National Transportation Safety Board

Washington, D.C. 20594

Pipeline Accident Brief

Pipeline Accident Number:	DCA-95-MP-001
Type of System:	Gas distribution
Accident Type:	Explosion and Fire
Location:	Waterloo, Iowa
Date and Time:	October 17, 1994; 10:07 a.m. local
Owner/Operator:	Midwest Gas Company[1]
Fatalities/Injuries:	Six fatalities and seven non-fatal injuries
Damage:	$250,000
Material Released:	Natural Gas
Pipeline Pressure:	25 pounds per square inch, gauge (psig)
Component Affected:	1/2-inch plastic pipe at steel tapping tee mechanical compression connection to steel main

The Accident

At 10:07 a.m. central daylight savings time on Monday, October 17, 1994, a natural gas explosion and fire destroyed a one-story, wood frame building in Waterloo, Iowa. The force of the explosion scattered debris over a 200-foot radius.

Six persons inside the building died, and one person sustained serious injuries. Three persons working in an adjacent building sustained minor injuries when a wall of the building collapsed inward from the force of the explosion. The explosion also damaged nine parked cars. A person in a vehicle who had just exited the adjacent building suffered minor injuries. Additionally, two firefighters sustained minor injuries during the emergency response. Two other nearby buildings also sustained structural damage and broken windows.

Site Information

The destroyed building was a neighborhood tavern known as Buzz's Bar. Adjacent to and east of the bar was Woodland Pattern Company, which was provided gas service by a 1/2-inch-diameter plastic polyethylene service pipeline. The service pipeline was installed by Iowa Public Service Company on September 3, 1971, and was operated at a maximum pressure of 25 psig.

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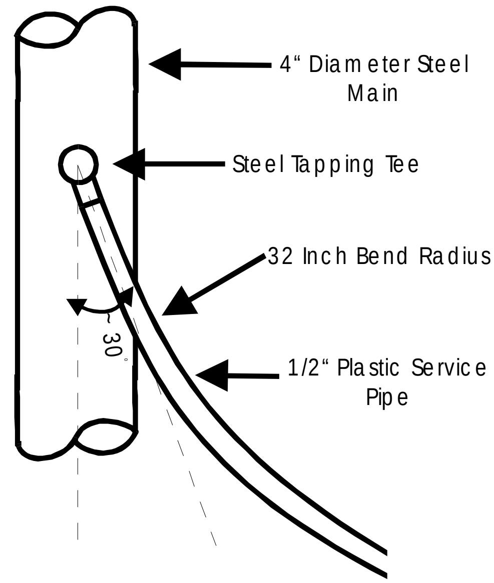
[1]Because of a series of organizational changes and mergers, the name of the owner/operator of the gas system at Waterloo, Iowa, has changed over the years. In 1971, Iowa Public Service Company installed the gas service that ultimately failed. At the time of the accident, the gas system operator was known as Midwest Gas Company, while the current operator's name is MidAmerican Energy Corporation.

The underground pipeline connected with the steel gas main and entered the Woodland Pattern Company building between Buzz's Bar and the Woodland Pattern Company.

The area between Buzz's Bar and Woodland Pattern Company was unpaved and, according to those familiar with the location, was regularly used by beer trucks making deliveries to Buzz's Bar and by semitrailers delivering materials to Woodland Pattern Company. These trucks had been seen to drive over the area of the piping assembly that cracked. At various times, beer trucks servicing Buzz's Bar had been observed to park directly over the location of the pipe break. One witness stated that a beer delivery truck had been parked over the area of the pipe break at approximately 7:00 a.m. on the day of the accident.



Service-to-main connection at site of Waterloo accident.

Excavations following the accident uncovered a 4-inch-diameter steel main at a depth of about 3 feet. Welded to the top of the main was a steel tapping tee with markings indicating that the tee had been manufactured by Continental Industries, Inc. (Continental). Connected to the steel tee was a 1/2-inch-diameter plastic service pipe leading to Woodland Pattern Company. 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, and marketed by Century Utility Products, Inc. (Century). A circumferential crack through the plastic pipe was found at the tip of the tee's internal stiffener that protruded beyond the tee's coupling nut. A 1- to 2-foot-diameter "hard ball" surrounded the cracked pipe.[2]

Because Safety Board investigators did not arrive at the accident site until after excavation of the failed pipe, investigators had to consult several sources to determine the condition of the piping at the time of excavation. Photographs of the excavation, a Waterloo Fire Department video tape, and several witnesses all indicated that the downstream portion of the plastic pipe was found broken off and vertically displaced below the plastic pipe portion still attached to the steel tee. However, an Iowa State Fire Marshall's Office investigator, who directed and participated in the excavation, reported that the pipe was displaced by the excavation activities. That investigator also reported no observed voids in the soil under the failed assembly.

Service-to-main connection at site of Waterloo accident.

