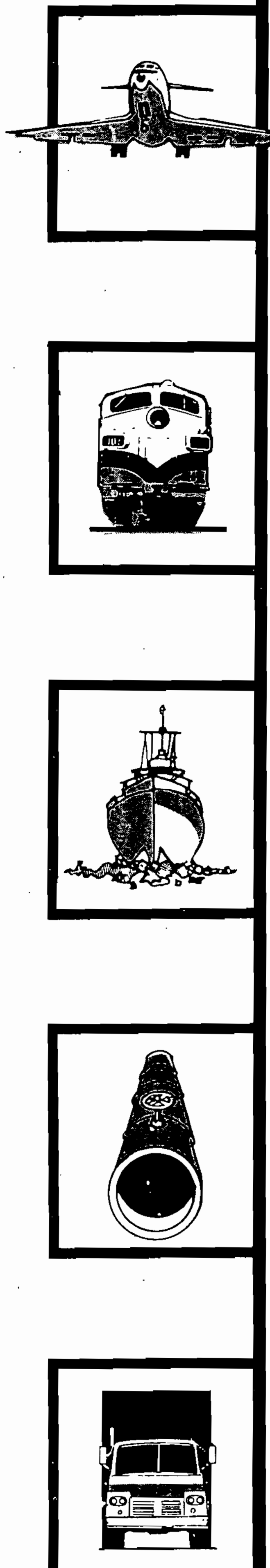

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

PIPELINE ACCIDENT REPORT

NEBRASKA NATURAL GAS COMPANY PATHFINDER HOTEL EXPLOSION AND FIRE

FREMONT, NEBRASKA

JANUARY 10, 1976

REPORT NUMBER: NTSB-PAR-76-6

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB-PAR-76-6	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Pipeline Accident Report - Nebraska Natural Gas Company, Pathfinder Hotel Explosion and Fire, Fremont, Nebraska, January 10, 1976		5. Report Date July 7, 1976
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Surface Transportation Safety Washington, D. C. 20594		10. Work Unit No. 1741-A
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594		13. Type of Report and Period Covered Pipeline Accident Report January 10, 1976
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

At 9:32 a.m. on January 10, 1976, gas which was leaking into the Pathfinder Hotel in Fremont, Nebraska, ignited. The gas was leaking from a 2-inch plastic pipe which had pulled out of its compression coupling; the gas seeped into the hotel because it had been capped above by frozen earth and a concrete road surface. The hotel exploded and fire ensued; the explosion and fire destroyed the hotel, damaged nearby buildings, and broke windows within a one-block radius. Thirty-nine persons were injured and 20 persons were killed.

The National Transportation Safety Board determines that the probable cause of the accident was the contraction, due to cold temperatures, of a 2-inch polyethylene plastic main within a 4-inch casing. The contraction of the plastic main caused the pipe to pull out of the inadequately connected compression coupling.

As a result of its investigation of the accident, the National Transportation Safety Board made recommendations to the Nebraska Natural Gas Company, the Department of Transportation, and the City of Fremont.

17. Key Words Thermal contraction; polyethylene plastic pipe; compression couplings; main insertions; transition fittings; system design inadequacy; pullout; emergency plans.		18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22151.	
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 28	22. Price

NTSB Form 1765.2 (Rev. 9/74)

FOREWORD

This report is based upon an investigation by the National Transportation Safety Board under the authority of the Independent Safety Board Act of 1974. The Office of Pipeline Safety of the Department of Transportation, the Pipeline Safety Division of the Nebraska State Fire Marshal's Office, the Nebraska Natural Gas Company, and the Fire Chief and Fire Marshal of the Fremont Fire Department cooperated in the investigation.

TABLE OF CONTENTS

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D. C. 20594

PIPELINE ACCIDENT REPORT

Adopted: July 7, 1976

NEBRASKA NATURAL GAS COMPANY PATHFINDER HOTEL EXPLOSION AND FIRE FREMONT, NEBRASKA JANUARY 10, 1976

SYNOPSIS

At 9:32 a.m. on January 10, 1976, gas which was leaking into the Pathfinder Hotel in Fremont, Nebraska, ignited. The gas was leaking from a 2-inch plastic pipe which had pulled out of its compressin coupling; the gas seeped into the hotel because it had been capped above by frozen earth and a concrete road surface. The hotel exploded and fire ensued; the explosion and fire destroyed the hotel, damaged nearby buildings, and broke windows within a one-block radius. Thirty-nine persons were injured and 20 persons were killed.

The National Transportation Safety Board determines that the probable cause of the accident was the contraction, due to cold temperatures, of a 2-inch polyethylene plastic main within a 4-inch casing. The contraction of the plastic main caused the pipe to pull out of the inadequately connected compression coupling.

FACTS

The Accident

At 4:50 a.m. on Saturday, January 10, 1976, a man smelled gas as he entered the west vestibule of the Pathfinder Hotel, located at the intersection of 6th and Broad Streets in downtown Fremont, Nebraska. He informed the night desk clerk, who checked the second and third floors for odors but did not detect the smell of gas. The night clerk did not check the west vestibule or the basement. At 6:35 a.m., the day desk clerk arrived at the hotel and also smelled gas; the clerk checked the gas appliances in the kitchen for a leak, but found none.

At 8:02 a.m., an employee of the bakery across the street from the hotel telephoned the gas company to report a strong gas odor which he believed was coming from the alley behind the bakery. A recording at the gas company furnished him with three phone numbers of gas company servicemen who were on call that weekend and informed him that there would be a $10 service charge for weekend calls to repair customer piping. He called the first number and talked to a serviceman, who said that he would investigate the odor. The serviceman arrived at the alley at 8:10 a.m., confirmed the odor of gas, and left for the gas company warehouse to obtain a gas detection instrument. When he arrived at the warehouse, he had difficulty locating the flame ionization (FI) gas leak detection instrument. When he did find it, the instrument would not work; he attempted to fix it, but the necessary replacement parts were not available. He and his supervisor consequently were informed of the possible leak at the hotel and they returned to 6th and Broad Streets.

The day clerk at the hotel began to smell gas in the hotel lobby about 8:12 a.m.; she telephoned the hotel maintenance man and the gas company, where she heard the recording which listed the three available servicemen. She called the first number and the wife of the first serviceman said that her husband was on another call. She called the second number and that serviceman told her that he would respond; he called his supervisor to inform him of the gas odor at the hotel and then he responded to a previously received call from another customer. The supervisor went to the hotel.

