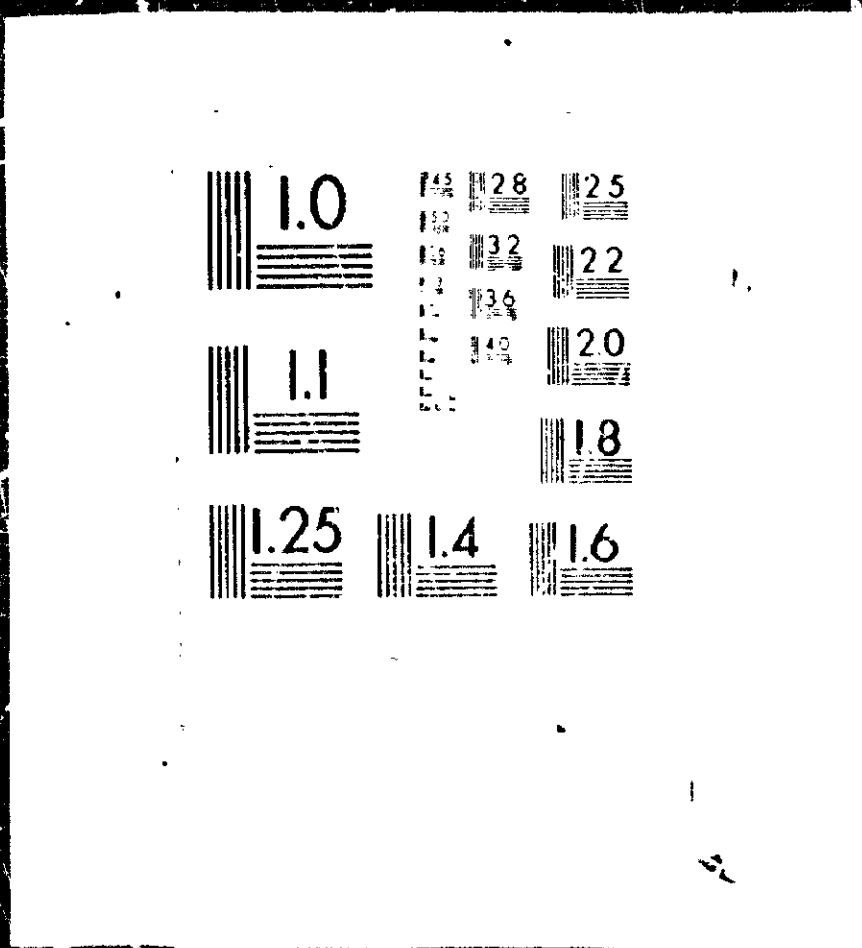


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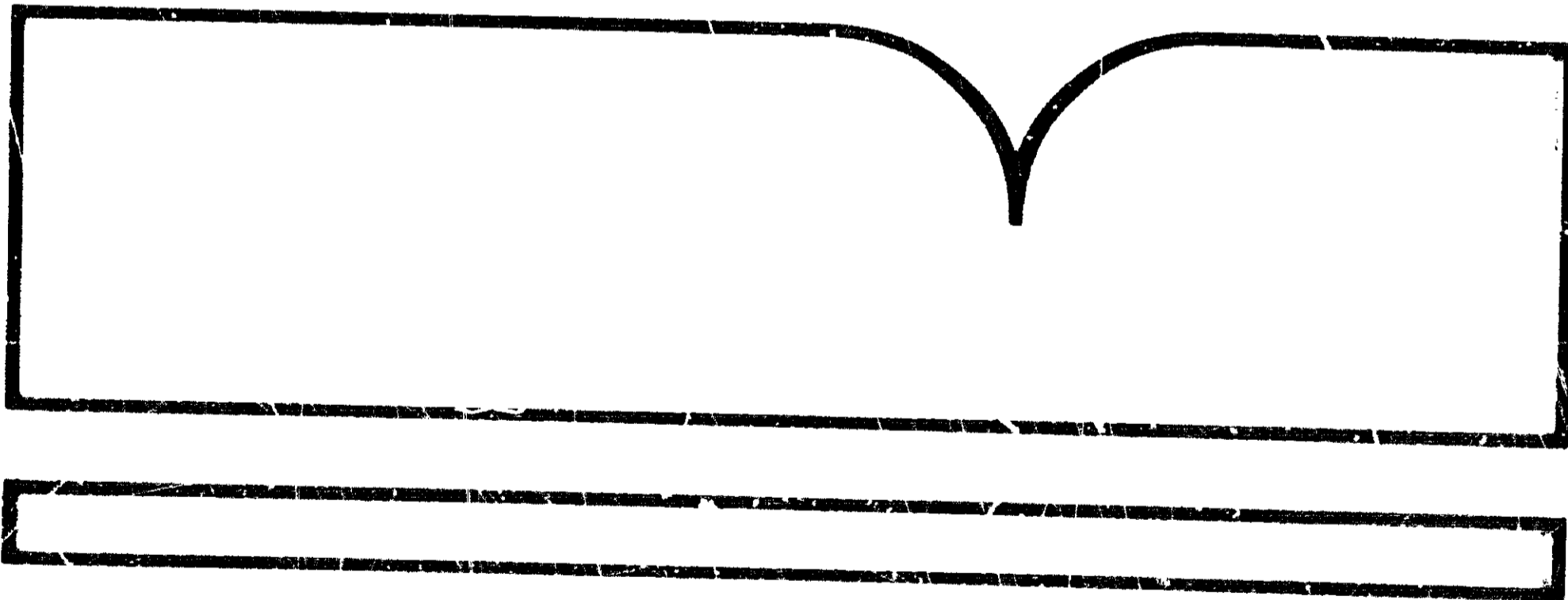


PB86-916503

Pipeline Accident Report - Northeast
Utilities Service Company, Explosion and
Fire, Derby, Connecticut, December 6, 1985

(U.S.) National Transportation Safety Board
Washington, DC

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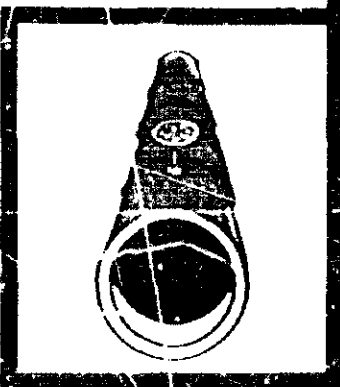
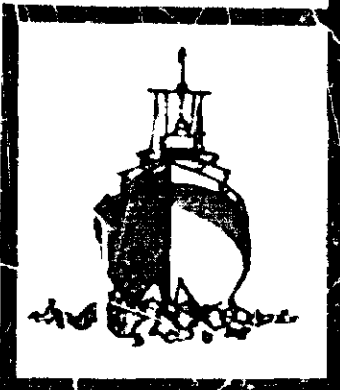
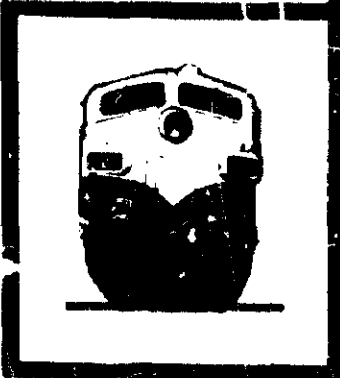
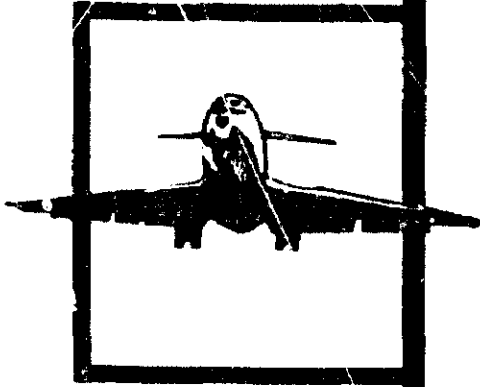
PIPELINE ACCIDENT REPORT

