

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

PIPELINE ACCIDENT REPORT

**THE GAS SERVICE COMPANY
NATURAL GAS PIPELINE RUPTURE
AND FIRE
KANSAS CITY, MISSOURI
JUNE 12, 1978**

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB-PAR-78-5		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Pipeline Accident Report -- The Gas Service Company, Natural Gas Pipeline Rupture and Fire, Kansas City, Missouri, June 12, 1978				5. Report Date December 7, 1978	
				6. Performing Organization Code	
7. Author(s)				8. Performing Organization Report No.	
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Accident Investigation Washington, D.C. 20594				10. Work Unit No. 2533	
				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 June 12, 1978	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract <p>At 1:30 p.m., c.d.t., on June 12, 1978, a 10-inch pipeline owned by the Gas Service Company was struck and ruptured by excavation equipment during construction of a sewer in Kansas City, Missouri. Natural gas, at more than 110-psig pressure, escaped from a 5-inch-long hole in the 2-foot-deep pipeline. At 3:15 p.m., the gas ignited while two gas company employees were cleaning the pipe with hand tools prior to installing a pipe repair clamp. Both men were burned seriously.</p> <p>The National Transportation Safety Board determines that the probable cause of the accident was the rupture of the pipeline by heavy excavating equipment operated by an unsupervised equipment operator. The sewer contractor had failed to previously establish the exact horizontal and vertical locations of the pipeline either by digging test holes or by requesting the gas company to locate the pipeline more precisely. Sparks from hand tools used to clean the pipe prior to its repair ignited the escaping natural gas which seriously burned two gas company employees.</p>					
17. Key Words Excavation damage; equipment operator; pipeline rupture; working foreman; pipe-cleaning tools; emergency valve; repair clamp; protective clothing; emergency plan; pipeline cover; State excavation damage laws; electronic pipe locator.				18. Distribution Statement This document is available to the public through the National Technical Informa- tion Service, Springfield, Virginia 22151	
19. Security Classification (of this report) UNCLASSIFIED		20. Security Classification (of this page) UNCLASSIFIED		21. No. of Pages 24	22. Price

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Adopted: December 7, 1978

THE GAS SERVICE COMPANY
NATURAL GAS PIPELINE RUPTURE AND FIRE
KANSAS CITY, MISSOURI
JUNE 12, 1978

SYNOPSIS

At 1:30 p.m., c.d.t., on June 12, 1978, a 10-inch pipeline owned by the Gas Service Company was struck and ruptured by excavation equipment during construction of a sewer in Kansas City, Missouri. Natural gas, at more than 110-psig pressure, escaped from a 5-inch-long hole in the 2-foot-deep pipeline. At 3:15 p.m., the gas ignited while two gas company employees were cleaning the pipe with hand tools prior to installing a pipe repair clamp. Both men were burned seriously.

The National Transportation Safety Board determines that the probable cause of the accident was the rupture of the pipeline by heavy excavating equipment operated by an unsupervised equipment operator. The sewer contractor had failed to previously establish the exact horizontal and vertical locations of the pipeline either by digging test holes or by requesting the gas company to locate the pipeline more precisely. Sparks from hand tools used to clean the pipe prior to its repair ignited the escaping natural gas which seriously burned two gas company employees.

INVESTIGATION

The Accident

On June 6, 1978, the Torson Construction Company (contractor) called the Gas Service Company (gas company) dispatcher and requested that the gas company's natural gas pipeline be located in an area where the contractor was installing an 18-inch-diameter, clay tile sewer for the city of Lee's Summit, Missouri (city), within the city limits of Kansas City, Missouri. An inspector from the gas company located the 10-inch pipeline with an electronic pipe locator and placed two flags over it 75 feet apart, one on each side of the permanent sewer easement. Each of the yellow flags was 2 feet high and had the words "buried gas line" printed on it. The contractor was shown the location of the two flags, but did not inquire, and was not told, about the depth of the pipeline. There were permanent pipeline markers over the pipeline 149 feet to the west and 575 feet to the east of the proposed sewer crossing. These markers were partly obscured by weeds on the pipeline right-of-way. The pipeline markers in relation to the sewer easement

indicated that a trench for the proposed sewer would cross the pipeline at an angle of 60 degrees. (See figure 1.)

On June 12, 1978, the contractor planned to grade the sewer easement in the area where the plans showed the sewer crossing the pipeline. About 7 a.m., the superintendent instructed an equipment operator to dig a 5-foot-deep and 15-foot-wide "bench" along the centerline of the sewer with a large diesel Caterpillar tractor, Model 977 Highloader, from which a medium-size backhoe could excavate down to the planned 20-foot depth of the sewer. The equipment operator was shown the location flag on the east side of the sewer right-of-way but not the other location flag or the permanent pipeline markers.

The superintendent for the contractor had placed an iron stake in the ground over the centerline of the proposed sewer near the intersection with the gas pipeline as a guide for the excavation and also to mark the limit of construction for the highloader. He stated that he had told the operator, who was excavating from the north, to stay 5 feet north of the stake, and that the depth of the pipeline was about 30 inches.

The operator stated after the accident that he had been told that the pipeline was south of the stake, and that his instructions were to excavate up to the stake but not beyond it. He apparently did not realize that the pipeline crossed the sewer easement on a 60-degree angle, and that the pipeline would be about 3 feet farther north and closer to his bucket at the west side of the excavation than where the stake had been placed.

At 11:30 a.m., the superintendent called the gas company's engineering department and requested the depth or "cover" of the gas pipeline, and asked who was to support the pipeline across the open excavation. The engineering department told the superintendent that most of the company's newer pipelines were buried 30 inches deep, but that this 48-year-old pipeline had been purchased from another company, and, because there were no records concerning its depth, he would not speculate as to its cover. He suggested to the superintendent that the gas company dispatcher could send an inspector to the site to establish the exact location and depth of the pipeline, and that the inspector should be there when the contractor supported the pipeline across the open excavation. However, the dispatcher's line was busy when an attempt was made to transfer the call to request that an inspector be sent. The superintendent was given the dispatcher's telephone number and was asked to call when the line was not busy. The superintendent did not call the dispatcher as recommended because the contractor's large backhoe, the primary piece of excavating equipment, was more than 100 feet from the pipeline crossing and would not be used at the crossing that day.