The hotel maintenance man arrived at the hotel at 8:25 a.m., entered the basement, and checked the gas boilers. No gas was leaking from the boilers or from the three gas meters. The maintenance man then entered the area under the vaulted sidewalk, on the northwest corner of the hotel, and smelled a strong gas odor. He ran out of the basement and told the desk clerk to call the gas company again; she called the third number, but there was no response because the serviceman was not at home. The maintenance man called the police emergency number to report the strong gas smell, but the police gave him the same gas company number which the desk clerk already had called; the police did not give him any emergency numbers. The maintenance man finally obtained the telephone number of the gas company's district manager and eventually contacted him. The district manager also went to the hotel.

By 9:10 a.m., three gas company supervisors and a serviceman had arrived at the hotel and had begun to check for the gas leak with a combustible gas indicator (CGI). When they inserted the probe of the CGI into an opening on the north foundation wall, under the vaulted sidewalk, the CGI meter indicated 100-percent gas, and they told the maintenance man to evacuate the building immediately. The building exploded at 9:32 a.m., before the occupants could evacuate.

The force of the explosion blew a 6- by 6-foot concrete sidewalk square across the street and through the roof of the bakery. Concrete sidewalk squares also destroyed two automobiles and damaged several others. The explosion shattered windows within a one-block radius.

The explosion gutted the northwest corner of the hotel, and persons who were in that corner on the first and second floors fell into the basement with the rubble. The explosion and the ensuing fire injured 39 persons and killed 20 persons, including three supervisory employees of the gas company. The hotel was destroyed and several nearby buildings were damaged extensively. The source of ignition could not be determined.

Postaccident Activities

The Fremont fire department and fire departments from nearby communities responded to the fire, which began on the northwest corner of the hotel. As the fireman were fighting the blaze, several firemen saw fire burning in the street about 12 feet from the northwest corner of the hotel. The firemen extinguished the fires by early afternoon. (See Figure 1.)

By 11:30 a.m., the gas company had shut off the gas supply to half of Fremont at four district regulator stations. There were 27 valves on the gas mains in Fremont, and the gas company personnel did not know if they could close certain valves to isolate a small area around the hotel. At 2:30 p.m., 5 hours after the explosion, the gas company cut and capped the four gas mains which supplied the intersection of 6th and Broad Streets.

The Nebraska National Guard arrived in Fremont in the afternoon, cordoned off the four blocks around the hotel, and secured the area.

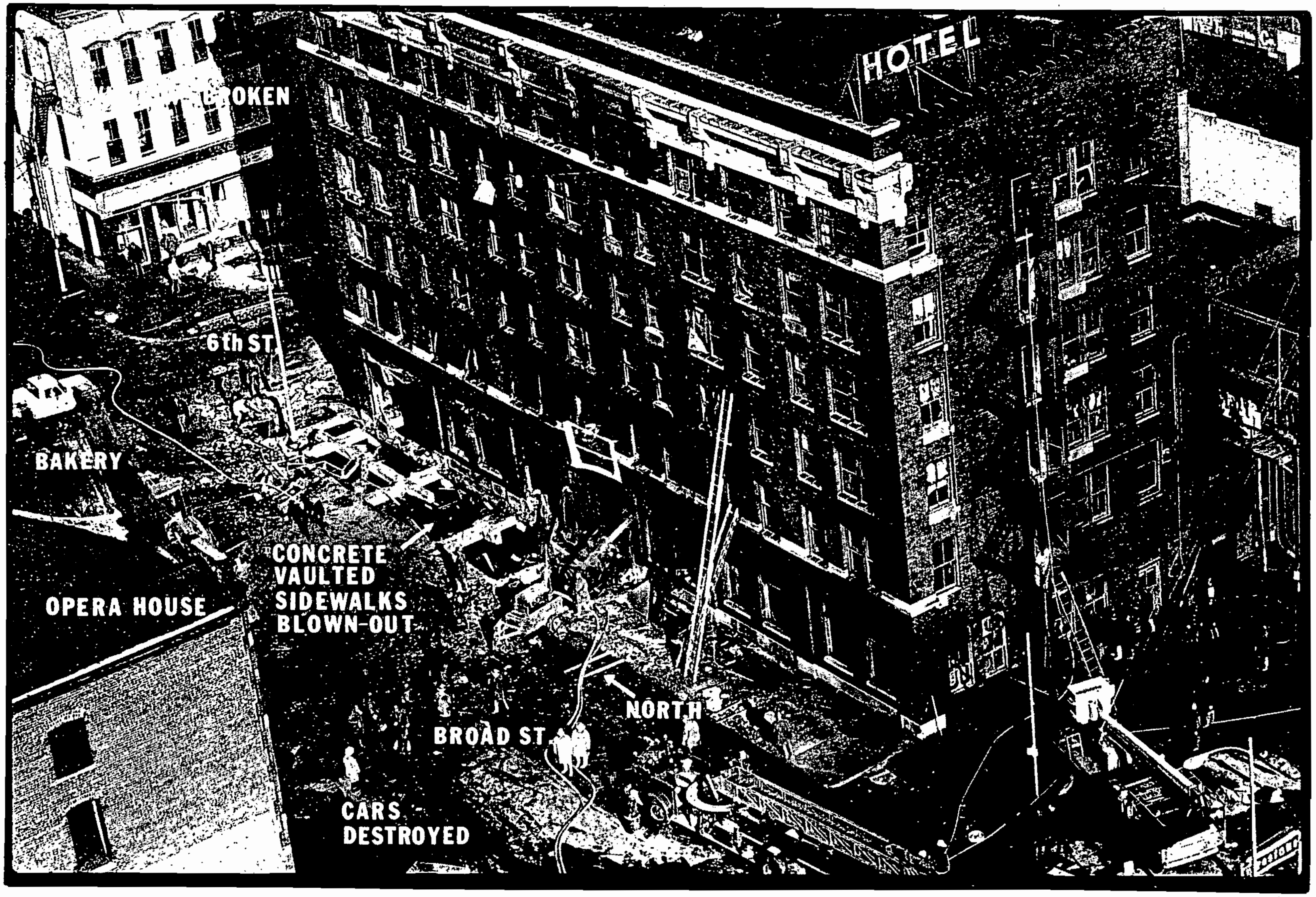

Figure 1. South and West sides of Pathfinder Hotel.

At 10 p.m., a gas check under the intersection of 6th and Broad Streets showed that a gas concentration of 60 to 70 percent was still present. At 10:20 p.m., gas flow was restored to all areas. Gas service was restored to all customers, except to those within the four-block area of the hotel, at 2:30 a.m. on January 11, 1976. The accident had interrupted gas service to 900 persons.

On January 12, the gas company personnel excavated near the northwest corner of the hotel, where firemen had seen fire burning in the street. They found a 2-inch compression coupling on a 2-inch plastic main, about 12 feet from the vaulted sidewalk. The ground was frozen for 33½ inches, but at 45½ inches, they found the soil dry, powdered, and a different color. At 52 inches, they found the plastic main, which had contracted 2 3/8 inches and had pulled out of the compression coupling. They also excavated on the other end of the 2-inch plastic main at 6th and Park Streets, one block east of the hotel. That end of the main had contracted 5/8 inch in the coupling, but no gas was leaking from it because the pipe had not pulled out completely. (See Figure 2.)

