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NATIONAL TRANSPORTATION SAFETY BOARD

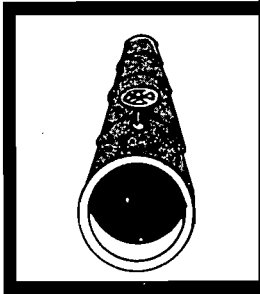
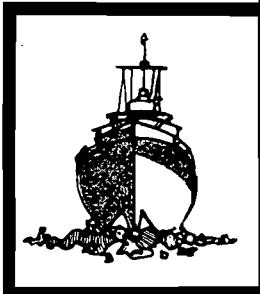
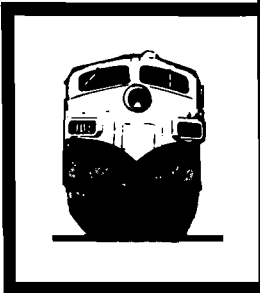
WASHINGTON, D.C. 20594

PIPELINE ACCIDENT REPORT

**ARIZONA PUBLIC SERVICE COMPANY
NATURAL GAS EXPLOSION AND FIRE
PHOENIX, ARIZONA
SEPTEMBER 25, 1984**

NTSB/PAR-85/01

UNITED STATES GOVERNMENT



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<p>16. Abstract At 3:30 a.m., on September 25, 1984, an explosion followed by an intense natural gas-fed fire destroyed two apartments at 3022 North 37th Street in Phoenix, Arizona. Of the 12 persons injured in the fire, 5 persons later died. After the fire was extinguished, the 1 1/4-inch-diameter acrylonitrile butadiene styrene (ABS) plastic gas main supplying gas to the destroyed apartments was excavated and a 3-inch-long longitudinal split was discovered in the bottom of the pipe 18 feet from the gas meters on the apartment building. Gas at 30 psig had escaped through the longitudinal split, migrated into and under the apartments, ignited, exploded, and burned.</p> <p>The National Transportation Safety Board determines that the probable cause of the accident was the deterioration and ensuing rupture of a 1 1/4-inch-diameter ABS plastic pipe due to weakening from internal environmental stress cracking that resulted from a chemical reaction between the pipe and liquid entrapped in a low spot in the pipe, which allowed natural gas at 30 psig to escape from the failed pipe and to migrate through the adjacent soil into and under two apartments, where it accumulated and was ignited by the gas pilot light of a furnace. Contributing to the accident was the failure of persons who had detected gas odors earlier to report those odors to the gas company or to the fire department. Also contributing to the accident was the absence of a gas company program to analyze the cause of leaks as they occurred.</p>					
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**NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594**

PIPELINE ACCIDENT REPORT

Adopted: June 12, 1985

**ARIZONA PUBLIC SERVICE COMPANY
NATURAL GAS EXPLOSION AND FIRE
PHOENIX, ARIZONA
SEPTEMBER 25, 1984**

SYNOPSIS

At 3:30 a.m., on September 25, 1984, an explosion followed by an intense natural gas-fed fire destroyed two apartments at 3022 North 37th Street in Phoenix, Arizona. Of the 12 persons injured in the fire, 5 persons later died. After the fire was extinguished, the 1 1/4-inch-diameter acrylonitrile butadiene styrene (ABS) plastic gas main supplying gas to the destroyed apartments was excavated and a 3-inch-long longitudinal split was discovered in the bottom of the pipe 18 feet from the gas meters on the apartment building. Gas at 30 psig had escaped through the longitudinal split, migrated into and under the apartments, ignited, exploded, and burned.

The National Transportation Safety Board determines that the probable cause of the accident was the deterioration and ensuing rupture of a 1 1/4-inch-diameter ABS plastic pipe due to weakening from internal environmental stress cracking that resulted from a chemical reaction between the pipe and liquid entrapped in a low spot in the pipe, which allowed natural gas at 30 psig to escape from the failed pipe and to migrate through the adjacent soil into and under two apartments, where it accumulated and was ignited by the gas pilot light of a furnace. Contributing to the accident was the failure of persons who had detected gas odors earlier to report those odors to the gas company or to the fire department. Also contributing to the accident was the absence of a gas company program to analyze the cause of leaks as they occurred.

INVESTIGATION

The Accident

Shortly before midnight on September 24, 1984, five persons entered apartment No. 9, one of 10 apartments at 3022 North 37th Street in Phoenix, Arizona. (See figure 1.) They smelled the odor of natural gas in the apartment, but because their telephone was out of service, because they were tired and had early appointments the next day, and because once, a year before, they had contacted the gas company about gas odors and had to wait several hours before the gas company arrived, they did not notify the gas company or the fire department about the gas odors. They opened some windows in the apartment to dissipate the odors, later closed the windows, and went to bed.

About 3:30 a.m., on September 25, 1984, one of the five persons was awakened by "popping noises" and saw flames covering a bedroom wall. He carried another person out of the bedroom and out of the apartment. The other three persons in apartment No. 9 and four persons in the adjacent apartment No. 10 escaped from the building but were burned badly and had to be helped to safety by neighbors, who had been awakened by the explosion. One of these neighbors and two policemen who were in the area at the time of the explosion at 3:30 a.m. received burns while helping the injured.

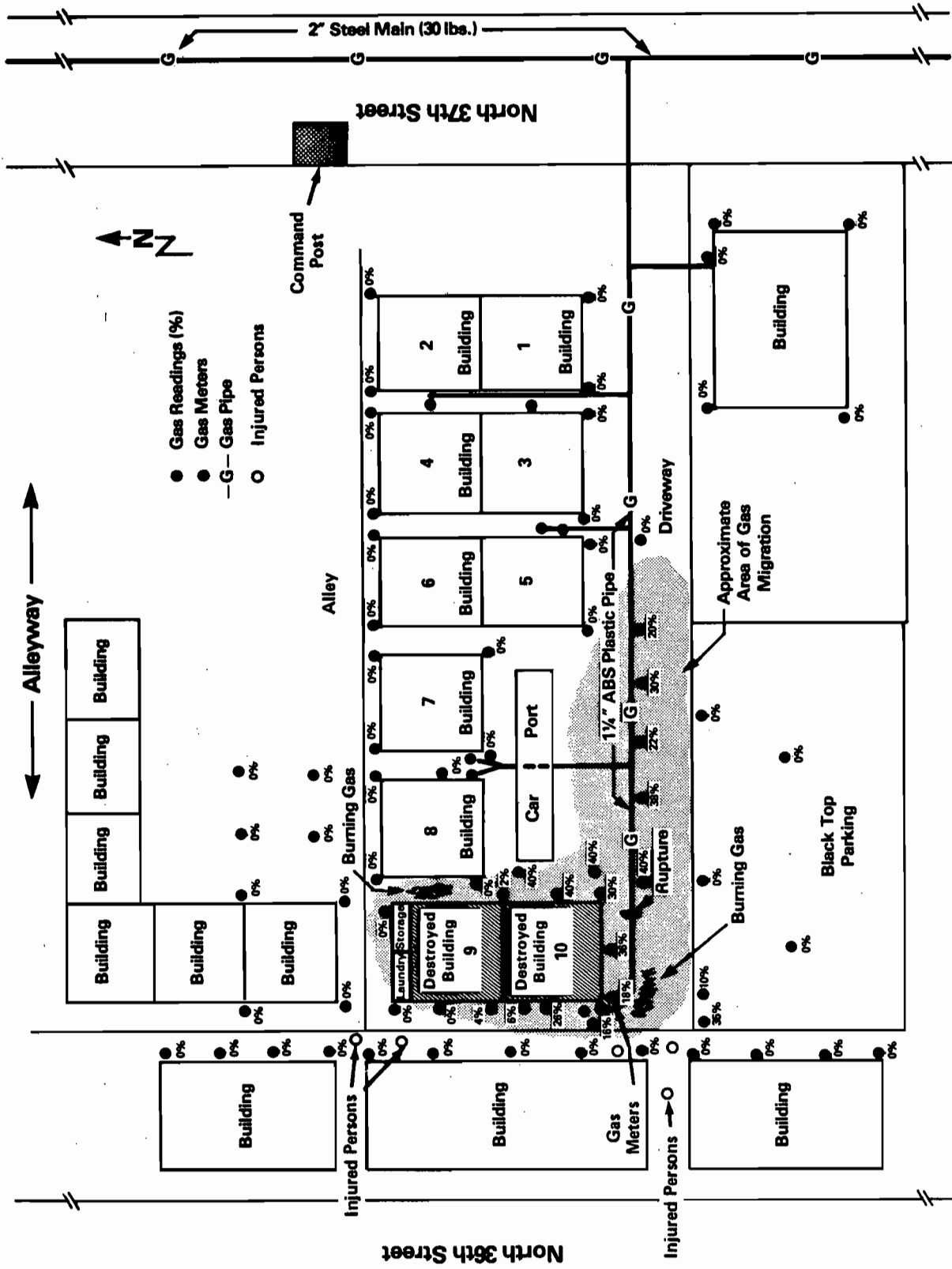


Figure 1.--Plan view of the accident site showing locations and results of gas company's bar hole tests.