NORTHEAST UTILITIES SERVICE COMPANY
EXPLOSION AND FIRE
DERBY, CONNECTICUT
DECEMBER 6, 1985

NTSB/PAR-86/02

UNITED STATES GOVERNMENT

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16. Abstract About 3:55 p.m., eastern standard time, December 6, 1985, a natural gas explosion and fire destroyed the River Restaurant at 268 Main Street in Derby, Connecticut. Gas escaping from a broken gas main at a pressure of about one pound per square inch had escaped, migrated into the restaurant basement, ignited, exploded, and burned. Of the 18 persons inside the restaurant at the time, 6 were killed and 12 were injured; 1 passerby and 1 firefighter were also injured. After the accident the street adjacent to the restaurant, was excavated where a 24-inch diameter sewer system had just been installed; an 87-year-old, 3-inch diameter, cast-iron natural gas main was found to be broken. The National Transportation Safety Board determines that the probable cause of the explosion and fire in the restaurant was the improper planning, execution, and supervision of construction activities on the parts of the construction company and the gas company which resulted in the undetected fracture of the 87-year-old, 3-inch diameter, cast-iron gas main.					
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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

PIPELINE ACCIDENT REPORT

Adopted: November 14, 1985

NORTHEAST UTILITIES SERVICE COMPANY
NATURAL GAS EXPLOSION AND FIRE
DERBY, CONNECTICUT
DECEMBER 6, 1985

SYNOPSIS

About 3:55 p.m., eastern standard time, December 6, 1985, a natural gas explosion and fire destroyed the River Restaurant at 268 Main Street in Derby, Connecticut. Gas escaping from a broken gas main at a pressure of about 1 pound per square inch had escaped, migrated into the restaurant basement, ignited, exploded, and burned. Of the 18 persons inside the restaurant at the time, 6 were killed and 12 were injured; 1 passerby and 1 firefighter were also injured. After the accident the street adjacent to the restaurant was excavated where a 24-inch diameter sewer system had just been installed; an 87-year-old, 3-inch diameter, cast-iron natural gas main was found broken.

The National Transportation Safety Board determines that the probable cause of the explosion and fire in the restaurant was the improper planning, execution, and supervision of the construction activities on the parts of the construction company and the gas company which resulted in the undetected fracture of the 87-year-old, 3-inch diameter, cast-iron gas main.

INVESTIGATION

Events Preceding the Accident

In 1985, the city of Derby, Connecticut, contracted with the New England Railroad Construction Company (contractor) to separate the city's combined storm and sanitary sewer system into individual systems. This Federally assisted project included the installation of new storm sewers, the disconnection of related service laterals from the older combined system, and the reconnection of these laterals, as appropriate, to the individual storm or sanitary system. This contractor had six years of experience in constructing sewer, water, and other systems.

Section 12.1 of the contract specified that:

- 12.1 The CONTRACTOR will supervise and direct the WORK. He will be solely responsible for the means, methods, techniques, and procedures of construction. The CONTRACTOR will employ and maintain on the WORK a qualified supervisor or superintendent who shall have been designated in writing by the CONTRACTOR and the CONTRACTOR'S representative at the site. The supervisor shall have full authority to act on behalf of the CONTRACTOR and all communications given to the supervisor shall be as binding as if given to the CONTRACTOR. The supervisor shall be present on the site at all times as required to perform adequate supervision and coordination of the WORK.

The city of Derby also hired Philip W. Genovese and Associates, Incorporated (Genovese), consulting and design engineers, to monitor the work performed by the contractor. Genovese was formed in 1940 and since that time have designed numerous rail, highway, water sewer, and related projects. Sections 2.9, 2.11, and 2.13 of the agreement between Derby and Genovese describe some of the duties, limitations, and responsibilities of, and the hold harmless clause protecting Genovese:

2.9 The ENGINEER shall not be responsible for the acts or omissions of any Contractors, any subcontractors or any of the Contractors' agents or employees or any other persons (except his own employees and agents) at the project site or otherwise performing any of the work on the project.

* * * * *

2.11 If requested by the OWNER, a Resident Project Representative and assistants will be furnished and will act as directed by the ENGINEER in order to provide more extensive representation at the project site during the construction phase.

* * * * *

2.13 Through more extensive on-site observations of the work in progress and field checks of materials and equipment by the Resident Project Representative (if furnished) and his assistants, the ENGINEER shall endeavor to provide further protection for the OWNER against defects and deficiencies in the work, but the furnishing of such Resident Project Representative will not make the ENGINEER responsible for construction means, methods, technique, sequences or procedures or for safety precautions or programs, or for the Contractors' failure to perform the construction work in accordance with the Contractor Documents.

Genovese and this contractor previously had not worked together. Genovese held a preconstruction meeting on July 19, 1985, which was attended by representatives of Northeast Utilities and its operating company, the Northeast Utilities Service Company (gas company), other underground utility companies, and the contractor. Before the meeting, the gas company had received a copy of the construction plans and drawings which they checked for accuracy and on which they superimposed the parts of their system which were not shown on the original drawings. The gas company approved the drawings at this preconstruction meeting.

In addition, a prepared list of concerns of the gas company was distributed at this meeting. Page 2, special notes, sheet 13 reads, "The installation of manhole 4915, 4913 (this number was handwritter) is very close to our existing 3 inch cast iron main. Caution is advised." The gas company stressed the importance of its being notified by telephone when a gas main was struck so that the gas company could respond, assess, and repair any damage that may have occurred. They stated that all exposed gas mains must be supported and no backfill was to be dumped directly over the gas mains. A document distributed by the gas company at the preconstruction meeting stated that gas company employees would be making frequent visits to the construction site to observe the contractor's activities. Company policy states that "... it is Northeast Utility's policy to patrol distribution gas mains to locate and identify conditions which could cause failure or leakage and consequent hazards to public safety. . . ." Except for visits to the site made

after the contractor called, there is no written record of any visits by the gas company employees to the construction site. (Visits could have been made without a written record, however, there is no evidence of such visits.) Gas company personnel stated they did not expect any disturbance of their gas mains if the contractor followed good construction practices. The gas company did not request the contractor to notify them when construction work would occur near their gas mains.