The Accident Site

The six-story Pathfinder Hotel was built in 1917 of brick and of reinforced concrete. The hotel was bounded on the south by an alley and on the north and west by a vaulted sidewalk. (See Figure 3.) The basement extended under this sidewalk. The foundation walls of the vaulted sidewalk were constructed of brick and clay tiles instead of concrete because the walls did not bear the weight of the hotel. Brick and clay are pervious to natural gas.

On February 23, 1954, natural gas had seeped through the west wall of the vaulted sidewalk and had ignited. The resulting explosion broke part of the concrete sidewalk at the west entrance, broke windows, and destroyed basement partitions.

On January 9, 1976, two gas company employees conducted a gas leak survey in downtown Fremont. During the survey, they checked the gas main in front of the hotel and they checked the basement foundation wall with an FI detector, but they found no leaks. They also checked the bakery for leaks, but they found none.

PHOTOGRAPHS SHOWING 3" THERMAL CONTRACTION ON BOTH ENDS OF 348' OF 2" POLYETHYLENE PLASTIC INSERTED WITHIN A 4" CASING IN 6TH STREET

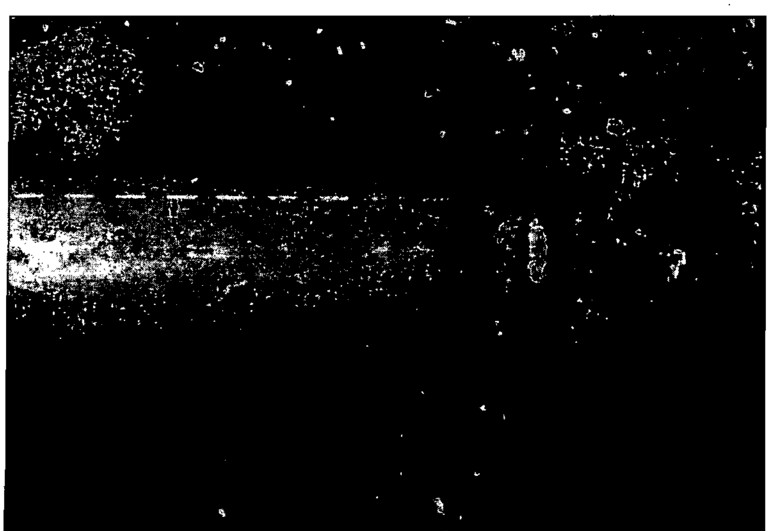

Figure 2. Compression couplings at 6th and Broad Streets and 6th and Park Streets.

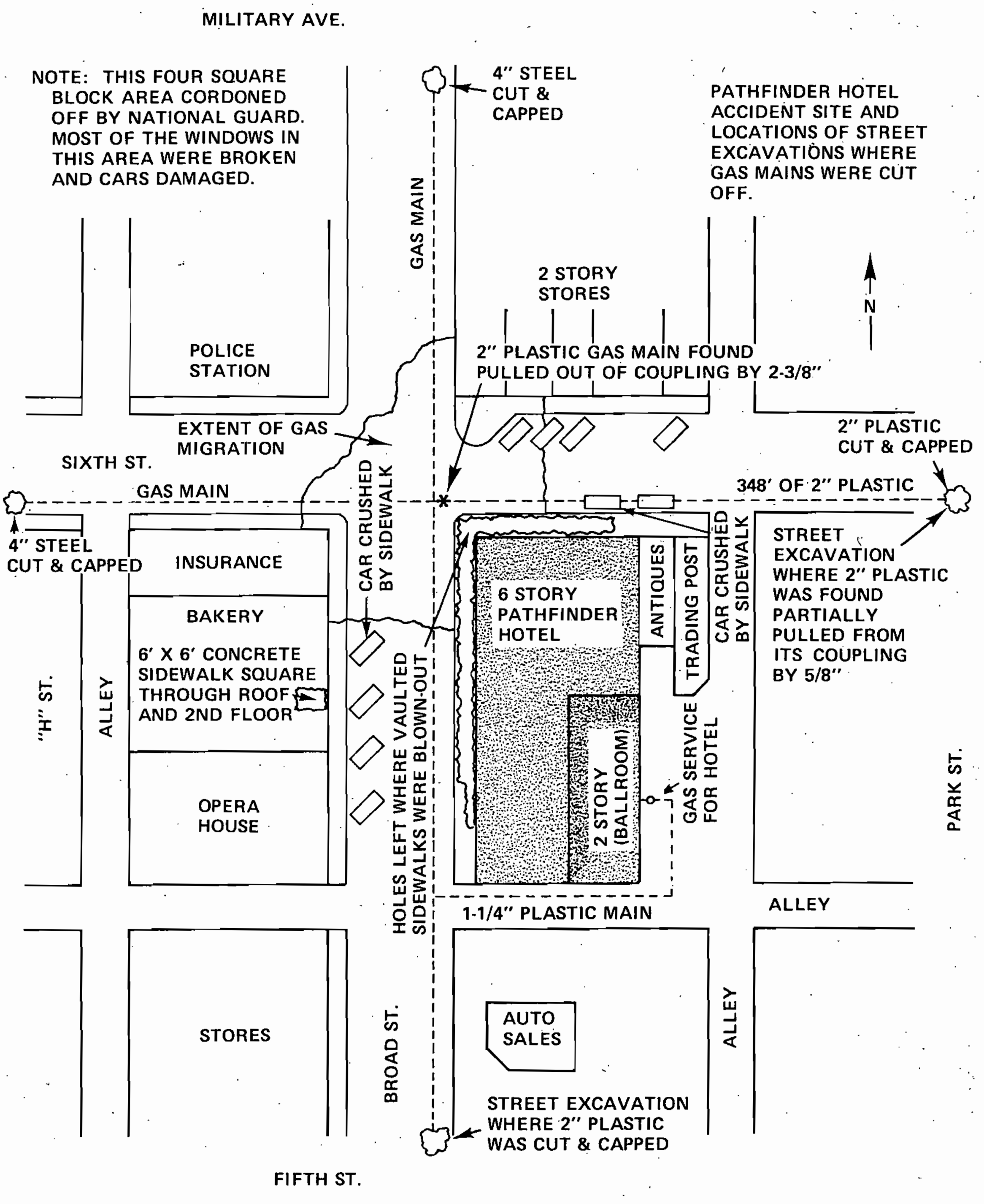

Figure 3. Accident site.