The Phoenix Fire Department (fire department) received the first report of the explosion and fire about 3:30 a.m., and firefighters arrived at 3:35 a.m. The fire department established a command post on the east side of North 37th Street at a point northeast of apartment No. 2. (See figure 1.) Firehoses were connected to a hydrant close to the command post and were extended west along an east-west alley located on the north side of apartment Nos. 2, 4, 6, 7, 8, and 9. The firefighters attacked the fire in apartment No. 9 from the west end of the alley. Additional firehoses also were extended west along the east-west driveway located on the south side of apartment Nos. 1, 3, 5, and 10. The firefighters attacked the fire in apartment No. 10 from the west end of the driveway.

Firefighters noticed blue-colored flames burning 8 to 10 inches high above the ground at the north and east walls of apartment No. 9 and at the south and west walls of apartment No. 10. Realizing that the flames apparently were being fed by natural gas, firefighters allowed them to burn. Firefighters also noticed natural gas bubbling up through water which had accumulated in the driveway on the south side of apartment Nos. 5 and 10, but the gas bubbles did not ignite. Personnel from two units of the fire department's Hazardous Incident Response Team (HIRT), fully equipped with protective clothing and self-contained breathing apparatus, entered the accident area about 3:55 a.m. to take gas readings to ascertain the extent of the migration and permeation of the gas in the area. One four-person HIRT team checked the area around apartment Nos. 9 and 10, and another four-person HIRT team checked the area around apartment Nos. 7 and 8 and the carport area south of these apartments. Both HIRT teams used combustible gas indicators (CGI's) to check for gas concentrations in the air. Each team checked the area for gas concentrations 4 to 6 inches above the ground level around the apartments and at ceiling levels in apartment Nos. 7 and 8. Neither team checked for gas concentrations in the ground.

After the accident, the fire department determined that the only gas appliances in apartment Nos. 9 and 10 were hot-air furnaces located in the attic of each apartment. Fire department personnel determined that the probable source of ignition of the natural gas was from the pilot light in the gas furnace in the attic of apartment No. 9.

About 3:42 a.m., the fire department notified the Arizona Public Service Company (gas company) by telephone of the explosion and fire, that natural gas appeared to be involved, and that the gas company should respond. The gas company dispatcher telephoned a gas company "troubleman" ^{1/} at 3:45 a.m. and ordered him to respond immediately to the accident site. The "troubleman" arrived at the accident site at 3:55 a.m. and reported to the command post. A fire department captain requested the "troubleman" to check for gas at apartment Nos. 9 and 10. The "troubleman" first attempted to reach the gas meters at these apartments by walking west along the alley on the north side of apartment Nos. 2, 4, 6, 7, 8, and 9, but he encountered intense fires both in apartment No. 9 and in the trees on the west side of that apartment. He also observed a high-voltage wire directly above these flames, and he considered the area unsafe to enter. The "troubleman" was trying to determine if the meters or regulators to apartment Nos. 9 and 10 had been damaged, whether they were leaking, and if he could shut them off.

^{1/} A "troubleman" responds to emergencies, assesses the conditions, and attempts to rectify or mitigate the problem himself or calls the gas company for more assistance.

The "troubleman" walked back to North 37th Street and walked west along the driveway on the south side of apartment Nos. 1, 3, 5, and 10 in an attempt to reach the gas meters from that side. The "troubleman" was wearing work clothes, a hard hat, steel-tipped work shoes, and a gas company identification badge on his lapel. He did not have protective clothing or self-contained breathing apparatus as did the firefighters. Before he arrived at the gas meters at apartment Nos. 9 and 10, he was stopped by firefighters, told that it was unsafe to enter the area, and told to return to the command post. He did not explain specifically what he was in the area to do. The "troubleman" returned to his truck and radioed the gas company dispatcher, reported his initial observations of a gas-fed fire, requested a gas company crew with excavation equipment, and asked the dispatcher to notify appropriate gas company personnel that a major emergency existed. The "troubleman" then walked west along the alley on the north side of the accident site where he met and began questioning one of the injured persons from apartment No. 9. At that time a Phoenix Police Department policeman ordered him out of the area and told him to report to the command post.

About 4:25 a.m., the gas company general foreman arrived, and at 4:30 a.m. a gas company maintenance crew arrived at the accident site; initially, they also were excluded from the site. About 4:50 a.m., a pipeline safety engineer from the Arizona Corporation Commission (commission), who had been notified by the gas company, arrived on site. 2/ Gas company personnel informed him that the firefighters had prohibited gas company personnel from entering the accident site. The commission representative went to the command post and explained that gas company personnel were needed to check for gas migration, to check for any gas accumulations, and to locate the leak and shut off the flow of gas. The fire department granted permission for three gas company employees to enter the accident area and to conduct the gas survey. The employees made bar hole tests around the buildings and in the driveway using CGI's to determine the extent of gas migration and the concentration of gas in the soil. The employees found extensive gas migration, gas accumulation, and gas ignition around the apartment. The commission representative requested and received permission from the fire department for additional gas company personnel to enter the accident area. Gas company personnel together with the commission representative continued the gas survey.

A 1 1/4-inch-diameter plastic gas main located under the driveway supplied gas to the apartments at 3022 North 37th Street. Gas company personnel, using a backhoe, excavated the main at its connection with a 2-inch-diameter steel gas main under the east side of North 37th Street where a valve connecting the gas mains was located. (See figure 1.) The valve was difficult to close, and to ensure complete shutoff of gas into the smaller gas main, gas company employees cut a hole in the top of the smaller gas main, inserted a stopple, 3/ and shut off the gas flow about 6 a.m. Shortly thereafter, the gas-fed flames around apartment Nos. 9 and 10 burned out. By 6:43 a.m., the fires were out, the interiors of the destroyed apartments were searched for victims, and the fire damage was assessed.

2/ The Arizona Corporation Commission, under section 5(a) of the National Gas Pipeline Safety Act, assumed regulatory and enforcement authority over intrastate gas facilities. The commission has adopted gas pipeline regulations at least as stringent as the Federal standards and must provide for enforcement authority for those standards by injunction and monetary sanctions.

3/ A stopple valve is bolted directly on the 1 1/4-inch-diameter plastic pipe, a hole is cut through the top of the plastic pipe, the plastic coupon is removed, and the stopple is inserted in the hole to block the flow of gas.

Gas company workers then used a backhoe to excavate around the 1 1/4-inch-diameter gas main where it terminated at the gas meters at the southwest corner of apartment No. 10. The main itself was uncovered by using hand shovels. An air compressor was connected to the main at the meter riser on the southwest corner of apartment No. 10, and air was compressed into the main. Blowing air and dirt revealed a leak in the main 18 feet east of the meter riser, at a point where the main had 31 inches of cover.

Gas company workers and the commission representative carefully examined the soil over, under, and around the 1 1/4-inch-diameter gas main during the excavation. The soil was a sandy, loamy mixture, well compacted, free of rocks and other debris, and provided good pipe support; no voids were found under the pipe. During the excavation, the odor of gas impregnated in the soil was very strong. The main was found to have a slight vertical bend or sag, but when the failed section of pipe was cut out, the pipe was in neither compression nor tension; no noticeable external forces were exerted on the pipe. A 10-foot-long section of the pipe containing the failure was removed.