MidAmerican Energy estimated that the steel tee on the steel main was installed so that the polyethylene pipe exited the tee at an approximate 30° angle to the steel main. (See figure.)

[2]A "hard ball" is a term used in the gas industry for a soil condition where leaking natural gas over a period of time dries and hardens the soil adjacent to the leak.

The plastic service pipe leaving the tee immediately curved horizontally. After a portion of the pipe was taken to the laboratory for testing, the bend radius was measured at about 34 inches. Based on field conditions and photos, MidAmerican Energy has estimated the original installed horizontal bend radius to be approximately 32 inches.[3] This bend is sharper than currently recommended by industry guidelines for modern piping adjacent to fittings. However, a former Iowa Public Service Company employee stated that Iowa Public Service Company, in an effort to reduce the stress at the connection point, often attempted to install polyethylene services at an angle to the main to match the residual bend left after uncoiling the pipe.[4] This former employee stated that no set time was prescribed to allow for complete relaxing of the pipe, but that the pipe would be placed in the ditch, and the crews would weld the tee at what they judged to be the appropriate angle, in consideration of the natural bend of the pipe.

Also immediately from the tee outlet, the polyethylene bent downward. The tee outlet did not have a protective sleeve to reduce shear and bending forces at the connection.

Tests and Examination

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 greater susceptibility to brittle-like cracking under 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[5] characterized by high leakage rates at points of stress intensification due to crack initiation and slow crack growth typical of brittle-like cracking.

To facilitate identification, the fracture surfaces were divided into two regions, A and B, around the circumference of the failed pipe. If a cross section of the pipe, looking toward the tee, were superimposed on a clock face, region A would extend from approximately the 9:00 position up across the top and down to about 1:30, with the center of the region at about 11:15. Region B took up the remainder of the pipe surface, extending from about the 1:30 position down across the bottom and up to 9:00.

[3]Polyethylene pipe installed with a bend often, over time, permanently deforms in the direction of the bend. This permanent deformation partially reduces the stresses generated by the bending forces. When the pipe is released from its installation configuration, the pipe can straighten to some extent.

[4]MidAmerican Energy has indicated that Iowa Public Service's plastic service pipe was received in coils from Century. After uncoiling the pipe, some residual bending remains. The amount of residual bending depends on the factory coiling conditions.

[5]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, and 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.

The fracture in region A was located immediately outside the tee's internal stiffener. The crack was perpendicular to the pipe wall and directly in line with the end of the tee's internal stiffener. The inside surface of the pipe throughout region A was characterized by a circumferential impression from the tip of the tee's stiffener. A similar impression was not found in region B. This impression was only found on the pipe segment that was still attached to the steel tee, and was not evident on any part of the pipe segment that was detached from the steel tee. Region A was characterized by several brittle-like slow crack growth fractures, each of which initiated on or near the pipe inner wall just outside the depression associated with the tip of the tapping tee's stiffener. These slow crack fractures propagated on almost parallel planes slightly offset from each other through the wall of the pipe. As the cracks from different planes continued to grow and began to overlap one another, ductile tearing occurred between the planes, which produced a jagged appearance in parts of the overall circumferential crack in region A Thus, even though substantial deformation was observed in part of the fracture, the initiating cracks were still classified as brittle-like.

Region B contained two brittle-like crack growth sections that initiated from each end of region A. Cracks from each end of region A propagated through region B on approximate 45° planes towards the tee (partially exposing the tee's stiffener) and met at the bottom (the 6:00 position). The remaining ligament tore with visible deformation at the bottom.

Laboratory comparisons showed that the fractures that initiated and grew in region A were consistent with fractures generated by long-term shear and bending forces at the end of the stiffener. The fractures in region B were consistent with a continuation of the same loading system described for region A but occurred subsequent to those in region A. The last ligament that fractured at the 6:00 position in region B was consistent with ductile tearing. Examination could not determine whether the last remaining ligament tore because of concentrated stresses prior to the excavation or because of excavation activities after the accident.

Other Information

Flooding was reported in the area during the summer of 1993. Midwest Gas's most recent leak surveys, performed in March 1994, did not detect a leak in this area. Records of odorant tests performed in September 1994 and on October 17, 1994 (two and a half hours after the accident), show odorant levels that met the level required by Federal standards.[6]

Probable Cause

The National Transportation Safety Board determines that the probable cause of the natural gas explosion and fire in Waterloo, Iowa, was stress intensification, primarily generated by soil settlement at a connection to a steel main, on a 1/2-inch polyethylene pipe that had poor resistance to brittle-like cracking.

Adopted April 23, 1998

For additional information regarding this accident, see NTSB special investigation report *Brittle-Like Cracking in Plastic Pipe for Gas Service*, NTSB/SIR-98/01.

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[6]Federal standards require the odorant in natural gas systems to be detectable at one-fifth of the lower explosive limit, which is typically at gas/air concentrations of 0.9 to 1.0 percent and above.