At 6 p.m. on January 9, an emergency repair crew was called to repair a leak at 5th and D Streets, three blocks east of the hotel. The crew found another 2-inch plastic main which had pulled out of its 2- by 5-inch compression coupling.

When the hotel exploded, the gas temperature in the mains was 24°F and the minimum ground temperature at the depth of the gas main was 36°F.

Gas Distribution System

The Nebraska Natural Gas Company owns and operates the gas system in Fremont, Nebraska. Gas is supplied at 35 psig to about 20 district regulators, which supply gas to the distribution system at 13 psig. There are 27 valves on the distribution system mains. The gas company had not plotted the locations of these valves on a system map in order to facilitate shutting off the gas supply to small areas during emergencies. The gas company did have cards which indicated gas facilities on each block in Fremont; however, these block cards were stored in the warehouse and were not available on emergency vehicles.

In 1972, the gas company began to introduce plastic mains and services into the pipeline system, which previously had been constructed only of steel. On June 26, 1974, 348 feet of 2-inch Aldyl "A" plastic pipe were inserted in 337 feet of existing 4-inch steel piping in the street on the north side of the hotel; this left $5\frac{1}{2}$ feet of extra pipe on each side of the casing for tie-ins. The polyethylene (PE) plastic pipe was manufactured by DuPont in accordance with ASTM 2513 specifications and was a medium density PE 2306. The design pressure rating for this 2-inch standard dimension ratio (SDR) 11 plastic pipe in a Class 4 location was 50 psig, and the pipe's wall thickness was .216 inch. The thermal coefficient of expansion of the plastic resin used to manufacture the pipe was $9X10^{-5}$ in/in/°F; this is about 15 times greater than the coefficient of expansion of steel. In 49 CFR 192.123, the design pressure of plastic pipe is limited to 100 psig and the operating temperature of thermoplastic pipes such as polyethylene is limited to between -20°F and 100°F.

While this pipe was being installed, the weather was hot, and on 3 days the temperature exceeded 100°F. On the day that the line was connected to the gas distribution system, the high temperature was

86°F, the low was 60°F, and the average was 73°F. The minimum ground temperature at the depth of the gas main was interpolated from engineering handbooks to be 60°F; the probable ground temperature was estimated to be closer to 66°F.

To connect the 348-foot length of plastic pipe to the 2-inch steel main, 5-inch-long, smooth metal stiffeners which were purchased from DuPont were inserted into each end of the plastic pipe, and 2-inch-diameter compression couplings with 5-inch-long barrels and brass-beaded gaskets, which were manufactured by Norton McMurray, were installed over the stiffeners. The stiffeners fit inside the pipe, underneath the compression nut of the couplings. The construction crew used 24-inch pipe wrenches to tighten the compression nuts on the couplings. They telescoped together pieces of 3- and 4-inch polyvinyl chloride plastic and used them as a protective sleeve over the 2-inch plastic main. They did not seal the steel casing around the 2-inch plastic main nor did they anchor the plastic main to the ends of the steel casing.

In order to connect the new plastic main to the live gas main, the crew had to use a line-stopper fitting at each end of the new plastic main to control the gas flow. The 4-inch fittings were welded to the old gas main 2 feet from where the crew was to connect the new main. They used a special tapping valve, which was mounted on top of the fitting, in order to drill a 4-inch-diameter hole through the old 4-inch main at both locations. Then they inserted rubber plugs in the holes to stop the flow of gas so that they could cut and weld along the line which was to be abandoned. When they were ready to start gas flow through the new plastic main, they removed one of the rubber plugs, and gas pressure then purged the air out of the plastic main, which had been connected on one end only. After the air had been purged from the new plastic main, they used a squeeze-off tool to pinch the plastic pipe 10 inches from the other end until the gas stopped flowing. They then inserted that end of the main into the compression coupling, they tightened the compression nut, and they removed the squeeze-off tool. To complete the job, they removed the other rubber plug from the fitting and they capped and buried the fitting. (See Figure 2.) The plastic main was free to expand or contract within the steel casing, limited only by seven 3/4-inch plastic service lines.

The pipe was not installed in accordance with several important manufacturer's recommendations, and the quality of workmanship at the tie-ins was marginal. The crew cut the pipe ends on angle with a hack saw and they cut the top of the pipe $\frac{1}{4}$ inch shorther than the bottom. They also misaligned the pipe 5° when they connected it to the compression coupling. 1/ Because these two errors were cumulative, the top part of the coupling's gasket had contracted almost to the end of the pipe before it failed and the beaded part of the gasket dug into the plastic 3/8 inch from the end of the pipe. DuPont's installation bulletin states: "Aldyl 'A' pipe should be cut with pipe and tubing cutters designed for plastic pipe. If carpenter or hack saws are used to cut the pipe, special care must be taken to insure square cut ends." 2/

In other information which DuPont furnished the gas company concerning its products, DuPont stated, "Since inserted pipe is not restricted in linear movements as in direct burial, the effects of expansion and contraction (1-inch per 100 feet for 10°F change) must be considered when using compression-type fittings. In relatively short service runs (100 feet) properly tightened fittings will hold over normal temperature range; however, in longer runs positive transition fittings 3/ may be required to prevent pull-out." 4/

Gas Company Emergency Procedures

On June 1, 1973, the Nebraska Natural Gas Company issued a set of standards and procedures which were in effect at the time of the accident. The standards and procedures included a section on emergency procedures; however, the procedures covered only natural and civil disturbances, and did not include such items as evacuation procedures and gas leak emergencies, although they did include a procedure to restore gas service after an outage. The procedures were not specific as to emergency training for employees. The three employees who were on call when the hotel exploded were an appliance installer, a truck foreman, and a maintenance man for trucks and equipment; these men had no formal

1/ Gas company standards allow a 4° misalignment.

2/ DuPont Aldyl "A" Installation Bulletin 100.

3/ DuPont describes a positive transition fitting in Installation Bulletin 106 as a factory-fabricated transition fitting that is heat-fused to the plastic main and welded to the joining steel main in order to produce a joint that is as strong as the plastic pipe.

4/ DuPont Technical Data Sheet #680.

training in emergency procedures, although they had received on-the-job training from another serviceman with regard to normal servicing such as cleaning and relighting gas pilots. The employees were not trained in operating leak detection equipment nor in classifying leaks by degree of hazard. They did carry soap cans to test exposed pipes and fittings for leaks, but their emergency vehicles were not equipped with leak detection equipment.

The gas company had sent a notice to all customers in Fremont regarding emergency calls. The notice warned customers to call immediately if they smelled gas, stated that there would be no charge for repairs which were made on company equipment and piping regardless of the time of call, and stated that customers would be charged $10 for after-hours calls to repair customer-owned equipment and piping. The gas company also sent the police department a list of home telephone numbers of gas company employees who could respond to an emergency.