The failed gas main was ABS plastic pipe. The failure was a 3-inch-long longitudinal split located on the bottom of the pipe. The maximum opening of the split, measured without pressure, was 1/32 inch; under 30-psig operating pressure, this opening would have been larger. (See figure 2.) After the 10-foot-long section of ABS plastic pipe containing the failure had been removed, the remaining pipe was checked again for leaks; the pipe held a 90-psig test pressure. The main was later abandoned in place, and a new 3/4-inch-diameter, polyethylene (PE 2306) plastic gas main was installed to supply gas to apartment Nos. 3, 4, 5, 7, and 8.



Figure 2.--Failed section of ABS plastic pipe.

After the accident, the gas company records for gas odor complaints from the accident area were reviewed; no gas odor complaints had been received. The residents of apartment Nos. 5, 6, 7, and 8 located east of the destroyed apartments stated that they did not smell any gas odors at any time before the explosion. A resident of 3031 North 36th Street, immediately west of the destroyed apartments, stated that she did not smell any gas odors when she arrived home from work at 1 a.m. on September 25, 1984. However, she stated that she had smelled gas odors during the afternoon of September 24, 1984, but she had not reported the gas odors to the gas company or to the fire department.

The operating pressure in the area of the accident always had been 30 psig, and it was not reduced after the accident when the new pipe was installed. However, after the accident, the gas company reduced the operating pressure in other areas of the system where ABS plastic pipe was in use from 39 psig to 30 psig, a pressure reduction of approximately 25 percent. According to the gas company, the pressure reduction was made to prevent, or reduce the number of, similar ABS plastic pipe failures.

Injuries to Persons

	<u>Gas company employees</u>	<u>Emergency response personnel</u>	<u>Area residents</u>	<u>Total</u>
Fatal	0	0	5	5
Nonfatal	0	2	5	7
Total	0	2	10	12

Damage to Pipeline

The gas company abandoned approximately 200 feet of the 1 1/4-inch-diameter ABS plastic pipe and replaced it with PE 2306 plastic pipe. The two gas regulators and meters in apartment Nos. 9 and 10 were scorched but were otherwise undamaged. A gas company crew and foreman with radio trucks and a backhoe were dispatched, as were a superintendent and division manager. The gas company operating vice president and president were notified by telephone and kept informed of the details. No estimate of the cost of this activity was available.

Other Damage

Apartment Nos. 9 and 10 were destroyed (see figure 3), and apartment No. 8 sustained some structural damage and broken windows. One automobile was destroyed, two automobiles were damaged heavily, and three other automobiles and a motorcycle also were damaged.

Pipeline Information

A 2-inch-diameter, coated, wrapped, and cathodically protected steel gas main operating at 30 psig under North 37th Street supplied gas to this area of Phoenix. The 1 1/4-inch-diameter ABS plastic gas main involved in the accident was connected to the steel gas main by a valve (see figure 1). The ABS plastic main, which had been installed in 1969, extended west from its connection with the steel gas main under the driveway south of apartment Nos. 1 through 9 and terminated at the meters for apartment Nos. 9 and 10. Apartment Nos. 3, 4, 5, 7, and 8 were served by separate 1 1/4-inch-diameter extensions of this line; apartment Nos. 1, 2, and 6 were not served by gas.



**Figure 3.--Apartment No. 9 (top)
and apartment No. 10 (bottom) destroyed by fire.**

The ABS pipe involved in the accident was designated as type I grade II, new service thermoplastic pipe in the Plastic Pipe Manual for Gas Service published by the American Gas Association (AGA) and was manufactured by Kerona. ABS pipe is a blend of acrylonitrile, butadiene, and styrene. The three components are combined into a plastic material by the manufacturer and are supplied to the extruder in a granular form. The granules are processed by passing them through an extrusion machine which increases the temperature and pressure on the granules until the granules become a viscous mass. The viscous mass is forced through a die which forms it into the shape of pipe. ABS pipe is resistant to alcohols, mineral oils, and aliphatic (nonaromatic) hydrocarbons, but can be damaged by contact with acids, aldehydes, ketones, esters, and chlorinated hydrocarbons. The ABS pipe is semirigid, manufactured in 20- to 30-foot lengths, and is assembled by cementing two lengths together in a coupling and allowing the cement to dry for 10 to 15 minutes. The pipe also can be assembled using compression couplings and stiffeners.

Pipeline System

The Arizona Public Service Company was engaged principally in the generation and sale of electricity and in the purchase and sale of natural gas within the State of Arizona. The gas company delivered natural gas to approximately 338,000 customers in the Phoenix area. The gas company received all of its natural gas from one gas transmission company, El Paso Natural Gas, at five major town border stations and other smaller receipt points; the gas was neither filtered, scrubbed, nor dehydrated as it entered the gas company's distribution system. The gas company did not "fog" 4/ its system at any location.

The gas company's pipeline distribution system has about 12,000 miles of gas mains and service lines. The type of gas main and gas service line piping and the amount of use is shown in Table 1.

Table 1.—Gas piping and types and use.

<u>Pipe material</u>	<u>Miles</u>	<u>Percentage</u>
Steel	7,500	63
ABS plastic	2,400	20
polyethylene (PE) 2306 plastic	1,200	10
polyvinylchloride (PVC) plastic	600	5
polyethylene (PE) 3306 plastic <u>1/</u>	300	2
cast-iron	(400 feet)	0
Total system piping	<u>12,000</u>	<u>100</u>

1/ Used only for gas service lines.

The gas company installed ABS plastic pipe in its system from 1959 through 1971; its use was discontinued, according to the gas company, because the manufacturers of the ABS plastic pipe could no longer competitively meet the specifications called for by the gas company, and because it was more profitable to make ABS pipe for water usage. The gas company needed a dependable source of plastic pipe to support its distribution system

4/ "Fogging" is a process of adding liquid vapor to the natural gas in a distribution system to increase its moisture content to prevent the dehydration of joint packing materials; steam or hot oils are commonly used.

expansion program in the 1960's and 1970's, and when the ABS plastic pipe manufacturers could not meet the gas company's needs, the gas company discontinued its use of ABS plastic pipe and began using polyethylene (PE 3306) pipe plastic pipe for its service lines and polyvinylchloride (PVC) plastic pipe for its gas mains of up to 2 inches in diameter. Later, the gas company began using PE 2306 pipe as a replacement for both the ABS and PE 3306 pipe. The PE 2306 pipe is still being used by the gas company.

The gas company leak records are neither computerized for rapid retrieval nor studied for statistical analysis or trending. Most of the leak records are stored in boxes in a company warehouse, and a comprehensive leak record search would involve the examination of thousands of records, many of which are written in longhand. Each record would have to be analyzed before a meaningful tally could be produced. Most of the older leak records involve steel pipe; the plastic pipe leak records considered reliable by the gas company cover the period from 1971 to the present. A gas company representative said that the gas company relied upon field reports from the maintenance crews and the judgment of its management staff concerning these field reports to determine whether certain types of pipe had serious leakage problems that needed systemwide attention. He stated, as an example, that the gas company made a determination at a meeting with the commission on November 24, 1981, that a problem existed in its PE 3306 plastic pipe and that it would begin a replacement program. This determination was reached not by an analysis of records of ABS plastic pipe leaks, but by the collective memory of the foremen and superintendents who had seen the leaks and had shared their information. The problem with the PE 3306 pipe was determined to be premature aging wherein some of the pipe developed cracks or splits allowing the escape of gas. At that time the gas company had approximately 40,000 PE 3306 plastic pipe service lines in its system. By September 1984, approximately 30,000 of those service lines had been replaced with PE 2306 plastic pipe, and by March 1985 replacement was complete.

Gas company records for its ABS plastic pipe show that there was one failure each year in 1972, 1973, and 1974, and 95 failures from 1977 through 1983, of which 25 were required by 49 CFR 191.5 to be reported to the U.S. Department of Transportation (DOT) because the leaks resulted in ignition, deaths, injuries, or other reportable criteria. (See table 2.) The 95 failures include only instances of material failure and do not include failures caused by events such as excavation damage, tree root damage, or line pull-outs. The gas company in 1981 began an accelerated leak survey program, beginning first with all ABS pipe and gradually increasing its leak surveillance systemwide to include all plastic pipe from a 5-year period to a 1-year period. Therefore, more leaks were found than in previous years.

Table 2.—Plastic pipe failures.