About 1:30 p.m., one of the 6-inch-long teeth on the bucket of the highloader struck the gas pipeline before the iron stake was reached. The operator realized that he had punctured the pipeline when the

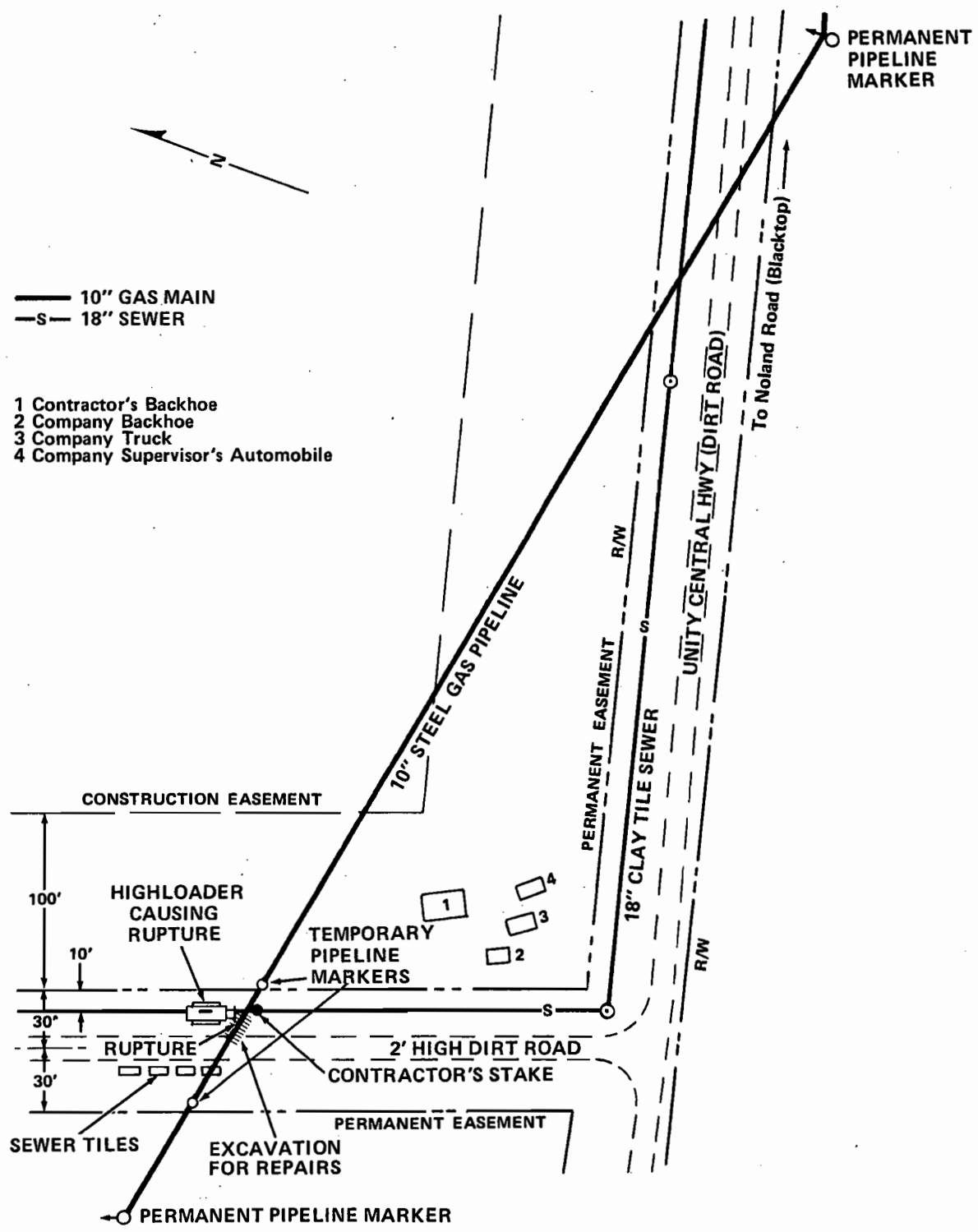


Figure 1. Plan view of accident site.

high-pressure gas blew dirt up as he backed from the 24-inch-deep excavation. He immediately shut off his highloader and ran clear of the blowing gas. The superintendent and another worker who were within 10 feet of the rupture also moved away.

The contractor soon notified the gas company dispatcher of the rupture and a leak specialty man (who was also the inspector that had located the pipeline earlier) went to the site, investigated the extent of the damages, and called for a repair crew. All of the repair crews assigned to the supervisor of the district where the accident occurred were on jobs that could not be left unfinished. A supervisor from another district had overheard the emergency radio transmissions, had a crew that was free to travel, and volunteered its use. A four-man crew was dispatched at 1:45 p.m. A "pressure and measurement" crew was also dispatched to lower the 130-psig pressure in the pipeline at a regulator station 11 miles upstream of the rupture.

At 2:20 p.m., a gas company supervisor joined the leak specialty man at the accident site and determined that a leak repair clamp could be installed without shutting down the pipeline and interrupting gas service. About 2:30 p.m., the working foreman and two members of the gas company repair crew arrived in their truck; a rubber-tired backhoe and the fourth man arrived later. The crew first insured that the engines of the contractor's equipment near the pipeline rupture were not left running near the blowing gas. Next, the crew arranged for the contractor's large backhoe to work upwind (north) of the rupture and to tow the abandoned highloader tractor from the rupture area. After securing the area, the crew unloaded some of its emergency repair equipment and a large 150-pound fire extinguisher.