Tests and Research

The Safety Board engaged an independent laboratory to test and analyze the plastic pipe and the compression coupling which were involved in the accident. (See Appendix A.) The laboratory tested a portion of the pipe to determine the thermal coefficient of expansion, which averaged 9.63×10^{-5} in/in/$^{\circ}$F. This compared favorably to the manufacturer's published coefficient of expansion for the base resin used in the pipe.

The laboratory conducted six tensile tests in which the compression nut on the coupling was torqued to 150 foot-pounds. After 15 minutes, the torque had relaxed an average of 16.1 percent or 24 foot-pounds. After the coupling was retorqued to 150 foot-pounds, the average force required to pull the pipe out of the coupling was 486 pounds. In the four tests which most closely simulated actual conditions, the forces required to pull the pipe out ranged from 450 to 495 pounds. When a coupling was retorqued twice to achieve a higher pullout force, a maximum force of 700 pounds was required to pull the pipe out of its coupling. This is only about 1/7 the yield strength of the pipe; the yield strength was calculated to be more than 5,000 pounds.

The laboratory also conducted a tensile test in which the pipe was inserted only 3/8 inch into the compression coupling and the coupling was torqued to 150 foot-pounds. Only 300 pounds of force were required to pull the pipe out of the coupling.

ANALYSIS

Behavior of Polyethylene Plastic Pipe

Based on the tensile tests and on the marks on the pipe, the Safety Board determined that the pipe pulled out of the compression coupling in two stages, over the two-winter period, because of thermal contraction.

When the pipe was installed, the compression nut was tightened with a 24-inch wrench, which would provide an average torque of 150 foot-pounds. The brass-beaded rubber gasket made deep marks on the pipe, which indicated that the pipe remained in its original position for about 6 months. (See Figure 4.)

During the first winter after installation, the ground temperature at the pipe depth did not get as low as it did during the second winter because the ground was insulated by a blanket of snow the first year. Thermal contraction created a pullout force of about 300 pounds. Because of a property of plastic which is known as cold flow, [5/] this force was not enough to pull the pipe completely out of the gasket.

As the pipe slowly pulled out of the gasket, the forces created by the compression gasket caused the plastic to cold flow toward the end of the pipe, inside the gasket. This bunching of the plastic made the outer diameter (OD) of the pipe larger. When the plastic wave reached 3/8 inch from the end of the pipe, it could not move further, and the plastic started to ball up inside of the gasket. It then would have required 480 pounds of force to pull the pipe out of the gasket because of the plastic wave. Since only about 300 pounds of force were available, the forces created by thermal contraction and by the compression gasket equalized and the plastic pipe stopped moving.

During the summer, the stiff plastic pipe became limp, and snaked back and forth within its 4-inch casing as it strived to retain its original length. The second, faint set of beaded gasket marks, 3/8 inch from the end of the pipe, indicates that the compressive forces of the gasket were enough to maintain gas tightness and to prevent the summer expansion forces from forcing the pipe back into the coupling, even though the compressive forces were now less than the 150 foot-pounds of original torque. When the forces which acted on the plastic pipe within the

---

5/ Cold flow is defined as the dimensional change with time of a plastic under load, following the instantaneous elastic or rapid deformation.

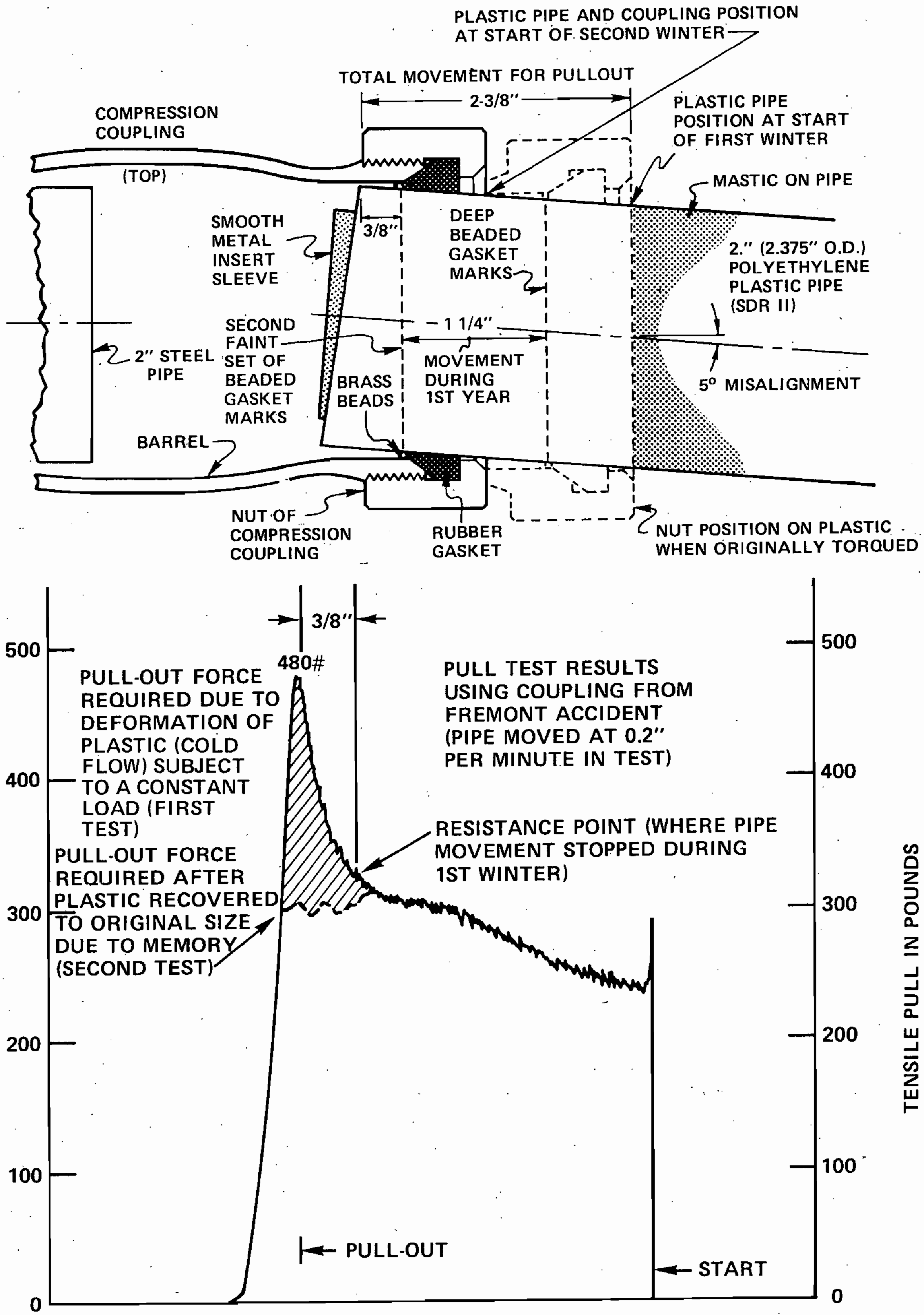

Figure 4. Cross-section of plastic pipe within compression coupling, and force diagram.