<u>Year</u>	<u>Total failures</u>	<u>Failures reportable to DOT</u>
1977	7	4
1978	10	8
1979	11	3
1980	13	1
1981	19	3
1982	13	3
1983	22	3
	<u>95</u>	<u>25</u>

The gas company told the commission in 1982 that it intended to replace all 3- and 4-inch-diameter ABS plastic pipe because the company could no longer find a supplier for these sizes and because, if a failure did occur in these ABS pipe sizes, it would be difficult to shut off the flow of gas to the failed section and difficult to replace the failed section with a PE-type pipe and reconnect it to the ABS pipe; there is a possibility of splitting ABS pipe of this size when squeezing it off. The commission noted that between 1972 and 1981 it had been notified of only two ABS pipe failures of the 3- and 4-inch-diameter sizes. The gas company had not replaced any of the ABS pipe at the time of the September 25, 1984, accident. After the accident, the gas company informed the commission that laboratory analysis of some of the previous ABS pipe failures indicated premature aging and that the gas company was commencing a replacement program.

Title 49 CFR 192.723 requires that leakage surveys of the distribution system outside of the principal business area be made as frequently as necessary, but at intervals not exceeding 5 years. By March 1984, the gas company was inspecting its entire system annually while the replacement program was underway. After the accident, the gas company again accelerated its leak survey program, and leak survey crews began operating on a 60-hour workweek, 50 percent more than the normal 40-hour workweek used before the accident; this provided for more than the annual inspection.

The gas company had surveyed the accident site on June 2, 1983, using hand-held flame ionization packs for the gas service lines and had conducted a mobile flame ionization leak survey of the gas mains on August 16, 1984; no leaks were detected in either of these surveys.

At the time of the accident, the gas company was negotiating for the sale of its entire gas distribution system to the Southwest Gas Corporation. The sale was made on November 1, 1984, and the gas company has agreed to help Southwest Gas Corporation finance the replacement of up to 2,400 miles of prematurely aging plastic pipe in the system. ^{5/} Most of the gas company personnel, both supervisory and nonsupervisory, are now employed by the Southwest Gas Corporation.

Personnel Information

The gas company "troubleman," who was the first gas company employee to arrive at the accident site, had been employed by the gas company for 25 years and had served as a "troubleman" for the last 6 years. Within the last 12 months he had attended the gas company's 2-week-long gas service school, where he received instruction in gas leak detection, gas leak repairs, gas leak problem analyses, use of a CGI, repairs to gas company facilities, and problem solving. This was a refresher course for the "troubleman"; he had attended similar courses in the past.

The "troubleman" stated that he had not received any formal training regarding coordination and cooperation with the fire and police departments. He stated that he had received verbal instructions from his supervisor about reporting to the fire department command post, if the fire department was involved, and identifying himself. The "troubleman" also stated that he often found firefighters at the scene of a gas leak, but that, until this accident, he had never had any problems with firefighters interfering with his work or restricting his on-site activities.

^{5/} Pipeline Gas Journal, December 1984.

The Phoenix Fire Department's Standard Operating Procedures, M.P.209.03, Tactical Plans Hazardous Materials, provide a basic philosophy and strategic plan for emergencies involving hazardous materials. The department's HIRT members are provided training in a variety of hazardous materials situations including fires, spills, transportation accidents, chemical reactions, and explosions. The training includes the identification of hazardous materials, the containment of the hazardous materials, the evacuation of a contaminated area, the establishment of security around a hazardous area, and the stabilization and/or removal of the hazardous material. HIRT personnel are instructed in how and when to use CGI's in gas-related accidents, how to detect gas leaks visually, and how to work with and use gas company employees to pinpoint leaks and shut off the gas supply. The gas company did not provide any training to the fire department nor did the fire department request such training. However, individually some fire department personnel have accompanied gas company personnel in responding to leak calls and gas odor complaints.

Meteorological Information

The National Weather Service Forecast Office at Sky Harbor International Airport in Phoenix reported the following weather conditions between midnight and 4 a.m. on September 25, 1984: light rain showers with winds variable from zero to 4 knots and winds shifting from 240 to 120 degrees. The temperature dropped from 87° F at midnight to 79° F at 5 a.m. The accident site is approximately 3.5 miles north of the airport.

Medical and Pathological Information

As a result of this accident, 12 persons were hospitalized. Of the five persons who had been in apartment No. 9, three later died as a result of their burns, one had moderate to serious burns on his feet, legs, hands, and face, and one had minor burns to her feet. Of the three persons who had been in apartment No. 10, two later died as a result of their burns and one had second- and third-degree burns to his hands and face. Three persons, a neighbor and two policemen, who helped rescue the victims were injured.

Tests and Research

After the accident, approximately 10 feet of the 1 1/4-inch-diameter ABS plastic pipe containing the failure was removed from the excavation. A 36-inch-long piece of the pipe with the fracture in the center was cut from the 10-foot-long piece and was tested by an independent testing laboratory under the direction of the Safety Board. The test results showed that the pipe had lost flexibility and that the 3-inch-long crack was a localized brittle environmental stress crack that resulted from a chemical reaction between the ABS and an entrapped liquid that had settled along the bottom of the pipe. The liquid had stained the pipe bottom for a distance of 4 feet and to a maximum depth of 1/3 inch. Samples taken from portions of the failed pipe other than from the stained area showed no evidence of cracking. The examination showed a relatively slow crack growth until the crack had penetrated the pipe wall by slightly over 50 percent. The pipe failed rapidly when the internal gas pressure (30 psig) blew out the pipe wall in the cracked area. No liquid was found in the pipe at the time it was removed at the accident site. The liquid components could not be identified from the stains on the pipe. The report by the testing laboratory concluded also that: "Further failure could occur where similar conditions would allow or have already allowed the accumulation of the same liquid."

Safety Board investigators examined the results of tests of 10 other pieces of ABS plastic pipe that the gas company had obtained at the sites of previous failures and had sent to a laboratory for testing and analysis. All of the pieces of pipe were not identified specifically as to time and place of failure. The test results showed the following:

- o In 8 of the 10 samples the fracture was on the bottom of the pipe sample, coincident with the stains or other deposits which had collected on the bottom of the inside of the pipe while in service.
- o Nine of the 10 samples contained from one to four primary cracks, ranging in length from 2 to 40 inches. With one exception, all cracks were parallel to the longitudinal axis of the pipe.
- o Stains or evidence of liquid deposit were observed on the inside pipe wall in seven samples. Stained areas usually coincided with the location of either primary cracks or microcracking.

The gas company routinely drained liquids entrapped in the natural gas entering its distribution system at its city gate stations and other system low points; the presence of such liquids in a natural gas pipeline system is not unusual. The liquids were stored in 55-gallon drums and routinely shipped for disposal. The analysis of some liquids sent for disposal on November 13, 1984, made by the Waste Management disposal company was:

natural gas compressor station lubricants
brown colored liquid
strong odor of mercaptan
flash point 50.3° F exactly
pH between 4.1 and 6.9 (acidic)
volatile chlorinated hydrocarbons - 99 mg/l
benzine 230 mg/l
toluene 540 mg/l
ethylbenzene 6.4 mg/l
sulfides 5.2 ppm

The disposal company classified the material as a water-oil mixture composed of well head oils and compressor lubricating oils. The liquid was acidic and contained chlorinated hydrocarbons and aromatic hydrocarbons, all of which have been shown to deteriorate ABS plastic pipe.

Several samples of these liquids were examined by the independent laboratory. The samples were (1) a clear yellow oil collected over a period of some months and saved by the gas company, (2) a dark oil, similar in appearance to a lightweight motor oil, also collected by the gas company over a long period of time, and (3) a similar dark oil obtained in October 1984 from a liquid trap on a pressure regulator in Phoenix. The samples were tested at strain levels of up to 1.2 percent for 20 days. Only the clear yellow oil sample produced observable crazing after 6 hours at 1.2 percent. The oil was absorbed partially into the crazing, but when the applied stress was removed, the oil was seen exuding to the specimen surfaces. No apparent effect due to the oil was observed at lower stress levels even after 20 days. The gas company did not undertake any additional in-depth, chemical analysis of the collected samples and did not consult the El Paso Natural Gas Company about the origin of the liquids.