At 2:35 p.m., the pipeline rectifier, about 1,000 feet east of the rupture, was shut off by a technician from the gas company's corrosion engineering department. About 2:40 p.m., the leak specialty man shut off a 10-inch pipeline valve approximately 2,000 feet to the east and downstream of the rupture to prevent a backfeed. He also helped a man from the pressure and measurement crew install a pressure gauge at this location to monitor the rate that the pressure was being bled off the pipeline through the rupture.

The repair crew positioned the fire extinguisher about 25 feet upwind of the rupture, and the hose and nozzle were brought to within 10 or 15 feet of the fire area. At 2:40 p.m., the crew started excavating around the ruptured pipeline with the rubber-tired backhoe positioned west of the rupture. They excavated a 6-foot-wide by 6-foot-long by 4 1/2-foot-deep opening around the pipe to provide working room for two men to install a repair clamp. The crew used hand signals to communicate with each other when the hole was being dug because of the roar of the escaping gas. Most of the crew wore earplugs because of the noise. The excavation was completed about 3:00 p.m., and the gas company backhoe was moved about 100 feet from the rupture and its engine was shut off.

The gas company supervisor's car was parked, with its engine off, more than 100 feet from the rupture. The supervisor, lying down in the front seat of the car and trying to communicate on a 2-way radio above the roar of the blowing gas, could not see the progress of the work and did not know that the workers were preparing to enter the excavation to clean the pipe. The men monitoring the pipeline pressure reductions radioed the supervisor and informed him that the pipeline pressure at the point of the rupture had been reduced from about 110 psig to 80 psig; the pressure had stabilized and was being reduced by the loss of gas through the rupture and by customer usage at the rate of 2 psig every 5 minutes.

Shortly before the excavation was started, it had been discovered that the wrong size full-encirclement repair clamp had been sent to the job site. The repair clamp was designed exclusively for cast-iron pipe which has a larger outside diameter (OD) than the steel pipe. The clamp could not be used on the steel pipeline because its minimum OD was 11 inches, which would have left a 1/4-inch gap for the gas to escape through. A repair clamp of the correct size was ordered and was en route to the site.

The supervisor had tentatively planned to install the repair clamp when the pipeline pressure had been reduced to about 30 psig, which would have been after 5 p.m. However, he did not tell this to the repair foreman, who had heard parts of an earlier radio conversation and thought that the clamp had to be installed at a pressure of about 60 psig. It was on the basis of this earlier information that the foreman entered the trench and started to clean the pipe without consulting his supervisor. He carried a hammer, rasp, hack saw, and safety walk tape (3-foot-long strips of 1-inch-wide grit paper generally used on concrete steps to provide better footing) into the trench with him.

A few minutes later, the pipefitter also entered the trench and started cleaning the pipe west of the rupture with a steel rasp. Each man had cleaned from 12 to 18 inches on the top and south side of the pipe to provide sufficient room to install the 15-inch-long repair clamp. The pipefitter was using the rasp to remove a tar-like coating that appeared to have been brush-coated on the pipe when it was installed. The foreman could not remove some wet clay that was sticking to the bottom of the pipe with the cleaning tools that he had brought into the trench. He asked the pipefitter's helper to get a "butcher-block" brush from a company truck. The 8-inch-long brush had flat, tempered-carbon steel bristles that were 0.115 inch wide by 0.017 inch thick by 1 inch long. About 3:12 p.m., after the foreman started to use the butcher-block brush on the pipe and while the pipefitter was also using the rasp on the pipe, the escaping gas ignited.

The men in the excavation heard a pop, and those farther away saw a 50-foot-high ball of flame erupt from the pipeline rupture. Both men climbed out of the shallow east end of the trench because the excavated

dirt had been piled high on the west end of the trench and could not be scaled. Coworkers extinguished the flaming clothing of both men who were later taken by ambulance to a local hospital.

The Kansas City Fire Department arrived at the accident site within minutes. Firemen could not extinguish the flames until the pipeline pressure was lowered to 10 psig at 5:22 p.m.

Injuries to Persons

<u>Injuries</u>	<u>Operating Personnel</u>	<u>Rescue Personnel</u>	<u>Other</u>
Fatal	0	0	0
Nonfatal	2	0	0

Damage to Pipeline

Because the pipeline was capable of being operated at over 20 percent of its specified minimum yield strength (SMYS), a repair clamp over the 5-inch-long hole would not, according to company procedures, constitute a permanent repair. It was initially thought that the temporary repair clamp could be safely installed without shutting down the pipeline and interrupting service to several hundred customers. However, after the fire started and the pipe became red hot, it would not have been possible to install the temporary repair clamp without first allowing the pipe to cool because the rubber gasket material on the clamp would melt. Therefore, the temporary repair clamp was not installed, and a "stopple" ^{1/} plug was inserted on the west side of the rupture by 10 a.m. on the day after the accident. This action resulted in all of the pipeline up to the closed valve 2,000 feet east of the rupture being taken out of service, and the gas to 13 customers was interrupted for several hours. The damaged section of pipe was then cut out of the pipeline and replaced with a 10-foot-long section of pre-tested pipe.

Personnel Information

On the morning of the accident, one of the four equipment operators for the contractor was rotated from his job as a crane operator to the job on the highloader. This rotation of operators was in accordance with a recent union agreement whereby the contractor could use operators on any equipment needed for a particular operation. The equipment operator had been hired by the contractor 3 weeks earlier and had worked exclusively as a crane operator up to that morning. The operator had extensive experience on large equipment and had operated highloaders on other construction projects. The contractor had not assigned a helper

^{1/} "Stopple," a trademark of T. D. Williamson, Inc., is a sealing device that can be inserted into a pipeline under pressure to stop the flow of gas and permit the portion of the pipeline between stopples to be cut out and the damaged pipe removed

to the operator as a line spotter or grade man to assist in locating underground utilities with a shovel before the operator began the excavation. Both the equipment operator and the contractor's superintendent resigned from their jobs shortly after the accident.