coupling decreased during the summer, the plastic wave which had formed in front of the gasket subsided and the plastic resumed its original dimensions. 6/

Since there was no insulating layer of snow during the second winter, cold temperatures penetrated the ground. The temperature differential of the pipe between the day that it was installed and the day that the hotel exploded was at least 24°F, but it probably was closer to 30°F. Given this temperature range, the force which was caused by thermal contraction would have been between 500 and 623 pounds. (See Appendix B.) The test with the partially inserted pipe indicates that with only 3/8 inch of pipe inserted in the coupling, there is not enough plastic material inside the gasket to cause a wave to build up and, therefore, only 300 pounds of force are required to pull the pipe out of the coupling.

Based on the 9.63×10^{-5} in/in/°F thermal coefficient of expansion of the pipe involved in the accident, 100 feet of the pipe should contract about 1 inch per 10°F. Given the 24°F minimum temperature differential of the pipe, the 348-foot-long pipe could have contracted $9\frac{1}{2}$ inches if it had been totally unrestrained. Since the pipe was restrained partially by seven service lines, by the friction in the compression coupling, and by the friction of the 4-inch casing, the pipe only contracted 3 inches. Plastic pipe which is buried directly rather than inserted into existing pipe is restrained by the weight of the soil, and it has to overcome soil frictional forces when the pipe contracts or expands. Therefore, the possibility that the pipe will pull out is minimized by direct burial, especially when the pipe is snaked in the ditch near the connections to provide slack and to insure that the pipe is in compression rather than in tension when the end is placed in the compression coupling. The Nebraska Natural Gas Company standards state, "Plastic lines do not need slack loops to compensate for the high coefficient of expansion, but they should be laid with as much normal slack as possible." However, the insertion of the pipe with only 11 feet outside the casing did not allow enough pipe to provide normal slack at the connections because of the stiffness of the plastic pipe over a short span like that at the accident site.

6/ Plastic is viscoelastic, which means that it relaxes or adjusts with time to stresses which are imposed by thermal or mechanical changes.

When a pipe is restrained on both ends within a casing, stresses develop within the plastic which tend to pull the pipe out of its compression fittings if it is not anchored firmly. This can be done by fastening the plastic pipe to the casing ends to prevent thermal contraction. Factory-fabricated transition fittings that are heat-fused to the plastic main and are welded to the steel main can be used in lieu of anchors because the heat-fused plastic joint is as strong as the elastic plastic pipe, which merely stretches if it is firmly fastened on both ends.

Compression Couplings on Plastic Pipe

With regard to joining materials by methods other than welding, 49 CFR 192.273 requires that pipelines be designed and installed so that the joints can sustain any longitudinal pull or thrust forces which are caused by contraction or expansion of the piping or by anticipated external or internal loading. With regard to plastic pipe joints and the use of compression-type mechanical joints, 49 CFR 192.281 states that "Each plastic pipe joint must be made in accordance with written procedures that have been proven by destructive burst test to produce joints at least as strong as the pipe being joined." The tests demonstrated that the coupling was not as strong as the pipe, because it allowed the pipe to pull out. The tests and the accident both demonstrated that the compression coupling could not withstand the longitudinal forces caused by thermal contraction.

Compression-type elastomeric sealed couplings have been used to join gas pipes for over 80 years and, consequently, some persons in the gas industry presume that such couplings are safe under any circumstances. However, compression couplings are designed only to be gastight. Manufacturers of compression couplings recommend that a standard compression coupling of 2 inches in diameter or larger, without proprietary lock inserts, be used only to seal a pipe joint. None of the manufacturers design standard couplings to withstand specific longitudinal pull forces. However, coupling manufacturers and plastic manufacturers can furnish proprietary transition fittings in certain sizes to withstand longitudinal pull forces. Several manufacturers also can furnish proprietary lock inserts in the 2-inch size that will prevent plastic pipe from pulling out of couplings.

For the 2-inch connection which was involved in the accident, the plastic pipe manufacturer recommends that its proprietary transition fitting be used because the main insertion was over 100 feet long. The coupling manufacturer also has a proprietary serrated "lock" stiffener in the 2-inch size which is advertised to "hold the plastic to failure." However, the Nebraska Natural Gas Company chose to use a smooth metal stiffener purchased from the plastic pipe manufacturer and to use a compression coupling of another manufacturer. The resulting combination of materials had not been proven by destructive burst tests; since the pipe did pull out of the coupling, the combination joint was obviously weaker than the plastic pipe which was being joined.

In 1972, accidents which were caused when pipes pulled out of compression couplings caused 9 fatalities, 35 injuries, and $1 million of property damage. As a result, the Safety Board warned in a 1973 report 7/ of the hazards of poorly constructed or improperly placed compression couplings. The Safety Board stated that "the frequency and severity of this type of accident raise some doubts whether the use of compression couplings is warranted," and concluded that 49 CFR 192.367(b), which governed the use of compression couplings on service lines, was vague and, therefore, inadequate. In a recommendation to the Office of Pipeline Safety 8/ of the Department of Transportation (DOT), the Safety Board recommended that OPS "undertake a review of 49 CFR 192.367(b) relative to the uncertainty as to the conditions which permit the use of compression couplings, and initiate a rulemaking which will definitely identify conditions which permit or prohibit the use of compression couplings. If necessary, the review should include a study of objective methods of readily identifying conditions which could produce forces or loads which cannot be sustained." (Recommendation P-73-3.) To this date, no new regulations concerning compression couplings have been adopted.

The Safety Board is even more concerned about the problem of compression couplings as a result of its investigation of this accident. The leak survey which the Nebraska Natural Gas Company conducted the day before the accident indicates that the gas company was conscientiously attempting to guard against gas leaks. However, a leak survey cannot protect against a pipe which suddenly pulls out of a

---

7/ National Transportation Safety Board, "Pipeline Accident Report - Northern States Power Company, Lake City, Minnesota, October 30, 1972." NTSB-PAR-73-1.

8/ The Office of Pipeline Safety became the Office of Pipeline Safety Operations in 1975.

compression coupling. Also, the large volume of gas which escapes when a pipe pulls out suddenly cannot dissipate quickly enough through the soil to escape into the atmosphere; it is more likely to migrate into nearby buildings before it is detected. DOT should study compression couplings with regard to the thermal contraction of plastics to determine if such couplings are unsafe at certain locations or under certain conditions. If they are, the regulations should be changed to prohibit their use for such applications.