Other Information

Public Awareness of Natural Gas Hazards.--The gas company periodically mails to its customers information concerning natural gas odorization, what to do when gas odors are detected, and who to call. The gas company also periodically places notices in newspapers to disseminate similar information. Handbills and pamphlets containing the same information are available at gas company offices.

Two survivors of the fire in apartment No. 9 were questioned about their knowledge of natural gas, how to identify it, and what to do if gas is detected. They both were aware of the natural gas odors and knew who to contact. In fact, they had contacted the gas company about a year before the accident when they had detected gas odors, and the gas company had responded; no gas leak was located at that time.

American Gas Association Plastic Pipe Survey.--The AGA commissioned a special task force in 1982 to review plastic piping performance and to communicate the results of the review to gas companies. The task force developed a questionnaire to collect information from gas distribution companies on plastic piping system performance. Statistical data used with the questionnaire were derived from the 1981 leak history as reported annually by utilities to the U.S. Department of Transportation (DOT). In asking the gas companies to respond, the AGA suggested that the information collected, which was sensitive, be destroyed after the questionnaire was completed. Responses were received from 100 distribution utilities, including the Arizona Public Service Company, which destroyed its information after completing the questionnaire.

The task group report, "Plastic Pipe Performance," was presented at the AGA's 1984 Distribution/Transmission Conference in San Francisco, California. The report concluded:

- o No significant problems are indicated with current plastic gas piping materials.
- o Plastic piping is shown to have provided excellent service.
- o Leaks per mile of main and service for plastic are significantly lower than for other distribution system materials.
- o Plastic installation costs are less than half of the installation costs for other materials in 2" and smaller sizes.
- o The use of plastic is increasing both in size and quantity.
- o PE 2306 polyethylene was the predominant type of plastic being installed in 1981.
- o Isolated material and installation problems related to use of plastic pipe have been identified and have been or are being corrected by reporting companies.
- o No major problems were identified.

Concerning replacement of plastic pipe, the report noted the following:

Companies were asked if they currently have or have had in the past ten years a planned program to replace specific plastic pipe or fittings in plastic piping systems. Twenty-five utilities responded positively to at least one portion of this question.

More specifically, eighteen companies described programs for replacement of plastic pipe in the past ten years because of obsolescence in most instances. Programs for ten of the companies were for replacement of PVC, ABS, or CAB [Cellulose Acetate Butyrate]. Several of the products are known poor performers that are no longer on the market. Other replacement programs were the result of manufacturer's recalls when known deficiencies occurred during manufacture.

Isolated problems and recalls were identified with a few valves, couplings, and transition fittings.

* * *

Thirty companies changed the type of plastic pipe being installed during the last ten years for reasons other than cost or availability. Seven switched from PVC and one from RTRP [Reinforced Thermosetting Resin Pipes]. Three companies switched from medium density to high density PE for better pressure and/or crack resistance properties. Others changed from one PE to another PE for various quality or performance reasons. One company ceased using plastic because of reduced growth.

The questionnaire and its results and conclusions were based solely on the companies' 1981 leak histories; the task group plans to repeat the survey for the next several years to examine trends in plastic pipe performance.

U.S. Department of Transportation Plastic Pipe Statistics.—Title 49 CFR 192.617 requires the investigation of pipeline accidents and failures as follows:

Each operator shall establish procedures for analyzing accidents and failures, including the selection of samples of the failed equipment or facility for laboratory examination, where appropriate, for the purpose of determining the causes of the failure and minimizing the possibility of a recurrence.

Since 1970, Federal Register 49 CFR 191.5 has required operators of natural gas distribution systems of 100,000 meters or more to submit written reports of pipeline accidents that result in ignition, deaths, injuries, or other reportable criteria within 20 days after the detection of the leak. In the more than 14 years that the leak reporting system has been in operation, thousands of leak reports have been received and filed by the Materials Transportation Bureau (MTB) of the DOT's Research and Special Programs Administration (RSPA), and the data have been entered on computers. While the leak reports are categorized by the type of pipe involved (steel, cast-iron, plastic, copper, etc.), the category of plastic pipe is not defined further as to the type of plastic pipe (PE 3306, PE 2036, PVC, ABS, CAB, or other). Consequently, in searching the DOT data for plastic pipe failure rates, it is impossible to segregate ABS failures from any other plastic pipe failures unless a gas company voluntarily has listed the type of plastic pipe, which is rarely done.

In a 1980 evaluation of the MTB's pipeline data system, 6/ the Safety Board stated:

The evaluation found that Materials Transportation Bureau staff resources are limited, and that, consequently, use of the data to direct and focus resources is essential for the effective and efficient administration of the Pipeline Safety Act. The Safety Board concluded, however, that the data currently collected are often inaccurate and are not representative of gas pipeline operators and gas pipeline accidents.

Furthermore, the system is seldom used by MTB offices in carrying out their regulatory and enforcement functions, and there is little coordination regarding the system between the Safety Data Management Branch and the regulation and enforcement offices. The study found that the MTB does not have a pipeline data analysis plan, which the Safety Board believes is necessary to coordinate and direct the MTB offices in the use of the data system as a management tool.

As a result of this evaluation, the Safety Board issued the following Safety Recommendations to the MTB of the RSPA on August 20, 1980:

P-80-61

Develop and publish for public comment a formal data analysis plan for the pipeline data system.

P-80-63

Postpone promulgation of proposed, revised pipeline data forms until development of a data analysis plan and coordination of the forms with the plan.

P-80-65

Train existing personnel to more effectively validate incoming leak report forms.

The RSPA has not developed and published for public comment a formal data analysis plan. In its final rulemaking promulgating changes to its annual reports and incident reports, published in the Federal Register at 49 FR 18956, the RSPA stated that the new annual reports and accident report forms and procedures for data collection "... will adequately monitor trends and provide indicators of potential problem areas. . . ." The RSPA stated further that "... by mid-1985, MTB plans to initiate such a study of pipeline safety reporting requirements and the uses of the data, and will invite specific input from the public and industry, in addition to NTSB."

The Administrator of RSPA now believes that it would no longer be in RSPA's best interest to "develop and publish for public comment a formal data analysis plan for the pipeline data system" as recommended because the RSPA already has issued new incident report forms and annual report forms for gas distribution systems (RSPA F7100.1 (3-84) and RSPA F7100.1-1 (3-84), effective July 1, 1984). The Safety Board had classified

6/ Special Study--"Safety Effectiveness Evaluation of the Materials Transportation Bureau's Pipeline Data System" (NTSB-SEE-80-4).

Safety Recommendation P-80-61 as "Open--Acceptable Action" based on the RSPA statement that it would publish such a data analysis plan. This recommendation, however, now will be classified as "Closed--Unacceptable Action."

Although the RSPA initially postponed promulgation of proposed, revised pipeline data forms, so that the Safety Board classified Safety Recommendation P-80-63 as "Closed--Acceptable Action," the RSPA issued the new forms effective July 1, 1984, without undertaking the data analysis plan recommended by the Safety Board. Based on the change in position by RSPA on the need for a data analysis plan, this recommendation will now be classified as "Closed--Unacceptable Action."

The RSPA has instituted improved quality control procedures and the Safety Board has classified Safety Recommendation P-80-65 as "Open--Acceptable Alternate Action" pending the full implementation of statistical sampling.

The MTB has been using the revised accident report forms since July 1, 1984. If the operator accurately fills out the accident report form and if the data contained therein are filed accurately in the MTB data storage bank, the type of plastic pipe involved (ABS, PE, PVC, etc.) and the mode of failure (outside damage, material failure, etc.) now can be identified. However, the accident report form still does not require any reporting of the causes of material failures.

Gas Company-Fire Department Coordination.--Early in 1984, because of a misunderstanding concerning when, during the course of investigating a gas leak, the gas company should notify the fire department, the gas company and the Phoenix Fire Department drew up a Memorandum of Agreement. Fire department and gas company personnel met to clear up the communications misunderstanding and to set down in writing the circumstances in which the fire department would be notified of a gas leak. On May 25, 1984, the gas company emergency procedures were amended to include the following:

1.0 PURPOSE

To describe unique reporting requirements of certain situations within the cities of Phoenix and Chandler.

2.0 SCOPE

This practice specifies situations which require that notification be given to the Cities of Phoenix and Chandler Fire Departments, and the method by which such notification will be given.