At the preconstruction meeting the gas company also reminded the contractor to use the one call system ^{1/} before excavating close to gas mains and to use proper backfilling procedures as this could affect the structural integrity of the gas main. The gas company specifically cautioned the contractor to be careful when excavating near its cast-iron gas mains. At the beginning of the job the contractor did use the one call system and requested gas main locations. Before the excavation was begun, the gas company located the position of its gas mains and service lines near the proposed sewer excavation and indicated their location with yellow paint on the road surface. Each of the other utility companies marked the location of their subsurface lines in the same general manner, each using a different color paint; the colors used were those universally accepted for the marking of underground utilities.

The contractor began work on November 21, 1985, and encountered many underground utilities in the course of construction. On that date, the contractor made the initial excavation at Main and Caroline Streets and struck and ruptured some telephone lines, fire alarm lines, and a gas service line. The gas service line had been correctly marked. However, the contractor stated that he thought it was deeper than it actually was and he hit it with the backhoe. The telephone and fire alarm lines had not been marked accurately. The gas service line extended from Main Street to the Derby Pizza House located on the northeast corner of Main and Caroline Streets (see figure 1).

On December 5, 1985, the contractor began work on a segment of the sewer extending from Main Street southward to a manhole on Caroline Street, approximately 83 feet away. The contractor stated that he excavated at Main and Caroline Streets to verify the location of the gas mains at that intersection so that he could determine their proximity to the planned excavation for the sewer project. At this location, the gas company operated a 12-inch diameter cast-iron, 30-inch water column (WC), low pressure gas main; an 8-inch diameter, steel, 50 psig pressure, high pressure gas main; and the 3-inch diameter, cast-iron, 30-inch WC low pressure gas main (see figure 1). The 3-inch diameter cast-iron gas main on the west side of Caroline Street was not exposed at this location. The excavation made by the contractor at Main Street to install the 24-inch diameter, 8-foot-long, reinforced concrete sewer pipe lengths was approximately 66-inches deep, 48- to 54-inches wide at the bottom and 60- to 72-inches wide at the top. As the contractor dug south in Caroline Street, the sewer trench gradually deepened until it was approximately 116-inches deep, 66-inches wide at the top, and 54-inches wide at the bottom.

After excavating the trench southward approximately 47 feet along Caroline Street, the contractor encountered an old, unmarked aqueduct which was not shown on the sewer construction drawings. The 3-inch diameter, cast-iron gas main lay on top of the aqueduct on the west side of Caroline Street (see figure 1). The aqueduct, which was

^{1/} One call system is a communication system established by two or more agencies or companies to provide excavation contractors, utilities, public agencies, and private citizens with one telephone number to call and notify operators of underground facilities for excavating, tunneling, demolition, boring, blasting, etc.

constructed of cut stone, extended under Caroline Street beginning in the basement of the River Restaurant (restaurant) where it was closed off by a wooden wall with a door; the room was used as a storage area. On the east side of Caroline Street and beneath the west curb of Caroline Street it was sealed off with masonry. The aqueduct had been severed earlier for the installation of two gas mains, a brick sewer, and a water main. The contractor stated that it was necessary to extend the break in the abandoned aqueduct using a Caterpillar 225 backhoe, and that most of the loosened stones which fell into the aqueduct were removed from the trench and hauled from the site in a dump truck.

The procedure for installing the sewer pipe was to place the individual 8-foot concrete pipe lengths in the ditch, attach the lengths to each other, backfill the pipe in the ditch using specified rock-free material, and then tamp the backfill to obtain the proper compaction. The contractor stated that the compaction was accomplished using a backhoe with a Hopac Compactor Driver, Model 9700C, attached to its boom. The equipment weighed more than 30,000 pounds, but was supported by caterpillar tracks which gave the unit a bearing weight of approximately 5 pounds psi. The Hopac operator stated that he had no means for determining the amount of compaction, but believed that he could tell by the sound of the compactor when the soil was properly compacted. He further stated that he compacted the backfilled trench twice, once when the trench was half-filled and again when the trench was completely filled. The contract called for a compaction of not less than 90 percent of the maximum unit dry weight attained in a laboratory compaction test performed in compliance with American Association of State Highway Officials (AASHO now AASHTO), Designation in T-180-57, Method D; however, no compaction tests were performed on Caroline Street before this accident.

While excavating later the same afternoon (December 5, 1985), the contractor uncovered and damaged two steel pipes that were perpendicular to the ditch. The contractor notified the gas company about the pipe. Two gas company personnel responded, inspected the exposed pipes, and found that the pipes were not connected to the gas system. Using a Combustible Gas Indicator (CGI), the gas company personnel determined that there was no gas leaking at this location.

By that evening, the contractor had exposed and cut into the aqueduct. The contractor discovered an old brick and mortar sanitary sewer inside the aqueduct which partially collapsed because of the excavating and began leaking sewage into the open trench. The odors emanating from the released sewage effluent were strong; however, workers, wearing rubber boots for protection, began to make repairs. The trench, saturated with the sewage effluent, remained open throughout the night and into the next day.

The Accident

Shortly before 7:00 a.m. on December 6, 1985, contractor personnel arrived for work and parked their vehicles in the parking lot on Caroline Street east of the rear of the restaurant. At that time and in that location the contractor's personnel detected an odor they believed to be natural gas, and reported the odor to the resident engineer at the site. They then resumed excavating in the aqueduct in Caroline Street adjacent to the restaurant and worked southward. At the public hearing held by the Safety Board on February 11 and 12, 1986, the resident engineer stated he had no sense of smell and could not smell odors of any type at the construction site.

At 7:30 a.m. the restaurant was opened by a cleanup man who said later that he had detected strong gas odors. When the restaurant owner arrived at 7:45 a.m., he also said that he detected strong gas odors. However, because the owner had also detected the gas odors on Main Street outside the restaurant and because his kitchen exhaust fans at the rear of the restaurant were running continuously, he assumed that the gas odors had been drawn in from the front of the restaurant and the gas company had been working in the area and had it under control. The owner assured the cleanup man that everything was all right.

At 8:30 a.m., about 1 hour 15 minutes after being informed of the gas odors, the resident engineer telephoned the gas company at its Stamford, Connecticut, Regional Customer Service Center. The gas company employee who received the telephone call listed the nature of the trouble as "gas odor-severe," classified it as an "emergency," and wrote on the trouble report "gas odor at corner/we checked lines for disc (discharge) but they still get the odor." The gas company employee handed the trouble report to the dispatcher at 8:33 a.m. and the dispatcher telephoned the information to the gas company's Shelton, Connecticut, Service Building (Shelton). Gas company personnel at Shelton then contacted a gas company serviceman and told him there was "a problem at the construction site on Caroline and Main Street in Derby." The serviceman stated that he was not advised of the nature of the complaint. The gas company serviceman arrived at the site at about 8:38 a.m., but because the sides of the 8-foot deep trench were not shored, ^{2/} he considered it unsafe to enter the trench. However, he saw two men in the trench and one man on top of the trench giving hand signals to the backhoe operator. The serviceman advised the gas company dispatcher at Shelton by radio of the unsafe condition and a gas company supervisor near the site, who heard the radio message, responded. The gas company supervisor only heard the serviceman's radio message about the unsafe ditch condition; he did not know the nature of the problem. At the public hearing held by the Safety Board on February 11, 1986, the gas company serviceman stated that while on site, he detected no gas odors and no one there mentioned gas odors to him.