Gas Company Emergency Procedures

The Nebraska Natural Gas Company had written emergency procedures as required by 49 CFR 192.615. However, the emergency procedures emphasized restoring service after an emergency rather than minimizing losses by planning how to handle gas leak emergencies. If the gas company had planned for emergencies, there might have been spare parts, maintenance instructions, and batteries for the FI leak detector. The leak detector should have been stored in a specific place in the warehouse so that it could be found readily, and it should have been checked for operability after each use before it was stored. The CGI which the gas company personnel finally used to check the concentration of the leak in the basement of the hotel was adequate for that purpose; however, it should have been a standard part of the work equipment on emergency vehicles. If the first serviceman had had a CGI in his vehicle and had been proficient in its use when he arrived at the bakery at 8 a.m., he could have used it to check the bakery and, failing to find a gas leak there, he might have checked nearby buildings. The leak at the hotel was so severe that he probably would have found it soon enough that the hotel could have been evacuated before the explosion.

The block cards which indicated the gas facilities on each block should have been kept in emergency vehicles. If the first serviceman had had a copy of the block cards or a distribution system map with him, he would have known that there were no gas facilities in the alley behind the bakery and he could have checked elsewhere for the gas leak.

In 1974, when the plastic mains were installed, readily accessible, key-operated valves should have been installed with valve boxes mounted over them. The use of line-stopper fittings and squeeze-off tools to control flow for tie-ins is the easiest way to make transition connections, but the installation of emergency shutoff line valves and purge fittings would provide the means to make better transition connections and would enhance shutoff capabilities. Also, more valves should be installed to reduce the time necessary to isolate the downtown area in emergencies, in accordance with 49 CFR 192.181(a), which requires that high-pressure distribution line valves be "spaced so as to reduce the time to shut down a section of main in emergency."

The three supervisors who were killed probably would have known which valves would have stopped gas service to the hotel area, but since no other available employee knew, the gas company had to shut off service to half of Fremont. If the gas company had had written records concerning the location of valves in the gas distribution system, this would not have been necessary. The gas company should draw up a color-coded distribution system map to show what area each of the emergency valves shuts off.

It is common practice in the gas industry to use servicemen to conduct on-the-job training. However, adequate training for emergencies requires a specialist. On-call servicemen must be trained thoroughly in emergency actions; they must know how to classify leaks according to degree of hazard, how to use leak detection equipment, how to evacuate buildings, etc. They also should be familiar with their companies' written emergency procedures. The Nebraska Natural Gas Company should develop a formal training program to teach emergency procedures to all employees who could respond to an emergency situation, and it should develop more comprehensive written emergency procedures.

It was only by chance that hotel employees contacted a serviceman, because one was on call and there was no way to reach him until he returned home; one was not at home; and the other was preparing to answer another call. Even after the serviceman was informed of the possible leak, an emergency check of the hotel was delayed by a lack of communications. The serviceman had no way to contact the other servicemen, and it took time for him to locate and to inform his supervisor of the possible leak at the hotel. The emergency procedures should have set priorities to assure that a serviceman would respond immediately to a suspected leak in a public building such as a hotel, and the procedures should have designated someone else to contact reserve or supervisory assistance. The delay of 1 hour between the time that the hotel employees first called the gas company and the time that the gas company employees arrived at the hotel is excessive. The Safety Board concludes that without a system of supervisory monitoring, logging, and assigning priorities to incoming calls, the gas company could not handle emergencies efficiently.

Large gas transmission and distribution companies have gas dispatchers on shift around the clock. Large municipal companies also usually man a telephone to handle any emergencies which involve gas, electricity, water, sewer, fire, etc. The Safety Board recognizes that this would be difficult for small companies; however, an effective communication system is essential and must be implemented by the Nebraska Natural Gas Company.

Each gas-utility operator is required by 49 CFR 192.615(d) to "Establish an educational program to enable customers and the general public to recognize and report a gas emergency to the appropriate officials." The gas company had sent a notice to customers to contact the company if they smelled gas. However, the notice did not include an emergency number to call, nor did it include aids to help customers recognize the odor of gas. Also, both the telephone recording and the written notice mentioned a $10 service fee for after-hours calls. Although this would not have deterred a commercial customer such as the hotel from calling to report a suspected leak, it might have deterred a residential customer. The customer education program should emphasize only safety. Notices concerning cost should be sent separately.

CONCLUSIONS

1. During two winters, thermal contraction caused the 2-inch polyethylene plastic main to contract 2 3/8 inches on one end and 5/8 inch on the other end.

2. The pipeline was not designed and installed so that the tie-in compression coupling would sustain the longitudinal pull or the thrust forces which were caused by the pipe's contraction within its 4-inch steel casing.

3. The pipe had not been anchored to the casing ends to prevent it from pulling out of the coupling.

4. The smooth steel stiffener which was used in the end of the plastic pipe, underneath the compression nut of the coupling, was not made by the same manufacturer that made the coupling, and the resulting combination produced a joint which was weaker than the plastic pipe that was being joined.

5. When the contracting pipe pulled out of the weaker compression coupling, leaking gas migrated into the hotel and was ignited by an unknown source.

6. The pipe was not installed in accordance with several important manufacturer's recommendations and the quality of workmanship at the tie-ins was marginal.

7. The gas company's emergency provisions were inadequate with regard to employee training, availability of emergency equipment, emergency communications, public education, and its liaison with fire and police officials.

8. The spacing of distribution valves in the downtown area was insufficient to shut off gas to the area quickly, and those valves which were present were not mapped to facilitate an emergency shutdown.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of the accident was the contraction, due to cold temperatures, of a 2-inch polyethylene plastic main within a 4-inch casing. The contraction of the plastic main caused the pipe to pull out of the inadequately connected compression coupling.

RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board made the following recommendations.