3.0 GENERAL

3.1 The reporting requirements described in this practice apply only within the boundaries of the Cities of Phoenix and Chandler.

3.2 Similar situations in other municipalities may warrant notification to local Fire Departments. See:

GPM-C/S 210.10 - Emergency Incidents - APS [Arizona Public Service] Facilities

GPM-C/S 210.15 - Emergency Incidents - Reporting

GPM-S/C 210.20 - Emergency Incidents - Customer Facilities

4.0 SITUATIONS

The Cities of Phoenix and Chandler Fire Departments shall be notified when the following type situations are encountered within their city limits.

- 4.1 Any time people are to be evacuated or advised to evacuate because of a gas problem.
- 4.2 A gas concentration greater than 2 1/2 % is encountered underneath or within any building or in the atmosphere adjacent to any building.
- 4.3 A gas line break or rupture releases gas under pressure directly to the atmosphere.
- 4.4 Any situation which in the opinion of the APS representative on the scene creates a danger of ignition, explosion or asphyxiation or when any of these conditions has already occurred. However, any situation which can be corrected by the use of the red tag or red lock does not require notification to either Phoenix or Chandler Fire Departments.

5.0 METHOD OF NOTIFICATION

- 5.1 Employees who encounter any of the situations described in 4.1 through 4.4 of this practice will notify Dispatch as soon as possible.

NOTE: If emergency action is required to make any situation safe, notification should be made immediately after the emergency action has been completed,

The Fire Department did not issue similar procedures at that time, but after several meetings with the gas company, the fire department in October 1984 revised its standard operating procedures regarding natural gas incidents. (See appendix B.) In summary the procedures:

- o Describe the characteristics of natural gas (lighter than air, explosive 4 to 15 percent, nontoxic, pockets in attics and dead air spaces, should not be extinguished if burning).
- o Discuss the evacuation of civilians when gas is involved and limit the number of emergency personnel (gas company) in the affected area.
- o Instruct firefighters to use CGI's to check for gas, to start close to the building, and to take readings farther away until zero readings are obtained.

- o Secure all sources of ignition and ventilate building.
- o Use ground probes for gas-in-ground and gas migration surveys--record and map said readings. Repeat readings at later times to determine gas dissipation.
- o Require that the command post effectively interact with gas company personnel on site--gas company personnel are responsible for locating and eliminating any gas leaks.
- o Instruct all personnel to wear full protective clothing and if working in a suspected ignitable area, to use self-contained breathing apparatus (SCBA) and be covered by a charged hose line.
- o Require the number of exposed persons to be kept to a minimum at all times.

ANALYSIS

The Accident

The results of tests made on the pipe fracture found in the ABS plastic pipe at the accident site revealed that the pipe had deteriorated from a chemical reaction between the ABS plastic pipe and a liquid that had settled along the bottom of the pipe. It was not possible to tell how long the pipe had been deteriorating because it was not possible to determine either what the specific liquid was or how long the liquid had lain in the bottom of the pipe. The deteriorated pipe resulting from environmental stress cracking in the bottom of the pipe finally ruptured through the remaining pipe wall allowing natural gas to escape. Therefore, the pipe failure resulted from several conditions: first, a chemical action which deteriorated the pipe and produced internal cracks, and later, the internal cracks propagated through the pipe wall until finally the remaining pipe wall thickness could no longer contain the internal pressure. Without these conditions, the accident would not have occurred at that time.

The Safety Board is concerned that the problem with ABS plastic pipe revealed in this accident may exist in many other natural gas distribution systems nationwide. The DOT records of gas company accident report forms, which are compiled to identify industry problems and accident trends, are of no help in determining the extent of the ABS plastic pipe problem because, other than polyethylene plastic pipe, the specific type of plastic pipe involved in a failure usually is not recorded, nor are all material failures required to be reported. Therefore, the DOT is unable to analyze the problem, to establish conditions for the continued use of ABS pipe, or even to warn the gas industry about the problems already encountered. The DOT's new incident report forms, which became effective on July 1, 1984, refer specifically only to polyethylene plastic pipe. Therefore, an operator who experiences an ABS plastic pipe failure must check a box on the form designated as "other" and describe the specific type of plastic pipe elsewhere on the incident report form; this does not encourage reporting and provides an opportunity for errors.

The identification of volatile chlorinated hydrocarbons and other chemicals in liquids collected in the gas distribution system raises the issue of the compatibility of any type of plastic pipe with chemicals that may be introduced into a natural gas pipeline

system. The Safety Board is concerned with the possibility that other types of plastic pipe currently in use in gas distribution systems may have incurred material failures similar to the failure in this accident. The Board is aware that there have been material failures in the other types of plastic pipe, but how many, where, and what the causative factors were cannot be determined because the DOT's incident report forms, particularly those in effect prior to July 1, 1984, do not include this information.

The leak report records recently requested from the gas companies by the AGA and which it analyzed in its report on the safety of plastic pipe gas distribution systems were for a 1-year period. That time span is not long enough to establish a meaningful trend and certainly is insufficient to support the generally positive conclusions presented. Moreover, while the thrust of the AGA report is that there are no plastic pipe problems, the report's first conclusion stated that "no significant problems are indicated with current plastic gas piping materials" (emphases added). The report does not define "significant problems" and does not state if any significant problems were found with previously installed plastic gas piping materials still in use even though the report acknowledges that some companies have replacement programs for some types of plastic pipe.

The Safety Board believes that the sparse data available on plastic pipeline safety are insufficient to show that there are no problems, and concludes that the AGA report raises more questions than it answers: e.g., who were the companies with the problems, where were they located, are the problems continuing, what caused the problems, have the plastic pipe systems been replaced entirely, and have the gas pressures been lowered in the affected systems? The Safety Board concludes that the DOT should place a high priority on the identification and analysis of plastic pipe material failures to determine the extent of any problem which may exist. It may be that ABS plastic pipe material failures are not epidemic, but the analysis of 1 year's accident statistics from some AGA member companies is not sufficient to put the issue to rest. An extensive evaluation by the DOT in cooperation with the natural gas industry is necessary.

Investigation of Pipe Failures

Pipeline leak records provide an important source of information to a pipeline operator concerning the physical condition of the gas distribution system. Leak reports, aside from showing where the leaks occurred so that permanent repairs or replacement can be undertaken at a later date, are examined by prudent pipeline operators to determine the number, frequency, and distance of leaks in areas and to determine whether problems, such as corrosion, material failure, and improper installation exist. When making subsequent repairs or replacements, the operator should examine the pipe on either side of the leak and determine its condition. By carefully monitoring reliable leak records, the operation and maintenance departments, together with the engineering departments, often can determine the emergence of a problem before many leaks occur and thereby can rectify or mitigate the conditions before a serious accident occurs. Leak records, and their accuracy and availability, are of prime importance in pipeline operations; unanalyzed leak records filed in boxes in a company warehouse cannot provide readily available information and are virtually worthless.

If the gas company had established, as Federal regulation 49 CFR 192.617 requires, "procedures for analyzing accidents and failures, including the selection of samples of the failed equipment or facilities for laboratory examination, where appropriate, for the purpose of determining the causes of the failure and minimizing the possibility of a

recurrence," systematic study of the ABS plastic pipe failures in 1972, 1973, or 1974 would have alerted the gas company to problems developing in the ABS plastic pipe sections of its distribution system. If these pipe failures had been analyzed in a laboratory at that time, the gas company would have learned that the pipe was reacting with liquids in the system and could have determined where the liquids were coming from and how to exclude them. At the same time, the gas company could have been draining any liquids from known low spots in its system, analyzing these liquids to determine if they were reacting with the ABS plastic pipe, and determining the extent of the problem. Such action would have given the gas company at least a 10-year headstart on a pipe replacement program, a pressure reduction program, and a leak survey program. Replacement pipe could have been installed on a yearly basis, commencing in the areas of the first three failures, instead of in a crash program that followed after this accident. If these things had been done--early failure analysis, drainage and analysis of liquids, the decision to replace the ABS plastic pipe, and reduction of pressure on the ABS part of the distribution system--the gas company might have been able to replace the ABS pipe before the accident at North 37th Street occurred. In addition, and perhaps more importantly, the gas company could have disseminated its newly discovered information on ABS plastic pipe deterioration to its pipe suppliers, to the AGA, and to other gas pipeline operators at regional meetings. This information would have given everyone a headstart on identifying and solving their individual problems or might have deterred them from installing any more ABS plastic pipe until more was known about the problem. The Safety Board believes that Federal regulation 49 CFR 192.617 was developed to achieve this end. The Safety Board finds that other gas companies also are lax in sending failed pipe for laboratory analysis, and the Board believes that the Federal regulations should be enforced more strongly.