On arriving at the site at 8:40 a.m., the gas company supervisor was lowered into the trench in the bucket of the backhoe, where he examined two 1-inch gas pipes that had been struck by the backhoe and found that they were not connected to the gas system. (These were not the same gas pipes that the gas company had inspected on December 5.) The gas company supervisor stated that while he was in the trench and in the work area, he did not detect any gas odors and he told the resident engineer that the area was safe (he did not use a CGI or other gas detection equipment). He further stated that the odor of gas was not discussed at all. The gas company supervisor did not check any adjacent buildings or any other areas where natural gas could accumulate because he assumed that the resident engineer's call to the gas company was to identify the small diameter lines which the contractor had uncovered. There were no other complaints about gas odors made to the gas company from that area that day.

The contractor stopped the flow of sewage effluent into the trench by repairing the sewer damaged the day before and then continued excavating southward to a manhole located about 25 feet south of the aqueduct. The resident engineer estimated the trench in this area was about 9-feet deep, 4-feet wide at the bottom, and 5- to 6-feet wide at the surface. While excavating in this sector, the contractor encountered water pipes and an 8-inch steel natural gas main. The contractor stated that the 3-inch cast-iron natural gas main was never exposed while excavating the trench.

^{2/} Wooden timber or steel sheets used to brace and hold up the sides of excavations to prevent cave-ins.

At 9:15 a.m. the restaurant owner's son entered the restaurant and mentioned the "... strong odor of gas on the exterior part of the building," and stated that "... it had permeated its way into the building." The owner said "... I think everything is OK." At 11:30 a.m. the restaurant owner's wife and another employee arrived and mentioned that "... there was a strong odor of gas on the exterior part of the building and (they believed) the odor was (also) inside the building."

The contractor's superintendent, who was also one of the owners of the construction company, usually supervised the work crew. However, he left the job site on Caroline Street at 11:30 a.m. and left a foreman in charge. The foreman had not attended the preconstruction meeting and had not been told about the cautions of working near cast-iron gas mains made by the gas company at the meeting. He was also unaware of the existence of the 3-inch diameter, cast-iron gas main in Caroline Street near the aqueduct.

During the lunch hour, the restaurant was busy and the continuous opening and closing of the doors together with the steady operation of the kitchen exhaust fans pulled outside air into the restaurant. No problems were encountered and the restaurant owner stated later that the gas odors did not seem to be as strong as they had been earlier in the morning. No one at the restaurant reported the gas odors to either the gas company or the fire department. When interviewed after the accident, some of the customers stated they did not smell the odor of gas while in the restaurant.

At 2 p.m. the restaurant owner walked over to the sewer construction site on Caroline Street and mentioned the gas odors in the restaurant to the resident engineer. The resident engineer told the restaurant owner that a representative from the gas company had been to the site on both December 5 and 6 and had assured them that the odors were from "gas pockets" and would dissipate. The restaurant owner expressed concern to the resident engineer about not having enough parking for 100 persons who were coming for dinner. The resident engineer said that the area would be backfilled and cleaned up, and that the equipment would be removed and parking made available for the diners.

Shortly afterwards, the contractor began backfilling and compacting the soil over the newly installed concrete sewer pipe. The tread-mounted Hopac was being operated adjacent to and over the 3-inch cast-iron gas main; the pavement had been marked with yellow paint to indicate the location of the gas main. The compactor operator said that he didn't see any paint marks, but he also said he "wasn't looking for any paint marks." At approximately 2:50 p.m., while compacting the backfill with the Hopac, the compactor operator stated that he detected a very strong odor of natural gas. The gas odor was so strong that he was afraid to light his cigar. The operator mentioned the gas odors to another equipment operator, but not to anyone else; nothing further was done. At 3:30 p.m. the operator finished compacting all of the soil and parked his equipment. Four of the contractor's employees were still on-site: one was picking up tools, two were sweeping the work area, and one was moving a piece of equipment out of the way.

At 3:55 p.m. the River Restaurant exploded, partially collapsed, and began to burn; 6 persons were killed and 12 were injured inside the restaurant. One person passing by the restaurant was injured and a firefighter was injured later.

After the accident the 3-inch diameter cast-iron pipe between the intersections at Main and Caroline and First and Caroline Streets was carefully excavated by hand to minimize any disturbance of the pipe because this section of pipe was thought to be the likely source of the gas leak. When the dirt above the pipe was removed, several large

stones were uncovered. One stone, measuring 17-inches wide, 21-inches diagonally, and 8-inches thick, was uncovered above the gas main. It was not resting on the gas main, but was less than one foot above it resting on other small closely packed stones which separated it from the gas main (see figure 2). The large stone was located about one foot south of the break in the gas main. Further hand excavation revealed that the gas main was resting on a concrete patch on top of the aqueduct. A circumferential break in the gas main was located about 1 inch south of the concrete patch. The section of pipe south of the break had been displaced about 1 inch below and about 1/8 of an inch to the left (west) of the north section. The pipe sections had been separated by about 1/16 of an inch (see figure 3). There was no indication of dried or caked earth around the pipe at the location of the fracture, a condition usually found when gas has been leaking through the soil for a period of time. The Connecticut Department of Public Utilities Control (CDPUC) found a paper cup buried near the stone and CDPUC personnel stated that fresh, green grass was also found in the trench that had been excavated to expose the fracture of the 3-inch cast-iron pipe.

After the accident, the gas customers south of the 3-inch diameter gas main rupture were questioned about experiencing any gas outage or diminished supply of gas. None of those customers had experienced anything unusual prior to the explosion.

Emergency Response

The Derby Department of Fire Service, located 10 blocks from the restaurant, received the first alarm at 3:56 p.m. The fire chief arrived at the scene at 3:58 p.m., put the city's disaster plan into effect, and summoned additional emergency response equipment and personnel from nearby cities.

The fire chief stated that when he arrived, Caroline Street and the south side of Main Street were blocked with debris and glass from broken windows, and the side of the restaurant on Caroline Street had collapsed. There was little or no smoke, but the area was full of reddish dust and when the dust started to clear, smoke began to fill the building. Emergency response personnel initially directed all efforts to rescue persons from the collapsed side of the restaurant. Two triage centers were established nearby.

Early in the rescue operations, all emergency response personnel were ordered out of the building and rescue operations stopped since the building was highly unstable. Voices were heard from the building as it continued to collapse, therefore, rescue operations were resumed in the basement of the building sharing a common wall with and to the west of the restaurant. Emergency response personnel drilled through the basement wall only to be blocked by a refrigerator in the restaurant; however, this hole improved voice communication with a victim trapped inside the restaurant. After the victim was located, a backhoe was used to remove the rubble above. The victim was freed 4 hours after the explosion. A list of the victims believed to be in the rubble was then compiled.