On February 24, 1976, the Safety Board recommended that the Nebraska Natural Gas Company:

> "Review its entire system to see if pipe had pulled out of its coupling elsewhere and to rectify any potentially hazardous conditions found. (P-76-3) (Class I, Urgent Followup)
>
> "Conduct tests below the frost level during this review of the system to monitor all plastic pipe joints made with short compression couplings where pullout and resultant gas leaks could occur. (P-76-4) (Class I, Urgent Followup)"

In addition, the Safety Board has recommended that the Nebraska Natural Gas Company:

> "Use manufacturer's proprietary transition fittings, installed in accordance with written procedures, or use pipe-to-casing anchors to limit contraction of plastic pipe, until a compression coupling is verified by tests to be as strong as the plastic pipe being joined. (P-76-48) (Class II, Priority Followup)
>
> "Develop written procedures and an inspection program to insure that all plastic pipe joints meet the design and installation provisions of 49 CFR 192(F), 'Joining of materials by means other than welding.' (P-76-49) (Class II, Priority Followup)
>
> "Revise the company's written procedures to include the maximum length of plastic pipe to be used with compression couplings, the number of foot-pounds of torque required for each size of compression coupling, a time interval during construction between retorquing of couplings, and the type of stiffener to be used with each brand of coupling. (P-76-50) (Class II, Priority Followup)
>
> "Develop written procedures to handle gas leak emergencies and evacuation, and instruct operating and maintenance employees as to their roles in carrying out these procedures. (P-76-51) (Class II, Priority Followup)
>
> "Develop a procedure to shut down the system during emergencies. As part of this procedure, develop distribution system maps showing valve locations, determine optimum spacing of high-pressure valves in each of the NNG distribution systems, and install additional valves, if necessary, to reduce the time required to shut down a section of main in an emergency. (P-76-52) (Class II, Priority Followup)
>
> "Develop a method of receiving emergency telephone calls in order to assure immediate response to emergencies. The method should include logging of all emergency calls. (P-76-53) (Class II, Priority Followup)

"Improve the customer education program and liaison between the gas company, the police, and the fire departments. Include in written procedures the methods for notifying police and fire departments of gas emergencies and the planned responses to them. (P-76-54) (Class II, Priority Followup)

"Equip emergency vehicles with combustible gas leak detectors, distribution maps, and other necessary work tools. (P-76-55) (Class II, Priority Followup)"

The Safety Board has recommended that the Department of Transportation:

"Study the plastic-to-steel transition problem and take appropriate regulatory action to correct any unsafe practices. (P-76-43) (Class II, Priority Followup)

"Revise 49 CFR 192.281(e)(2), 'Mechanical Joints,' to require that stiffeners be designed to be compatible with compression couplings so that pipes cannot pull out of the couplings. (P-76-44) (Class II, Priority Followup)

"Determine if there are locations or circumstances where standard compression couplings are unsafe, and amend 49 CFR 192 accordingly to prohibit their use for such applications. (P-76-45) (Class II, Priority Followup)

"Analyze the methods which operators use to receive and respond to emergency calls and, based upon this analysis, amend 49 CFR 192, 'Operations,' to specify minimum acceptable standards. (P-76-46) (Class II, Priority Followup)

"Amend 49 CFR 192,'Operations,' to require that operators record the receipt of emergency calls, the response to the calls, and the time of each significant action taken by the operator. (P-76-47) (Class II, Priority Followup)"

The Safety Board has recommended that the City of Fremont:

"Reemphasize to city personnel who are assigned to the emergency desk the importance of helping people who call in to report gas leaks, and require the personnel to furnish emergency gas company numbers to the public. (P-76-56) (Class II, Priority Followup)

"Coordinate emergency activities with the gas company and determine what responses should be made to various types of gas emergencies. (P-76-57) (Class II, Priority Followup)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ WEBSTER B. TODD, JR.
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A. HOGUE
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

July 7, 1976

APPENDIX A

REPORT OF LABORATORY TESTS RELATIVE TO PLASTIC PIPE/COUPLING PULLOUT FAILURE AT THE PATHFINDER HOTEL IN FREMONT, NEBRASKA ON JANUARY 10, 1976 (EXCERPTS)

INTRODUCTION

A group of 2-inch polyethylene pipe sections including couplings were submitted to ARTECH CORP. for determination of force required to separate the pipe and coupling by tension. Additional tests, including verification of thermal expansion properties and limited mechanical testing, were carried out to establish whether, under conditions of proper coupling installation and conformance of materials with applicable specifications, thermal contraction alone could account for the retraction of the pipe from its coupling.

* * * *

OBJECTIVES

To verify limited thermal and mechanical behavior of 2-inch polyethylene pipe.

To determine probable mode of separation of 2-inch polyethylene pipe from its coupling.

* * * *

CONCLUSIONS

Pipe indentation marks as found on actual pipe sections from Fremont, Nebraska, require more than 150 foot-pounds of torque at room temperature due to plastic memory.

Thermal contraction measurements carried out on actual pipe section confirmed published vendor data.

Thermal contraction probably pulled the polyethylene pipe from its coupling.

APPENDIX B

POLYETHYLENE PIPE DIMENSIONS AND THE FORCES WHICH WOULD BE DEVELOPED AT 35°F (EXCERPT FROM DuPONT BULLETIN NO. E06450)

Nominal Size (in.)	SDR	O.D. (in.)	Wall Thickness (in.)	Total End Area (to nominal O.D.) (sq. in.)	Max. Wall Area (sq. in.)	Min. Wall Area (sq. in.)	Pipe Yield Force at 35%F. Max. Wall Area (lbs.)	Pipe Yield Force at 35%F. Min. Wall Area (lbs.)	End Thrust at 60 psi (lbs.)	Thermal Contractive Force at 35°F from 65°F (Δ30°F) (max. lbs.)
Iron Pipe Size										
½"	9.3	.840±.004	.090 +.020 -.000	.554	.253	.211	918	765	33	97
¾"	11	1.050±.004	.095 +.020 -.000	.865	.342	.284	1,241	1,030	52	131
¾"	9.3	1.050±.004	.113 +.021 -.000	.865	.387	.331	1,404	1,201	52	148
1"	11	1.315±.005	.119 +.026 -.000	1.357	.535	.445	1,942	1,615	81	205
1"	9.3	1.315±.005	.141 +.026 -.000	1.357	.605	.518	2,196	1,880	81	232
1¼"	10	1.660±.005	.166 +.026 -.000	2.163	.887	.776	3,219	2,816	130	340
1¼"	9.3	1.660±.005	.178 +.026 -.000	2.163	.936	.826	3,397	2,998	130	359
1½"	11	1.900±.006	.173 +.026 -.000	2.834	1.067	.935	3,873	3,394	170	409
2"	11	2.375±.006	.216 +.026 -.000	4.428	1.625	1.460	5,898	5,299	265	623 *
2"	9.3	2.375±.006	.255 +.030 -.000	4.428	1.876	1.693	6,809	6,145	265	719
3"	11.5	3.500±.008	.307 +.035 -.000	9.616	3.399	3.070	12,338	11,144	577	1303
3"	9.3	3.500±.008	.376 +.044 -.000	9.616	4.072	3.679	14,781	13,354	577	1561
4"	11.5	4.500±.009	.395 +.040 -.000	15.896	5.565	5.080	20,200	18,440	954	2134
4"	9.3	4.500±.009	.483 +.057 -.000	15.896	6.729	6.079	24,426	22,066	954	2580

* PIPE SIZE INVOLVED IN FREMONT ACCIDENT.