The two injured gas company workers were experienced in gas pipeline maintenance and repair work. However, they had normally worked on distribution mains where the pressures did not exceed 30 psig. There had never been an unintended ignition on any of their previous repair jobs. This was the first time that they had repaired this large of a diameter, high-pressure transmission pipeline. Their training had consisted of mainly on-the-job type training. The company did not have a formal training program to instruct employees on the use of tools and how work on a higher pressure transmission pipeline might differ from that on a distribution main.

Other Damage

There was no other property damage in this accident. The nearest farmhouse was 365 feet to the southwest, and the next nearest structure was more than one-quarter mile away.

Pipeline System

The 10.75-inch OD, steel pipeline had been installed by the Panhandle Eastern Pipeline Company in 1930 and had been purchased by the Gas Service Company in 1960. It had been designed and operated for the transportation of natural gas in excess of the 275-psig pressure limitation that the Gas Service Company imposed on the pipeline when the company purchased it on October 1, 1960. At 28 percent of SMYS and a maximum allowable operating pressure (MAOP) of 275 psig, the maximum flow rate in the pipeline was 15 million cubic feet per day (MMCFD). Because the current daily flow rate was between 2 MMCFD and 3.5 MMCFD, the operating pressure had been reduced in late 1975 to 130 psig. The pipeline also was looped and fed from the west at 100-psig pressure. The pressure in the pipeline at the time and point of the rupture probably exceeded the 110 psig reported when it was first checked at 2:40 p.m., 70 minutes after the rupture occurred.

The physical and chemical specifications for the 48-year-old pipeline were unknown, but the pipe had a wall thickness of 0.219 inch which had not been reduced because of corrosion. The pipe had been brush-coated when installed with what appeared to be a type of tar, but the pipeline was considered to be bare pipe. The gas company had installed a cathodic protection rectifier 775 feet east of the rupture in October 1973, and pipe-to-soil readings taken before and after the accident showed the pipeline to be protected cathodically at the point of the rupture. The pipeline had a history of few leaks. On November 16, 1977, a walking patrol leak survey with a portable, flame-ionization detector did not find any leaks in the vicinity of the rupture; this was the last leak survey taken before the accident.

The nearest upstream valve was 10,400 feet west of the rupture and the nearest downstream valve was 2,000 feet east of the rupture. There were several hundred customers located between the two valves.

The gas company considered this entire pipeline to be in a Class 3 location ^{2/} even though the accident site was rural. The Federal regulation (49 CFR 192.327) requiring a cover of 36 inches in a Class 3 location did not apply to this pipeline because it was installed before 1970.

Meteorological Information

The sky was clear and the temperature at the time of the accident was 77° F. The wind was out of the north-northwest at 11 mph. However, the construction work was being done in a valley, and the workers described the wind there as a "slight breeze" from the northwest. The relative humidity was 44 percent.

Fire

The cylinder of the fire extinguisher was full of dry chemical which had been pressurized with compressed air. The man using the extinguisher had been trained in extinguishing medium-pressure (30-pound) gas fires burning in 2-foot-wide by 4-foot-long pits. However, because of the heat from the burning gas, the man could only get to within 15 feet of the rupture, which was not close enough to place the dry chemical at the base of the fire where it would be effective in extinguishing the fire. The escaping gas also blew the dry chemical away from the rupture.

The first firetruck to arrive had no water supply and there were no nearby hydrants. The firemen then radioed for additional help and for pumpers that carried their own water. Fifteen firetrucks eventually arrived from other locations. As many as three water streams were directed to the base of the flames at the same time but failed to extinguish the fire; the pressure in the pipeline was estimated to have been about 80 psig when the firemen began their effort. The firemen present, both regular and volunteer, had not been trained to leave a gas fire burning under controlled conditions. They stated that they believed they should extinguish the fire so that the pipe repair clamp could be installed. The gas company did not suggest to the fire department that there were alternatives to putting out the fire. The fire department stated that the gas company had said that to shut down the line completely was impractical because many feeds were involved.

^{2/} 49 CFR 192.5 defines a Class 3 location as basically an area that extends 220 yards on either side of a 1-mile-long segment of pipeline that contains 46 or more buildings intended for human occupancy.

After the pipeline pressure was lowered to 10 psig, the fire was finally extinguished after several loads of dirt were bulldozed over the rupture and water streams were simultaneously directed on the remaining flames.

Medical and Pathological Information

The injured workers had second- and third-degree burns over 60 percent of their bodies.

Survival Aspects

Both of the injured men were able to climb out of the east and south sides of the excavation, which were from 3 to 5 feet deep. The men were not able to scale the west embankment of the trench because of the height of the excavated dirt.

One of the injured men was wearing a short-sleeve polyester shirt and polyester pants. Flames burned and melted his clothes; someone extinguished the flames with a fire extinguisher. The other man was wearing a long-sleeve cotton shirt which caught on fire. Another worker tried to extinguish the flames by rolling the man on the ground. The shirt was finally ripped off the injured worker.

Both of the men wore safety equipment -- hard hats and safety goggles -- in accordance with company safety procedures. The equipment only partially met the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) regulations. No separate Department of Transportation (DOT) regulations have been issued by the Office of Pipeline Safety Operations (OPSO) in 49 CFR 192 about safety equipment or protective clothing for gas workers. However, an Advance Notice of Proposed Rule Making (ANPRM) about this subject was issued by the OPSO for the DOT on December 22, 1976. To date, a Notice of Proposed Rulemaking (NPRM) has not been issued as a result of the ANPRM.

Tests and Research

Tests were not made on the ruptured pipe. After the accident, the two location flags on either side of the sewer easement were found to have been correctly placed over the pipeline. The contractor's iron stake could not be found, however.