At about 5 p.m. strong natural gas odors were detected in the sewer manholes in the area where none had been detected before. The terrain slopes upwards from the accident site to the north and west, and gas-in-air readings of 100 percent were taken in the sewers at Main and Caroline and at Main and Minerva Streets. Readings of 75 percent gas-in-air were taken north on Minerva Street, at Caroline and Fifth Streets, and at Main and Elizabeth Streets (see figure 1). A fire department detachment was sent to vent the natural gas in these areas. By 5:30 the gas company concluded that the 3-inch diameter

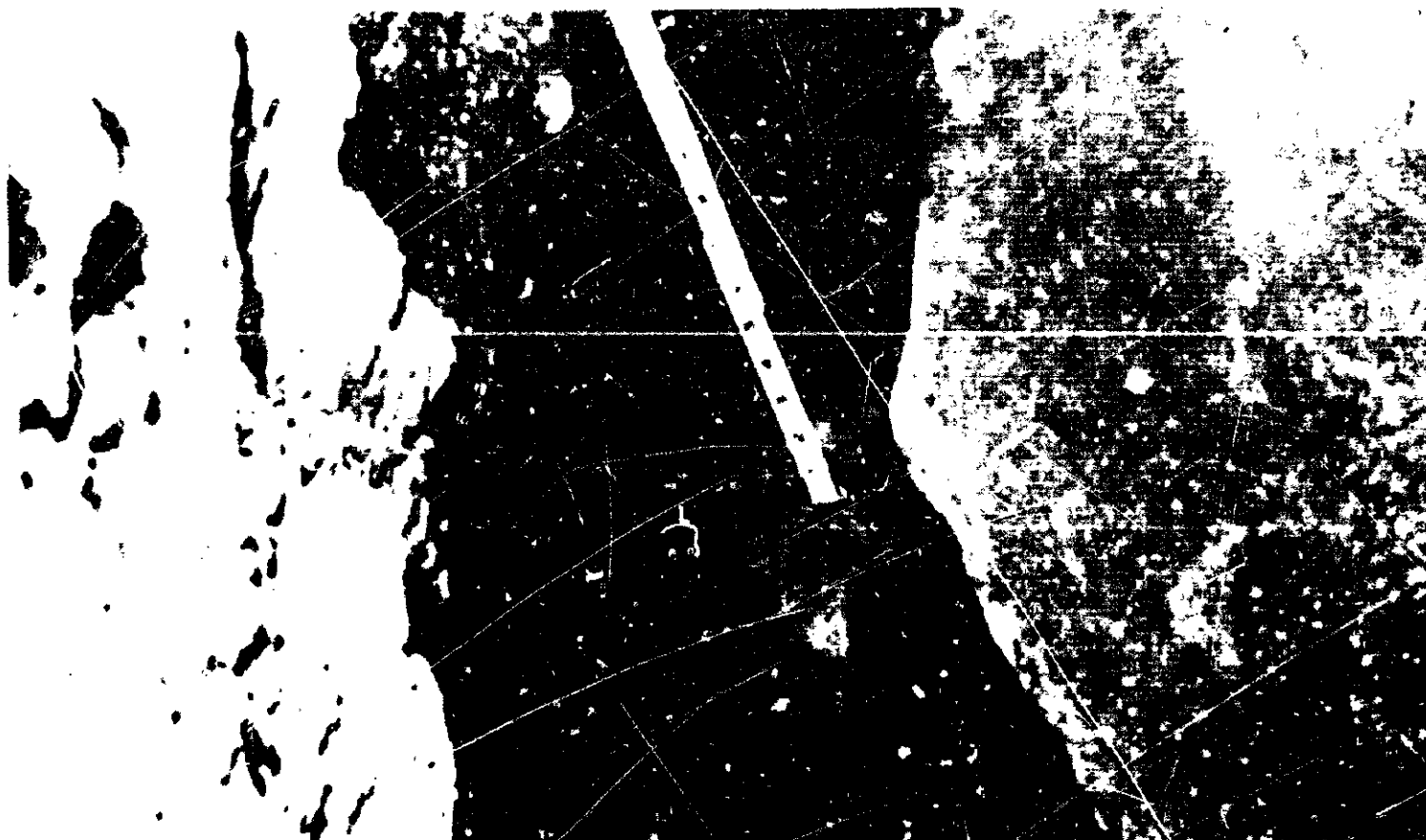


Figure 2.--Photograph of stone over gas main.

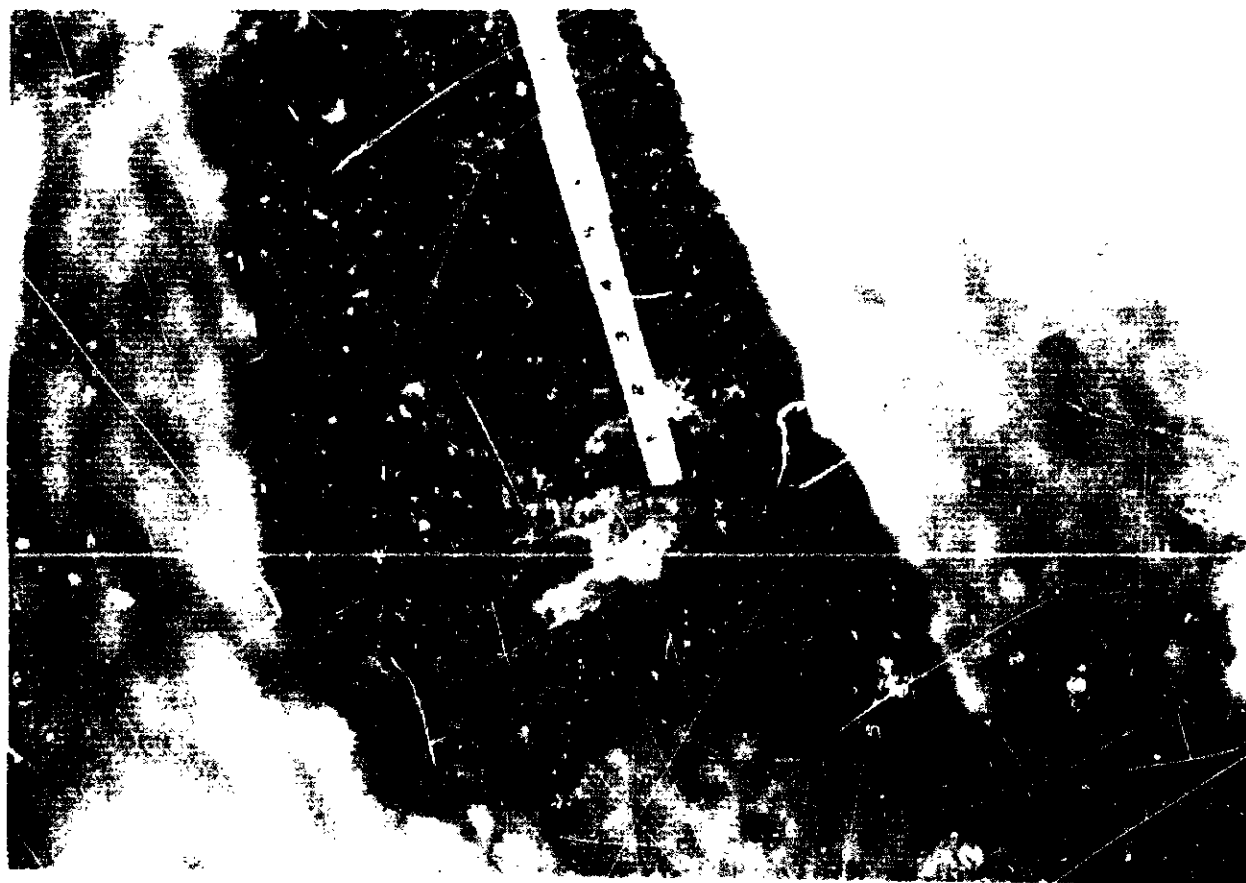


Figure 3.--Location of 3-inch break.