Emergency Response

The fire department's response to the fire was rapid. Firefighters correctly allowed the gas-fed flames to burn out in the ground rather than extinguishing them and risk allowing the natural gas to accumulate and reignite. However, the fire department's HIRT team did not use its CGI's correctly to determine the extent of gas migration and the extent of the gas hazard because they tested only in the open air and not within the ground around the apartments or other confined spaces.

Gas company personnel who first responded were excluded from the accident area first by the fire department and later by the police department and were therefore unable to determine, through their own investigation, the extent of gas leakage and the leak location. Nevertheless, the gas company "troubleman" should have specifically informed the first firefighter who barred him from the site that it was necessary for him to investigate to determine the extent of the hazard and that he had the expertise to do so. Unfortunately, the "troubleman" did not do so. The gas company personnel should have been used by the fire department as "experts" in leak search activities and should have been assisted by the fire department in the rapid pursuit of their work. If lack of protective clothing (including breathing equipment) was a factor in barring the "troubleman" and other gas company employees from the accident area, the clothing should have been provided. Firefighters did not realize the potential for additional gas fires or explosions because they had not probed in the ground with CGI's to determine more precisely the extent of gas migration, and they did not know where the gas was coming from.

The HIRT team used CGI's in apartment Nos. 7 and 8 to test the atmosphere. While the readings in the apartments both close to the floor and close to the ceiling showed no gas, gas may have been migrating into these buildings through the soil and within the walls and yet not have entered the apartments. The more responsible action by the fire department would have been to aid gas company personnel using CGI's by assigning, for example, two of the four HIRT team members to help the gas company employees and to obtain more gas in-soil readings. Such actions would have resulted in firefighters learning the extent of the gas migration more rapidly. Although the lack of cooperation and coordination between the fire department and the gas company did not prolong the fire or hinder the firefighting activities in this particular instance, under different conditions it could have proven catastrophic. The Memorandum of Agreement which both parties had previously adopted proved worthless because the fire department had not promulgated implementation procedures prior to this accident.

Public Awareness of the Hazards of Natural Gas

In this accident the gas was odorized adequately, as indicated by the heavy odors noticed when excavating for the leak and when tests were made after the accident at adjacent residences. The gas migration through the soil did not filter out much, if any, of the odorant because the people in apartment No. 9 were well aware of it at midnight as was the resident of an adjacent apartment earlier that day. Although no one telephoned the gas company or the fire department, they later said they were aware of the gas odors and were knowledgeable of what to do when odors were detected.

Even though gas companies have public awareness programs as prescribed by Federal regulations, the Safety Board continues to find cases involving a poorly informed or otherwise unresponsive general public. ^{7/} Perhaps by their nature company awareness programs cannot be strong enough, and the programs should be fostered or reinforced by Federal or State agencies to bring home the seriousness of the hazard of leaking gas. Gas companies are in business to sell natural gas and do not want to unduly alarm their customers and the general public about the potential hazards of escaping natural gas. For whatever reasons, they use low-key programs. State agencies having gas pipeline safety jurisdiction, together with the National Association of Regulatory Commissioners (NARUC), could make the awareness programs stronger, make them uniform nationwide, make them repetitive, and use a variety of media to reach all concerned. Such a program was undertaken by the Florida Public Service Commission in early 1979. The Safety Board believes that injuries might well have been prevented had the gas company or fire department been notified of gas odors. If the persons in apartment No. 9 or their neighbor who smelled gas had reported the gas odors to the gas company or to the fire department, this accident probably would not have occurred. There was ample time available to evacuate the area, to ventilate the buildings, and to shut off the gas supply before the explosion.

CONCLUSIONS

Findings

1. ABS plastic pipe can deteriorate by prolonged contact with acids and chlorinated hydrocarbons entrapped in natural gas distribution systems.

^{7/} Pipeline Accident Report—"Columbia Gas of West Virginia, Inc., Explosion and Fire, South Charleston, West Virginia, October 17, 1983" (NTSB/PAR-84/04).

2. An entrapped liquid which had lain for an unknown length of time in the bottom of the 1 1/4-inch-diameter ABS plastic pipe reacted chemically and produced internal environmental stress cracks in the bottom of the pipe which ultimately lead to the failure of the ABS plastic pipe.
3. The gas company does not and has not injected any liquids into its natural gas distribution system.
4. The liquids in the natural gas distribution system probably came from the gas transmission system and entered the distribution system at the town border stations.
5. The natural gas that the gas company receives from its sole supplier is neither filtered, scrubbed, nor dehydrated at any of the town border stations.
6. It is impossible to determine the extent of the problem nationwide because the accident reports filed with the Materials Transportation Bureau of the U. S. Department of Transportation do not identify the type of plastic pipe involved or the specific cause of failure, and few operators voluntarily report this information.
7. The American Gas Association's Plastic Pipe Survey based on some gas company leak reports for 1981 was not sufficiently extensive to produce conclusive results. An indepth, detailed leak history study is needed to verify that the continued use of ABS plastic pipe for gas distribution systems is safe.
8. The gas company's leak reports have not been kept current or properly filed for use in analyzing problems in its distribution system.
9. The gas company failure to analyze the cause of ABS leaks it encountered on a current basis delayed its discovery of the problem and initiation of its replacement program.
10. The gas company/fire department coordination and cooperation was ineffective during this accident even though a Memorandum of Agreement specifically directed toward improving their combined emergency activities had been implemented earlier between both parties.
11. Although the gas company program for educating its customers and the general public to the hazards of natural gas met the requirements of the Federal regulations, area residents who smelled gas before the accident did not have a sufficient sense of urgency and failed to notify the gas company or the fire department.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the deterioration and ensuing rupture of a 1 1/4-inch-diameter ABS plastic pipe due to weakening from internal environmental stress cracking that resulted from a chemical reaction between the pipe and liquid entrapped in a low spot in the pipe, which allowed natural gas at 30 psig to escape from the failed pipe and to migrate through the adjacent soil into and under two apartments, where it accumulated and was ignited by the

gas pilot light of a furnace. Contributing to the accident was the failure of persons who had detected gas odors earlier to report those odors to the gas company or to the fire department. Also contributing to the accident was the absence of a gas company program to analyze the cause of leaks as they occurred.

RECOMMENDATIONS

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

--to the Southwest Gas Corporation, as successor to the Arizona Public Service Company:

Continuously sample the natural gas stream at its town border stations for entrapped liquids, check the chemical composition of any liquids collected to determine their effects on ABS or other types of plastic pipe, and if indicated filter or otherwise remove these liquids before they enter the gas distribution system. (Class II, Priority Action) (P-85-8)

Periodically check for liquids accumulated at the low spots in its gas distribution system, remove any liquids found, and chemically analyze the liquids to determine their potential for deteriorating ABS or other types of plastic pipe. (Class II, Priority Action) (P-85-9)

Expedite the replacement of the ABS plastic pipe in its gas distribution system, beginning with known areas of liquid accumulation and other known low spots. (Class II, Priority Action) (P-85-10)

Continue its expedited leak survey program in all areas of its distribution system containing ABS plastic pipe until all of the ABS plastic pipe has been removed. (Class II, Priority Action) (P-85-11)

Operate the sections of its system using ABS plastic pipe at the lowest feasible pressure until all of the ABS plastic pipe has been removed. (Class II, Priority Action) (P-85-12)

Expedite the computerization of its leak reports to permit their rapid retrieval for review, analysis, and identification of potential material problems in its gas distribution system. (Class II, Priority Action) (P-85-13)

Establish failure analysis procedures in conjunction with computerizing its leak report system, to more rapidly detect and correct gas distribution piping problems. (Class II, Priority Action) (P-85-14)

Review with its dispatchers and operating personnel who routinely handle leak incidents, the Memorandum of Agreement with the Phoenix Fire Department, and emphasize the importance of coordinating and cooperating with firefighters. (Class II, Priority Action) (P-85-15)