Other Information

Events Preceding the Accident. -- Plans for the sewer construction were drawn by the city's consulting engineers and submitted to the gas company for comments in December 1976. The depth of the gas pipeline shown on the profile portion of the prints was drawn at 3 1/2 feet. In a responding letter, the gas company did not mention that the cover shown might not be correct, because the drawings were for design presentation purposes only and it appeared that the pipeline would not

conflict with a small-diameter sewer that was to be installed 20 feet deep. The prints were approved by the gas company and routinely stamped with the notation: "THESE ARE APPROXIMATE LOCATIONS AND ARE NOT TO BE TAKEN AS EXACT."

The gas company's letter covered four major points, as follows:

1. Weld reinforcing sleeves were to be welded on the pipe weld across the open-cut sewer excavation and 25 feet on either side of the cut area. The gas company was to do the welding on its own pipelines and was to be reimbursed for its expenses.
2. The consulting engineers would design a 12-inch-wide, 50-foot-long I-beam to suspend the gas main across the open-cut sewer excavation and submit the drawing to the gas company for approval.
3. The backfill and pipeline support restoration was to be adequate.
4. Prior notice was to be given to the gas company of intent to perform any work where the sewer would cross the gas main(s). This notification was to be for the purpose of having a gas company representative present to witness the work.

The bid documents and specifications dated August 24, 1977, stated that the city or engineers did not guarantee the accuracy or completeness of the subsurface information. It was the contractor's responsibility to "perform exploratory operations necessary to verify the location, elevation and dimensions of all known or suspected underground obstructions ahead of any work affected thereby and to use care to avoid damage to them." The contractor was also to notify the owning utility of the approach to its facility and to conform to the utilities requirements to protect it.

The 1977 specifications did not mention that the contractor should also comply with a Missouri law known as the Underground Facility Safety and Damage Prevention Act (Senate Bill No. 583) that became effective in 1976. This act requires that before making an excavation in any public street or easement, a contractor should give notice to and obtain information from the utility being crossed. The notice could be by written or telephonic inquiry. The utility should "inform such excavator as promptly as practical, but not in excess of two normal working days from receipt of the notice, unless otherwise mutually agreed, by some reasonable and customary means of the correct location of underground facilities in or near the area of excavation so as to enable the person engaged in the excavation work to locate the facilities in advance of and during the excavation work."

On January 12, 1978, a preconstruction meeting was held with the contractor, city representative, and the consulting engineer. The gas company was not invited to attend the meeting.

During January and February 1978, several other letters concerning the preparation of the drawing showing the I-beam pipeline support were sent to the gas company. The final drawing indicated that the cover on the 10-inch gas pipeline was 3 1/2 feet (plus or minus). One of the letters from the gas company to the consulting engineer stated: "As before it is essential that prior notice be given to the Gas Service Company of the intent to perform any phase of work related to the sewer crossing of gas main(s) and facilities."

Sewer construction started about March 1, 1978, and the gas company installed reinforcement sleeves over the welds on the 10-inch pipeline on March 15, 1978. The excavations made by the gas company were left open for several weeks because it was too wet to backfill the openings after the work on the welds was complete. The contractor was aware of the excavations and complained that they were interfering with his work. The consulting engineer made no attempt to change the profile drawings that showed the erroneous 3 1/2-foot cover measurement. The workers for the gas company did not measure the depth of the pipeline after reinforcing the welds even though there was a place for this information on the Pipe Condition Report Form which they had made up and sent into the office. The gas company did not require that all information requested on the form be supplied.

Emergency Plan. -- The gas company's 47-page emergency plan contained an index of emergency valve locations. The plan stated that the pressure in the pipeline was to be controlled by the pressure and measurement department. The one page of instructions for that department included the statement that "shutdowns are to be coordinated with other divisions."

In this accident only one emergency valve was operated, and the pressure reduction was coordinated with the other divisions. However, the determination of what constituted a safe repair pressure, or what would be the lowest allowable operating pressure of this segment of the pipeline, was not considered in the emergency plan or the maintenance procedures. The pressure reduction was handled on an ad hoc basis which required the supervisor to stay by his radio and help in the coordination of the pressure control activities instead of supervising the activities of the pipeline repair crew.

The gas company had met with some of the fire departments in the area and had shown training films which dealt mainly with gas fires in houses. However, there had been no coordination with fire department officials concerning both planned and actual response to gas pipeline ruptures, as required by 49 CFR 192.615, nor had there been any instructions to fire department personnel to leave gas-fueled flames burning under controlled conditions, where possible, so that reignition of the unseen escaping gas would not cause another accident.

ANALYSIS

The fact that the pipeline was shallower than usual and that nobody knew of its exact depth had little to do with this particular accident. If the pipeline had crossed the sewer easement at a right angle, a pipeline that was buried deeper might not have been hit because the equipment operator might have stayed farther away in order to leave a 1:1 angle of repose in the soil around the pipeline so that the reference stake would not be disturbed. Nevertheless, the heavy excavation equipment should not have been allowed to operate that close to the gas pipeline, especially without a line spotter or other close supervision for safer operation. The contractor was clearly in violation with the intent of the specifications and the State law which required that, "...the person engaged in the excavation work locate the facilities in advance of and during the excavation work."

The Federal regulations on cover, which were not in effect when this pipeline was installed, generally provide for a normal cover in a Class 3 location of 36 inches. A minimum cover of 24 inches would currently require that the pipeline be provided with additional protection to withstand anticipated external loads. Many companies design the protection against external traffic loads as also a shield against outside forces when costly city street construction justifies such expenditures. However, there are no simple remedies for protecting the shallow, older rural pipelines from damage by external outside forces except increased vigilance.

The gas company had located its pipeline twice before the accident. The first time was on March 15, 1978, when it exposed the pipeline to install weld reinforcement sleeves. The second time was on June 6, 1978, when the gas company staked the line. Each time, the contractor and the gas company could have begun to coordinate their activities and to establish the exact location and cover of the pipeline.