gas main had failed and they then dug down to the juncture of the 12-inch and 3-inch diameter cast-iron gas mains at Main and Caroline Streets and closed off the 3-inch diameter cast-iron pipe at that location. The fire chief stated that there was no noticeable change in the restaurant fire when the 2 inch diameter gas main was closed off; however, the gas in the sewer started to dissipate when the flow of gas was stopped. As a safety precaution all utilities to the restaurant were shut off. Throughout the fire fighting operation, small explosions or "poppings" were heard deep within the burning rubble that shook the ground as well as the building, causing more of the building to collapse. These gas-fueled explosions lasted for about 2 hours until 7:30 p.m. Between 7 and 7:30 p.m. the fire department began to evacuate residents in a four-block area north of Main Street between Caroline and Elizabeth Streets where natural gas in the sewers had been detected.

The fire was suppressed at approximately 7:30 p.m. and a search for victims was initiated. The still-smouldering debris was carefully removed from the restaurant and sifted for bodies; the sixth body was not recovered from the debris until 3 p.m. on December 7, 1985.

Injuries to Persons

	<u>Gas Company</u>	<u>Civil Agency</u>	<u>Restaurant Employees</u>	<u>Restaurant Patrons</u>	<u>Pedestrian</u>	<u>Total</u>
Fatal	0	0	2	4	0	6
Nonfatal	0	1	0	12	1	14
Total	0	1	2	16	1	20

Eighteen persons were inside the restaurant at the time of the explosion, 6 persons were killed, 12 were injured, and 2 persons outside of the restaurant were injured.

The Connecticut State Medical Examiner determined the cause of death of the six victims as follows:

- victim #1 - fractured neck
- victim #2 - chest injuries
- victim #3 - fractured spine/internal injuries
- victim #4 - smoke inhalation
- victim #5 - fractured neck
- victim #6 - compression of chest

Damage

The River Restaurant was destroyed by the explosion and fire; other buildings in the area sustained broken windows. Also, a building that shared a common wall with the restaurant received damages to the common wall, roof, and windows. Estimated damages are as follows:

The restaurant and contents	\$162,000
Other damaged buildings and contents	59,000
Miscellaneous damage and glass breakage	7,000
	<u>\$228,000</u>
Pipeline damages that did not include loss of revenue	50,000
Total	<u>\$278,000</u>

These estimates do not include business interruption costs, emergency response costs, or gas company and contractor's costs during rescue operations.

Pipeline System

The gas company is an electric and natural gas utility company with approximately 2,400 miles of gas mains in Connecticut serving approximately 162,000 gas customers. (It ranks in the top 10 percent of the nation's gas distribution companies.) Of its gas distribution system, 580 miles (about 24 percent) are composed of cast-iron pipe, 90 percent of which are operated at 1/4 psig. The remaining 10 percent are operated at 1 to 4 psig. In the city of Derby, the gas company owns and operates 36.9 miles of gas mains of which 10.7 miles (about 29 percent) are cast-iron mains. The installation dates of the cast-iron pipe throughout the system range from the 1880's to the late 1940's. After the late 1940's, the gas company used steel and plastic pipe for its gas mains. The 3-inch diameter cast-iron gas main involved in this accident had been installed before 1898.

From 1981 through 1985, the gas company had experienced a total of 729 leaks in its cast-iron system as shown below. However, only 3 of these 729 leaks were reportable to DOT under 49 CFR 191.9 (Distribution System: Leak Reports).

<u>Year</u>	<u>Third Party</u>	<u>Joint Leaks</u>	<u>Main Breaks</u>	<u>Total</u>	<u>Reportable to DOT</u>
1981	6	55	75	136	0
1982	9	40	70	119	1
1983	4	44	67	115	1
1984	15	66	80	161	0
1985	9	118	71	198	1
	<u>43</u>	<u>323</u>	<u>363</u>	<u>729</u>	<u>3</u>

When the gas company locates a break in one of its cast-iron mains, the repair crew at the site inspects the break visually, but the pipe is not removed for metallurgical analysis; repairs are made by covering the break with a sleeve or a clamp while the line is still in service. If the gas company deems it necessary to replace the affected gas main (e.g., when there are two circumferential breaks close together), it is replaced with polyethylene (PE) plastic pipe which is then connected to the cast-iron pipe at each end by compression couplings.

The gas company has an established program to replace between 6 and 10 miles of cast-iron pipe per year. The 3-inch diameter cast-iron gas main on Caroline Street had been scheduled for replacement in 1987. In determining which gas mains to replace the gas company considers the pipe diameter, load factors, and leak frequency. Where possible, replacement of the smaller diameters of cast-iron pipe (4 inches and under) has a higher priority because these pipes have a higher failure rate. The replacement program has been in effect for almost 5 years and approximately 32 miles of cast-iron pipe have been replaced. The program has a goal to replace all of its smaller diameters (4 inches and under) of cast-iron pipe within a 20- to 25-year period. The cast-iron pipe is being replaced primarily with PE plastic pipe, but 25 to 40 percent of the replacements have been made with steel pipe because of high pressures or high external load factors. Replacement costs for the entire 580 miles of cast-iron pipe have been estimated by the gas company at \$200 million.

The gas company stated that it has a policy for monitoring its system in construction areas and that its cast-iron system receives more attention than its steel or plastic system. Generally, gas company personnel monitor the area by driving by and observing the construction site periodically. The gas company did not assign full or part time inspectors to monitor the sewer construction work on Caroline Street or elsewhere during the sewer construction project.

Gas Odors

One restaurant patron who was in the building at the time of the accident stated that he did not notice the odor of gas nor was it mentioned in the conversations with the other patrons before the explosion; however, after the explosion, the odor of natural gas was present outside the building in the area of the construction. Another patron stated that when he arrived at the restaurant prior to the accident he noticed the odor of gas outside the restaurant but not inside the restaurant.

An employee of the restaurant stated that as he left the restaurant on the night before the accident at 11:30 p.m., he had detected the odor of gas coming from the sewer construction site beside the restaurant and on that night some of the customers had spoken of the gas odor; however, he could not recall the customers' names. The employee further stated that when he reported for work on the day of the accident, he noticed the odor of gas and that the son and wife of the owner told him that they had smelled the odor of natural gas. He also stated that the construction activities had caused dishes in the restaurant to shake.

The owner of an adjoining business stated that the odor of natural gas had been present a few weeks before the accident and that on November 29, 1985, a representative of the gas company had entered his store, inquired if the odor of natural gas had been noticed, and stated that the owner of a business across the street had detected the odor of natural gas.

The city of Derby Police canvassed Main and Caroline Street for several days after the accident and found that 14 other people had detected the odor of natural gas in the area of the restaurant several days before the explosion; however, none of these persons had reported their observations to the gas company or to the fire department.

