 through -9 to the Plastics Pipe Institute; P-98-10 to the Gas Piping Technology Committee; P-98-11 and -12 to the American Society for Testing and Materials; P-98-13 to the American Gas Association; P-98-14 and -15 to MidAmerican Energy Corporation; P-98-16 and -17 to Continental Industries, Inc.; P-98-18 to Dresser Industries, Inc.; P-98-19 to Inner-Tite Corporation; and P-98-20 to Mueller Company.

Please refer to Safety Recommendations P-98-1 through -5 in your reply. If you need additional information, you may call (202) 314-6469

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By:



Jim Hall  
Chairman