When the gas company excavated the pipeline and installed the weld reinforcement sleeves, the contractor should have marked the exact location and cover of the pipeline for future reference. The long delay in backfilling provided ample opportunity for the contractor either to measure the 2-foot pipeline depth and locate the pipeline himself or to arrange to have the gas company install 4-foot-long, wooden lath-type, temporary pipeline markers over the pipeline. The delay in backfilling also provided the consulting engineer ample time to determine precise elevations on the exposed pipeline and change the profile drawings that showed the erroneous 3 1/2-foot cover measurement.

The gas company crew that welded on the weld reinforcement sleeves and completed the Pipe Condition Report Form failed to determine the depth of the pipeline and record it on the form because the gas company

did not insist on the form being completed in every respect. It is possible that the company emphasized the reporting of corrosion damage, which was of more interest than the depth of the pipeline. In this particular instance, the depth of the pipeline was possibly the most important information. It should have been recorded on the form and sent to the engineering department for incorporation on a pipeline map because the cover was less than current standards. Then, when the contractor called, the engineering department could have told him that the cover was only 2 feet, and that it was 1 1/2 feet shallower than shown on the consulting engineer's drawings.

The second time the gas company located the pipeline, on June 6, 1978, it was located by an inspector using an electronic pipe locator. The previously excavated openings over the pipeline had been backfilled and the location flags were placed over the pipeline where the pipe locator signals were the greatest. After the accident, the two location flags on either side of the sewer right-of-way were found to have been correctly placed over the pipeline; the iron stake the contractor had installed was missing. The flagging accuracy was probably due to the fact that the pipeline was very shallow and there were no other underground metallic lines to interfere with signals transmitted to the electronic pipe locator. Interference probably would have occurred in an established street which contained other utilities. A less proficient gas company inspector using an electronic pipe locator in a more congested location might have staked a deeper pipeline a foot or more from the actual centerline of the pipeline.

Some State excavation damage laws, such as Michigan's, require a minimum 3-foot-wide strip of protection around the utility to provide for possible location errors. The Missouri law does not provide such a buffer zone for instrument or operator error. The Missouri law should be changed to include hand-dug test holes, or other proven, accurate methods, to establish the precise location of underground utilities. All other location methods should be considered to have determined only approximate locations that require a buffer zone. A wider buffer zone for underground utilities crossing at less than a right angle should also be considered in the proposed law amendments.

On June 6, 1978, when the gas company inspector showed the contractor the two yellow flags he had placed over the pipeline, the contractor did not question the depth of the pipeline. If the depth of the pipeline had been questioned, the inspector could have used a probe bar to establish the depth of the pipeline. Because this meeting in the field was the first face-to-face meeting between the contractor and the gas company regarding the gas pipeline crossing, all of the questions regarding the crossing should have been asked and discussed at that time. If the gas company had had a project coordinator, he could have accompanied the inspector to the site to discuss the crossing in detail

with the contractor. A project coordinator also would have had a copy of all drawings and correspondence that the engineers had agreed on concerning the crossing. The drawings that were in the contractor's and gas company's offices showing the I-beam pipeline support and the gas pipeline at a 3 1/2-foot depth, could have been brought out to the field and discussed in detail. Such a discussion really should have taken place at the preconstruction meeting, but the gas company had not been invited to participate in this meeting.

A project coordinator also could have kept the gas company engineers and the consulting engineers informed. The 3 1/2-foot depth that was shown on at least two of the consulting engineer's drawings, between December 1976 and February 1978, was not questioned by the gas company's engineering department. However, someone involved in the gas company's field maintenance operations probably would have known from previous excavations that the pipeline cover was actually closer to 2 feet than to 3 1/2 feet and might have questioned the accuracy of the stated cover.

On June 12, 1978, the contractor's superintendent called the gas company engineering department specifically to inquire about the depth of the pipeline and asked who was to support the pipeline across the open excavation. The superintendent should have had the two drawings in the field that showed the erroneous 3 1/2-foot cover. When he was told that the gas company did not know the precise depth of the pipeline, he should have suspected that the drawings might not be correct.

The superintendent did not call back the dispatcher and ask for an inspector as instructed; it was the contractor's responsibility, as stated in the specifications, to "verify the location, elevation, and dimensions of all known or suspected underground obstructions ahead of the work"

With a 160-foot-wide construction and permanent easement available, the 50-foot-long I-beam pipeline support could have been installed before June 12, 1978, without too much interference with the large construction equipment. It would not have taken much time for a small crew with an operator, a line spotter, and a small rubber-tired backhoe to completely expose the 10-inch pipeline in the presence of the gas company inspector and support it with the I-beam as shown on the drawing. While the use of a small rubber-tired backhoe and a line spotter is a better practice than using heavy equipment near the pipeline, it certainly is not the best practice. Hand excavation until the pipeline is exposed and precisely located is by far the safest practice.

Apparently, there had been a lack of communication between the equipment operator and the superintendent as to how close the highloader should come to the pipeline. There should have been a helper or line

spotter standing over the pipeline to keep the bucket at least 5 feet from the pipeline, if that was the superintendent's intent, instead of allowing the bucket of the highloader to dig up to the unattended iron stake as the equipment operator thought was his order. The superintendent, who was standing within 10 feet of the highloader at the time of the pipeline rupture, also should have been aware that the highloader was too close to the pipeline and should have checked its progress before the pipeline was punctured.

The superintendent should have briefed the equipment operator, who had been operating a crane on a different portion of the sewer project before that morning, more adequately especially since its exact depth was not known. If the operator had been shown the permanent pipeline markers on either side of the excavation, which were 725 feet apart, instead of just the one temporary marker flag and the iron stake, he would have known that the sewer excavation would cross the pipeline at a 60-degree angle, that the pipeline was close to his proposed excavation, and that the pipeline would be almost 3 feet closer to the tractor's bucket on the west side of the excavation than at the center of the excavation.