From November 1, 1985, until December 6, 1985, the gas company had received 131 telephone calls from Derby residents. Most of these calls concerned no heat, pilot light out, no hot water, or gas odor complaints due to appliance leaks. Only five telephone calls concerned gas odor complaints or outside party damage:

- (1) November 21, 1985 at 9:40 p.m. - gas leak in the street at Main and Caroline Streets - contractor hit line
- (2) November 29, 1985 - gas leak in Main street
- (3) December 1, 1985 at 29 Minerva - gas leak in the street
- (4) December 5, 1985 at 1:44 p.m. - gas odors on Main street
- (5) December 6, 1985 at 8:30 a.m. - call from Genovese - gas odors

Gas company personnel responded to the first four leak reports, CGI's were used, and the facilities were checked and repaired where necessary. A summary of the witness statements taken by the Connecticut State Fire Marshal following the accident indicated that gas odors had been prevalent for several days in and around Main Street and Caroline Street and gas company vehicles were often seen in this area.

On December 2 and 3, 1985, an annual street survey was conducted for the gas company by an independent inspection company using flame ionization gas indicators. Caroline Street and Main Street were included in that survey and no gas leaks were detected on either street adjacent to the restaurant.

Public Awareness

As part of its public education and awareness program the gas company used advertisements, gas facts mailed with the gas bills, "scratch and sniff" cards containing gas odorant, and gas facts pamphlets.

During October and November of 1985, approximately 1 million "scratch and sniff" cards and gas information pamphlets were mailed to gas company customers (both electric and gas) in Connecticut. The card, when scratched, emits the odor of natural gas. The text in the pamphlet advises customers to call the gas company when they detect that odor. The gas company supplements this program by delivering speeches on gas safety and by giving gas facts to schools and other organizations. During the Safety Board's public hearing on February 11 and 12, witnesses who were questioned said that they could identify natural gas in general by its smell and were aware, in a general way, of the customer information data.

Meteorological Information

The following weather conditions are based upon the weather observations at Westchester County Airport at the time of the accident. Westchester County, New York, approximately 35 miles west-southwest of Derby, was selected because it is approximately the same distance from Long Island Sound as Derby and because it has 24-hour weather observations.

The weather records at Westchester County Airport indicated that between December 3, 1985, and the time of the accident, 3:55 p.m. on December 6, 1985, the temperature ranged from a low of 20° F to a high of 35° F. On the morning of the accident, light snow fell at the airport from midnight until noon. Derby had a trace of snow.

The Derby Fire Chief stated that at the time of the accident, there was a light wind blowing from the northeast towards the southwest.

Tests and Research

In its laboratory in Washington, D.C., the National Transportation Safety Board tested a 36-inch long section of the 3-inch cast-iron pipe which contained the fracture.

All tests, including an examination by a scanning electron microscope, were conducted on one fracture face; the mating fracture face was kept intact. Microscopic examination of the fracture revealed features typical of an overstress separation in gray

cast-iron material. This examination revealed a few small secondary cracks branching at shallow angles in opposite directions away from the main fracture plane. The location of the secondary cracks indicated the local fracture propagation directions and suggested that the initial fracture through the pipe wall occurred in the vicinity of the 7:30 o'clock position and could have resulted from an external force at about the 1:30 o'clock position. Two transverse saw cuts made north of the fracture face intersected many areas of graphitic corrosion, commonly referred to as graphitization. The extent to which the graphitization penetrated the wall of the pipe varied greatly with the circumferential and longitudinal position on the pipe. Scanning electron microscopic examination of the two specimens confirmed the earlier optical observations and revealed that corrosion products and damage on the fracture face were more severe near the 6 o'clock position than at the 12 o'clock position. Visually the depth of the graphitization appeared to be about .07 to .08 inches or approximately 25 percent of the wall thickness. However, when the sample was examined at higher magnifications (200 to 300x), the graphitization was found to penetrate approximately 40 to 50 percent of the wall thickness.

Other Information

Gas Company Line Abandonment and Customer Reconnection.--After the accident, the gas company abandoned all of the 3-inch cast-iron gas mains in Caroline Street from Main Street south to its connection with the 6-inch steel gas main serving the sewer plant; eight customers had been served from this segment on Caroline Street. In addition, the 3-inch cast-iron gas main on First Street was also abandoned; three customers had been served from this segment on First Street.

The 6-inch steel gas main was capped where it had been disconnected from the 3-inch cast-iron gas main and a temporary connection was made between it and the existing 8-inch steel high pressure gas main on the east side of Caroline Street. The customers on First Street were provided with electric heaters until their gas service could be restored.

Approximately 1 1/2 weeks after the accident, a 2-inch PE plastic gas main was installed in First Street and connected to the 8-inch steel, high pressure gas main in Caroline Street to permanently serve the First Street customers.

An existing 4-inch steel service line to the sewer plant was also connected to the 8-inch steel high pressure gas main and the other seven gas customers south of First Street in Caroline Street also were each connected to the 8-inch gas main by 1/2-inch PE plastic service lines.

Gas Company Leak Investigation Procedures.--The gas company has an established written procedure for receiving and dispatching information on and investigating, correcting, and reporting gas odors or gas leakage. (See appendix C.) It is the policy of the company to eliminate any leak or other uncontrolled escape of gas. The procedure states that reports of gas odors take precedence over all other activities and that a qualified company person must be available at all times to respond to reports of gas odor and/or leakage. The procedure describes the steps to be taken by the first employee to arrive at the location of the reported leakage or odor. These steps are to determine the location, source, and magnitude of the leak; to protect the public and property from damage by evacuation; to shut off the gas supply until help arrives to reduce the likelihood of explosion and fire; to make repairs; to report the conditions; and to request help if required. The procedure requires CGIs to be used on all gas odor and/or leakage investigations and specifically states that the employee is not to rely solely on the sense of smell to detect and locate gas odor and/or leakage. In addition, this procedure

instructs gas company personnel not to assume there is no gas leak without a complete investigation. In the case of street gas odor and/or leakage, the gas company procedure is to take CGI readings at manholes, curb valve boxes, sewer accesses, pavement and curb cracks, utility poles, other subsurface openings, and along the service and foundation walls. The procedure also requires gas company personnel to investigate the basements of buildings in the vicinity of reported gas odor, even if CGI readings are negative.

Gas Company Personnel Training.--The gas company serviceman was employed by the gas company in 1968 as a construction mechanic. In 1981 he became a customer serviceman and entered a 5-year formal training program together with on-the-job training. Leak survey, leak detection, and leak reporting subjects were studied and both written and oral tests were given by his supervisors. As he progressed through the program, he provided on-the-job training to other persons working with him. In addition, he attended safety training sessions at which time leak survey, leak detection, and leak reporting were discussed.

The gas company supervisor was employed by the gas company in 1970 as a gas mechanic helper. He was given a 4-year formal and on-the-job training program with classroom and on-site training in leak survey, leak detection, and leak reporting. He was given both written and oral tests by his supervisors. After he was promoted to gas company supervisor, he taught and tested junior employees in leak survey, leak detection, and leak reporting. On November 6, 1984, he attended formal classroom training given by the area superintendent. The courses included gas odor and gas leak investigation and procedures for the prevention of accidental ignition.