--to the Phoenix Fire Department:

Review with its firefighters and Hazardous Incident Response Team members the Memorandum of Agreement with the Arizona Public Service Company, and emphasize the importance of giving gas company personnel access to gas leak sites so that they can determine the areas of gas hazard, locate the sources of leaking gas, and as required, shut off the flow of gas. (Class II, Priority Action) (P-85-16)

Review with the Southwest Gas Company or the equipment manufacturer the correct use of combustible gas indicators and the proper procedures for determining the extent of gas migration and degree of hazard, and retrain members of its Hazardous Incident Response Team. (Class II, Priority Action) (P-85-17)

--to the Research and Special Programs Administration of the U.S. Department of Transportation:

Establish a program to determine whether the problem of chemically induced ABS plastic pipe failure is nationwide. Include a review of the data maintained by the Plastic Pipe Institute, the American Gas Association, the Gas Research Institute, and others on ABS plastic pipe material failures. (Class II, Priority Action) (P-85-18)

Publish and distribute ABS plastic pipe failure data to gas operators nationwide, and develop recommended methods of eliminating or mitigating such failures. (Class III, Longer-Term Action) (P-85-19)

--to the Committee on Gas of the National Association of Regulatory Commissioners:

Develop programs to educate gas customers and the general public about the hazards of natural gas and actions to be taken during gas emergencies. (Class III, Longer-Term Action) (P-85-20)

--to the American Gas Association:

Notify its member companies of the circumstances of the natural gas pipeline accident in Phoenix, Arizona, on September 25, 1984, and urge them to analyze their leak records for similar ABS pipe material failures to determine whether a safety hazard exists within their systems. (Class II, Priority Action) (P-85-21)

--to the Plastic Pipe Institute:

In cooperation with the American Gas Association and others, determine what materials present in natural gas distribution systems may adversely affect ABS plastic pipe and what, if any, remedial actions should be taken. Publish and distribute this information to gas operators nationwide. (Class III, Longer-Term Action) (P-85-22)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G. H. PATRICK BURSLEY
Member

June 12, 1985

APPENDIXES

APPENDIX A

INVESTIGATION

The National Transportation Safety Board learned of this accident via the National Response Center at 10 a.m., e.d.t., on September 25, 1984, and an investigator from the Fort Worth Field Office was dispatched immediately to the site. Two investigators from the Safety Board's Washington, D.C., headquarters also were dispatched to the site. Parties to the investigation were the Arizona Public Service Company, the Arizona Corporation Commission, and the Phoenix Fire Department. A staff-conducted deposition regarding this accident was held in Phoenix, Arizona, on October 21 and 26, 1984.

APPENDIX B

PHOENIX FIRE DEPARTMENT
STANDARD OPERATING PROCEDURES

<p>Tactical Plans HAZARDOUS MATERIALS Natural Gas Incidents</p>	<p>PHOENIX FIRE DEPARTMENT STANDARD OPERATING PROCEDURES M.P. 209.03D 10/84-R Page 1 of 3</p>
<p>Fire Department units may encounter natural gas in a variety of situations and incident types, each presenting a different set of hazards and problems. The following guidelines present an approach which will be applicable in the majority of situations, but do not replace good judgment and experience in dealing with any particular incident. The guidelines should be used whenever situations are encountered that do not clearly indicate a different approach is required to more safely resolve the hazard.</p> <hr/> <p>Natural gas is much lighter than air and will dissipate rapidly in the outside environment. Inside buildings, however, it tends to pocket, particularly in attics and dead air spaces. The flammable limits are approximately 4% to 15% in air. Natural gas itself is nontoxic, however, it displaces oxygen and can result in asphyxiation if in a confined space.</p> <p>Burning natural gas should not normally be extinguished, since this would change the situation from a visible to invisible hazard with explosive potential. Fires should be controlled by stopping the flow.</p> <hr/> <p>A. <u>INCIDENTS AT WHICH AN EXPLOSION HAS OCCURRED</u></p> <p>Units arriving at the scene of a structure explosion must consider natural gas as a possible cause. Explosions have occurred in structures which were not served by natural gas. Underground leaks may permit gas to travel considerable distances before entering a structure through the foundation, around pipes or through void spaces. In these circumstances, the cause of the explosion may be difficult to determine.</p> <ol style="list-style-type: none">1. Until it can be determined that the area is safe from the danger of further explosions, evacuate all civilians and keep the number of Fire Department and/or other emergency personnel (i.e., gas company personnel) in the area to the minimum number necessary to stabilize the situation. Take a pessimistic point of view.2. Do not rely on gas odor. Use combustible gas indicators to check all suspected areas. Both gas company personnel and the Hazardous Incident Response Team (H.I.R.T.) have combustible gas indicators for this purpose.3. Check areas systematically using combustible gas indicators. Start close to the area of the explosion, and increase the area until readings indicate no detectable concentration. Map the readings for the affected area.	

<p>Tactical Plans HAZARDOUS MATERIALS Natural Gas Incidents</p>	<p>PHOENIX FIRE DEPARTMENT STANDARD OPERATING PROCEDURES M.P. 209.03D 10/84-R Page 2 of 3</p>
<p>4. If a gas concentration is encountered inside, adjacent to, or underneath any building, secure all possible sources of ignition in the affected area. Cut electricity from outside the affected area to avoid arcing. Ventilate buildings where gas is found.</p> <p>5. The use of ground probes is essential to evaluate potential underground leaks. When gas company personnel are on the scene, ground probe readings and locations must be coordinated. Time, location and concentration should be recorded for each probe - subsequent readings should be taken from same holes when possible.</p> <p>6. Command shall provide for effective interaction between gas company personnel and the Fire Department. Gas company personnel are responsible for locating and eliminating leaks in the gas system. As industry specialists, they can provide Command with valuable assistance in the effective handling of these incidents.</p> <hr/> <p>B. <u>INCIDENTS INVOLVING A REPORTED GAS LEAK - NO FIRE OR EXPLOSION</u></p> <p>Calls for "odor of gas," "gas leak," "broken gas line" and similar situations may range from minor to potentially major incidents. All of these should be approached as potentially dangerous situations.</p> <p>With gas company personnel on the scene of an incident, it shall be standard procedure for the first Fire Department unit to provide effective interaction between agencies. Gas company personnel shall be responsible for locating and eliminating leak sources. Gas company personnel and/or the H.I.R.T. shall obtain a sufficient number of gas concentration readings, using their combustible gas indicators for Command to evaluate the hazard and take appropriate action.</p> <p>In all cases, Fire Department units shall take whatever actions are necessary to provide for life and property safety.</p> <p>The Hazardous Materials Plan, M.P. 209.03, should be used as a basic guide for these incidents. A minimum number of personnel should be allowed to enter the area to size-up the situation while any additional units stage in a location out of the potentially dangerous zone.</p> <ol style="list-style-type: none">1. Evacuate any civilians in the area of escaping gas.2. Attempt to locate the source of the gas and any shutoff devices available.	

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<p>3. Gas leak situations within a building where the source of the leak is unknown or uncontrolled, the gas supply shall be shut off at the meter. Command shall ensure the meter is red-tagged and locked off until repairs are completed. This is most easily accomplished with the cooperation of the gas supplier at the scene.</p> <p>4. If there is any indication of gas accumulating within a building, evacuate civilians from the structure and control ignition sources. Shut off electrical power from an outside breaker. Check for explosive concentrations with a combustible gas indicator if there is any suspicion of accumulation within a structure. Ventilate using blowers to pressurize if necessary.</p> <p>5. If gas company personnel must excavate to shut off a leak, provide stand-by protection with a charged 1 1/2-inch line and a firefighter in full protective equipment.</p> <hr/> <p>C. PERSONNEL SAFETY</p> <p>All personnel working in the vicinity of a known or suspected gas leak shall wear full protective clothing. Personnel working in a suspected ignitable atmosphere (i.e., attempting to shut off a gas line) shall <u>USE</u> SCBA and shall be covered by a charged protective hose line. The number of exposed personnel will be kept to an absolute minimum at all times.</p> <p>A safety perimeter shall be established and maintained around any suspected gas leak. "Fire line" tape should be used to identify the safety perimeter when necessary.</p>	