If the gas company had had a project coordinator on this job, he could have made the crossing more obvious to any operator by having a right-of-way maintenance crew cut a wide path in the weeds up to and around the permanent marker signs. If the 3-foot-high weeds had been cleared from around the signs, the pipeline crossing location would have been clearer to everyone in the contractor's crew. A project coordinator also could have observed, from the progress of the elevated construction road and the stringing of the sewer tiles, that the west 2-foot-high pipeline marker flag would be obscured from view. He could have had the obscured flag replaced with another permanent pipeline marker or a more prominent temporary marker.

Emergency Procedures

The gas company repair crew cannot be faulted for piling up dirt on the west side of their excavation around the pipeline because the backhoe operator was working near blowing gas and wanted to get the job done rapidly. However, a place for a ladder should have been provided on the west side of the trench because the opening was more than 4 feet deep in addition to the height of the piled-up dirt. It cannot be determined whether the worker stationed west of the opening would have been burned less if he had had a ladder to climb, but if the worker east of the rupture had fallen and blocked the shallow east entranceway to the trench, only having one exit direction could have resulted in a fatality.

The roar of the escaping gas near the pipeline rupture prevented normal communications and probably contributed to what appears to have been a lack of communications between the foreman and the supervisor.

It should be noted, however, that the foreman and this crew were the only maintenance group available at the time of the accident and did not normally work for this supervisor. It would have been helpful if they had worked together previously and intuitively knew what each person would attempt to do. Equally important, the company should have had formal training for distribution repair crews to teach them how to safely work on the higher pressure transmission pipelines.

The foreman had overheard some of the radio conversation between the supervisor and the men monitoring the pressure shortly after he arrived. He was working under the assumption that the 80-psig pipeline pressure could only be lowered to 60 psig. The supervisor had not mentioned that he thought the pressure eventually could be lowered to 30 psig. It cannot be established with certainty that a fire would not have occurred even with the lower 30-psig pressure that the supervisor had thought of as a "safe" working pressure. However, at the lower pressure, the injured men might have been burned less severely and the fire might have been extinguished more easily. The gas company did not have procedures that stated what a "safe" repair pressure might be. The sequence of steps to be taken to repair the pipe had not been discussed and the time needed to complete each step had not been estimated. The foreman's last conversation with the supervisor, concerning the reordering of the correct size repair clamp, was before the rupture had been excavated completely.

The hand tools that the foreman carried into the trench were all company issued and were the type used to repair all distribution and transmission pipelines regardless of the operating pressure. The same type of steel tools, some of which would generate a spark if rubbed vigorously on a steel pipeline, had all been used previously by the crew but only on distribution gas mains with pressures up to 30 psig. They had never caused gas to ignite before when used around blowing gas. Because steel tools were used to clean the pipe and because these tools generate more sparks than tools designated as "spark proof", the gas company should have offset this additional spark hazard by requiring the men to wear more protective clothing to lessen the effects of an accidental ignition.

Usually, distribution main leaks occur at pressures of up to 30 psig. Even though the pressure in this instance was 80 psig, the gas could still only have ignited if the gas-air mixture was in the narrow 5 to 15 percent "explosive" mixture range. There are many cases where sparks have been generated in a trench but no ignition has occurred because the gas-to-air mixture was too lean (0 to 5 percent) or too rich (15 to 100 percent). However, the Safety Board concludes that even though no one saw the instantaneous spark, one must have occurred in that narrow 10 percent ignition range because the fire started in the trench where there were no other sources of ignition except for the rasp and butcher-block brush that were being used by the men in the trench.

The gas company's placement of the fire extinguishers to protect the workers in the trench was correct and the extinguisher was used effectively to put out the fire on one of the workers. However, the 150-pound fire extinguisher was not effective against this large fire even though it was operated properly by a man who was experienced in extinguishing smaller 30-psig pressure fires. The three water streams from the fire hoses also were not effective in extinguishing the fire until the pressure was reduced to 10 psig and dirt was pushed into the trench. By then -- 4 hours after the fire started -- it did not make much difference whether or not the fire was extinguished. The fire was not threatening life or property. In this particular accident, there was no need to extinguish the fire once it had started.

The gas company was concerned that service to many of its customers would be disrupted if the ruptured line was shut off completely by the use of emergency valves. Therefore, the gas company decided initially that its most expeditious procedure would be to put a temporary sleeve over the rupture and make permanent repairs at a later date and at an appropriate time. However, the steel pipe had become red hot and would require time to cool down after the fire was extinguished and before the clamp could be slid over the rupture, because the hot pipe would have melted the rubber gaskets of the clamp. Another option available to the gas company would have been to use a stopple, but this was not immediately available and would have required additional hours to install. By bulldozing dirt around the ruptured pipe, the flames were extinguished, gas service was maintained, and the gas company then made preparations to stopple the line, remove the ruptured section, and replace it with a new section.

The gas company did not have an effective emergency plan. It had not met nor coordinated with all of the appropriate fire department officials concerning both planned and actual response to gas pipeline ruptures. Liaison with the fire department was also lacking in that the fire department was not aware of the gas company's final decision to use stopples instead of the sleeve after the fire was put out. The fire department, had they been adequately trained, probably would have allowed the gas-fueled flames to continue to burn under controlled conditions; this would have reduced the possibility of an unplanned reignition of the gas. The Safety Board previously has commented on the advisability of allowing gas-fueled fires, once ignited and the damage done, to continue to burn under controlled conditions. In this case the gas company's concern for its customer service and its desire to let the pipe cool down caused them to extinguish the fire and risk reignition of the gas.

As a result of an accident which killed four men on March 29, 1978, in Oklahoma City, Oklahoma, the Safety Board recommended on August 28, 1978, that the Materials Transportation Bureau (MTB) of the U.S. Department of Transportation:

Expedite its role in setting standards for gas company (employees) safety and health, promulgate necessary regulations, and coordinate all actions with the Occupational Safety and Health Administration to assure that regulations developed are compatible.

In this accident, several aspects of employee safety were not covered by Federal regulations. Although the hard hats and safety goggles did provide some burn protection and possibly saved the vision of the injured men, a hood and flame-resistant coveralls and gloves, which are not currently required by Federal regulations, would have provided more protection. The MTB should either set clothing standards for gas company employee safety or assist OSHA in establishing these needed standards as soon as possible.

Polyester work clothing should be banned for all gas company employees working around blowing gas where ignition could occur and set their clothes on fire. In this accident, the worker wearing the short-sleeve polyester work uniform supplied by the company was burned more severely -- even though his flaming clothes were extinguished with the fire extinguisher -- than the worker who wore cotton clothing including a long-sleeve shirt.

CONCLUSIONS

Findings

1. The contractor violated Missouri law because he did not locate the pipeline in advance of the excavation work.
2. The contractor did not make a diligent effort to precisely establish the location and depth of the pipeline by digging tests holes, as called for in the construction specifications, before using excavation equipment in the vicinity of the pipeline.
3. No pipeline depth measurements were made by the gas company, contractor, or consulting engineer when the pipeline was exposed for maintenance in the spring of 1978.
4. The horizontal location of the buried pipeline was accurately flagged by a gas company inspector 1 week before the accident.
5. The contractor's first telephone inquiry about the depth of the pipeline, 2 hours before the accident, was not followed up by a second call for an inspector to establish the exact depth of the pipeline; the gas company also did not follow up on the telephone inquiry.

6. The contractor's superintendent did not give adequate instructions to the operator of the highloader concerning the gas pipeline's location and depth before the operator started the excavation.
7. The crossing of the pipeline at a 60-degree angle brought the west end of the pipeline 3 feet closer to the excavation equipment than it would have been at the centerline of the sewer, and its shallow 2-foot depth also made it more vulnerable to excavation damage.
8. The gas company crew had received on-the-job training, but they did not have formal training about how repairs to higher pressure transmission pipelines might differ from repairs to distribution mains.
9. There was a communication problem between the gas company foreman and his supervisor concerning the installation of a repair clamp because of the roar of the blowing gas.
10. The hand tools used by the gas company workers to clean the pipeline were made of steel and generated the spark that ignited the blowing gas.
11. The dry chemical fire extinguisher and three water streams from the fire engine pumpers were not sufficient to extinguish the large gas fire when the pressure was about 80 psig.
12. The pipeline crossing location would have been more noticeable to everyone in the contractor's crew if the 3-foot-high weeds had been cleared from the pipeline right-of-way and around the permanent markers.
13. The gas company had no procedures that stated what a "safe" repair pressure might be.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the rupture of the pipeline by heavy excavating equipment operated by an unsupervised equipment operator. The sewer contractor had failed to previously establish the exact horizontal and vertical locations of the pipeline either by digging test holes or by requesting the gas company to locate the pipeline more precisely. Sparks from hand tools used to clean the pipe prior to its repair ignited the escaping natural gas which seriously burned two gas company employees.

RECOMMENDATIONS

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

-- to the Gas Service Company:

"Improve liaison with the municipalities and consulting engineers within its operating area and request that the gas company be notified of all preconstruction meetings to determine if gas facilities will be affected by the construction activities. (Class II, Priority Action) (P-78-68)

"Improve communications and cooperation between its engineering and field personnel to insure that responsible gas company employees are aware of a contractor's questions regarding gas facilities as the contractor's work progresses. (Class II, Priority Action) (P-78-69)

"Require its personnel to record all information requested on the Pipe Condition Report Form. Any pipeline depth of less than the minimum required in 49 CFR 192.327 should be carefully noted on pipeline maps and other records. (Class II, Priority Action) (P-78-70)

"Revise its emergency plan to show what segments of a pipeline can be taken out of service for repairs, and establish the maximum safe operating pressures for repairs to such pipelines. (Class II, Priority Action) (P-78-71)

"Revise its emergency plan to include all of the liaison and coordination requirements of 49 CFR 192.615, and provide training material to local fire departments about the hazards of extinguishing gas fires. (Class II, Priority Action) (P-78-72)

"Include in company maintenance procedures the requirement that vegetation on pipeline rights-of-way and around line marker signs be cleared before construction equipment is used near gas pipelines. (Class II, Priority Action) (P-78-73)

"Require the use of flame-retardant material in the uniforms of personnel required to work in gaseous atmospheres. (Class II, Priority Action) (P-78-74)

"Train its distribution repair crews to work safely on high-pressure transmission pipelines. (Class II, Priority Action) (P-78-75)"

-- to the Torson Construction Company:

"Protect pipelines to be crossed during construction by verifying the location, elevation, and dimensions of all known or suspected underground obstructions ahead of the work and by reviewing all requirements in the specifications with its field supervisor. (Class II, Priority Action) (P-78-76)

"Establish an early liaison with the gas company before commencement of construction projects and coordinate the field activities of the construction crews to afford maximum protection of pipeline facilities. (Class II, Priority Action) (P-78-77)

"Require its employees to precisely establish the horizontal and vertical locations of gas pipelines by means of hand-excavated test holes before allowing heavy excavation equipment in the area of a pipeline crossing. (Class II, Priority Action) (P-78-78)"

-- to the Occupational Safety and Health Administration of the U.S. Department of Labor:

"Establish standards for gas industry safety clothing to protect workers repairing leaking gas pipelines where ignition of the gas could cause serious burns. (Class III, Longer Term Action) (P-78-79)"

-- to the Governor, State of Missouri:

"Amend State law to specify the use of hand-excavated test holes, or other proven, accurate method, to establish a precise depth or location of the underground facility, and to establish a wide buffer zone beside a pipeline location, over which heavy equipment cannot operate, to allow for errors in establishing the approximate location of underground facilities. (Class III, Longer Term Action) (P-78-80)

"Require municipalities to incorporate the amended State 'Underground Facility Safety and Damage Prevention Act' in the specifications of construction projects which use large excavating equipment and during which gas pipeline facilities will be crossed, and require that the contractor have the specifications with the State law requirements at the job site for ready reference by the workers. (Class III, Longer Term Action) (P-78-81)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A. HOGUE
Member

December 7, 1978