Pipeline Safety Requirements.--The Northeast Utilities Service Company makes each area superintendent responsible for providing inspection of pipelines in areas where excavation work is being done and where damage to the system could result. In addition it is the gas company's policy "... to patrol distribution gas mains to locate and identify conditions which could cause failure or leakage and consequent hazards to public safety." Further, the gas company has a policy for the protection and maintenance of its cast-iron gas mains which requires that its area superintendent, knowing the excavation work is being performed, "... shall determine whether the pipeline should be replaced or shall remain in place and be protected against damage" (see appendix C).

Title 49 Code of Federal Regulations (CFR) 192.614 requires that gas companies have a written program to prevent damage to pipelines caused by excavation (see appendix C). The one call system may be used, but its use does not relieve the gas company of its responsibility.

The American Society of Mechanical Engineers (ASME) Guide Material provides specific actions that gas companies are suggested to take to comply with the regulations and to protect their systems (see appendix C).

Occupational Safety and Health Administration Excavation Requirements.--The Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor regulations requires that trenches, dug 5-feet deep or more, have some means of protection against cave-in and have an adequate means of escape from the trench (see appendix C). The contractor did not use shoring on Caroline Street even though the excavation was more than 5-feet deep.

City of Derby Sewer Contract (D-81-01E).--The New England Railroad Construction Company was contractually responsible for initiating, maintaining, and supervising all safety precautions, programs. The contract stated that the contractor should take all necessary precautions for the safety of, and will provide the necessary protection to prevent damage, injury or loss to other property at the site or adjacent thereto, including utilities. In addition, the contractor was required to erect and maintain all necessary safeguards for safety and protection. Further the contractor was required to notify owners of adjacent utilities when prosecution of the work would affect them.

Federal Regulations for the Investigation of Failures.--Title 49 CFR 192.617 (Investigation of Failures) states:

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

This gas company's practice for the repair of cast-iron gas main leaks, like that of most gas distribution companies is to install a clamp or a sleeve over the leak while the gas main is still in operation. This repair procedure, does not require the interruption of gas service to customers and is less costly and time consuming than cutting out and replacing the failed section. The clamp or sleeve can remain in operation for years unless removed. However, the failed sections are often not subjected to metallurgical analysis; therefore, the cause of their failures are often not documented and data concerning the extent of graphitization in cast-iron pipe and the conditions under which it occurs is not known.

Cast-Iron Pipe.--The term "cast-iron," like the term "steel," identifies a large family of ferrous alloys. Cast-irons are primarily alloys of iron that contain more than 2 percent carbon and from 1 to 3 percent silicon.

Gray cast-iron, the material used in the manufacture of cast-iron pipe, is a brittle, non-malleable alloy (compared to some steels) having a large percentage of its carbon distributed freely throughout the casting as graphite in flake form. Grey cast-iron is subject to graphitic corrosion (graphitization) a condition in which the iron constituent is selectively oxidized leaving the carbon lattice structure relatively intact. Graphitic corrosion usually forms at the exterior surface of the cast-iron pipe, but it is not always visible to the naked eye. Even heavily graphitized pipe often appears to be in good physical condition and can transport natural gas without leakage as long as the pressure remains low and the pipe is undisturbed. The strength of cast-iron pipe is diminished by the amount of graphitization in the pipe wall; the strength remaining in the cast-iron pipe is a function of the remaining ungraphitized wall thickness.

Data obtained from the Office of Pipeline Safety (OPS) of the U.S. Department of Transportation (DOT) indicate that the mileage of cast-iron pipe in gas distribution systems nationwide has decreased from 1970 through 1983, but the number of reportable leaks during this same period appears to have remained relatively constant. (See appendix D.)

OPS statistics show that from 1970 through 1983, there were 1,270 cast-iron gas main failures which caused property damage sufficient to require them to be reported, an average of 90.7 cast-iron gas main failures per year. These figures reflect only those

leaks reported under 49 CFR 191.5 (Telephonic Notice of Certain Leaks) and 191.9 (Distribution System: Leak Reports) by operators of gas distribution systems with 100,000 customers or more. These operators represent about 10 percent of the gas distribution companies. However, there are many thousands of cast-iron gas main leaks that are not reported because they do not meet the criteria of the regulations.

In a Pipeline Accident Report issued in 1973 ^{3/}, the Safety Board stated, "In the 1960's, a 5-year survey was made of 18 companies, which operated 16,000 miles of cast-iron mains. Each year between 10,000 and 13,000 cast-iron mains broke."

Since 1972, the Safety Board has investigated 54 cast-iron gas main failures which resulted in the deaths of 88 persons, injuries to 152 persons, and substantial property damage.

ANALYSIS

The Accident

Although the failure of the 3-inch iron-cast gas main was not accompanied by the obvious, tell-tale signs such as loud hissing sounds of escaping gas, blowing dust and dirt, loss of service to downstream customers, or a sudden pressure drop in the gas system, there are certain known facts which help to determine the time and mode of failure. The examination of the earth around the broken pipe did reveal that the fracture and gas leakage were recent because the earth was neither dried out nor whitish in appearance both of which are typical of long-term gas leaks. The Safety Board's laboratory analysis of the failed pipe also showed that the fracture occurred very recently and very rapidly. Finally, the annual gas leak survey which had been conducted by an independent contractor on December 2 and 3, 1985, to comply with a regulatory requirement found no evidence of gas leakage over the area in Caroline Street where the break was later found to have occurred. Thus the break must have occurred between December 3 and December 6, 1985, within three days of the accident.

The odors that emanate from natural gas and sewage effluent are different, but because the pungency of each is due to compounds of sulfur, mixtures of either odor in the air could be sufficiently similar to the public so as to have caused confusion. Although the smell of "gas odors" had been reported at 1:44 p.m. on December 5, 1985, the gas company personnel responding to the report determined there was no leak. Further, at 4 p.m. on December 5, the contractor had installed, backfilled, and tamped the 24-inch concrete sewer pipe from the manhole at the intersection of Main and Caroline Streets to within 15 feet (north) of the aqueduct. In addition, the contractor had excavated up to the aqueduct, had cut into it, and had damaged an old brick sewer which began leaking effluent and sewage odors. That portion of the ditch was left open with traffic barriers around it and the sewer odors probably built up overnight because there was no activity or wind to dissipate the odors. Gas company personnel who had arrived earlier to identify some small diameter pipes claimed that they had not noticed any odor of natural gas. Also, no gas odors were detected or reported in the sewer system, the same system that had 100 percent gas readings after the accident. Up to this point, the gas main must have still been intact.

^{3/} Pipeline Accident Report--"Atlanta Gas Light Company, Atlanta, Georgia, August 31, 1972" (NTSB/PAR/73-3).

On December 6, 1985, the construction crew, gas company personnel, the restaurant owner, restaurant workers, and restaurant patrons began to notice "gas odors." Between 6:45 a.m. and 8:30 a.m. the smell of "gas odors" were reported to the resident engineer by the construction crew at the work site. These reported "gas odors" were probably from the sewage gas from the leaking brick sewer. While the odors were reported as very strong, evidently the odors were not strong enough to cause the construction crew to stop work. The backhoe was being operated, one person was standing at the edge of the trench giving hand signals to the backhoe operator, and two men were working in the trench when the gas company personnel arrived.

Between 8:38 a.m. and 9:00 a.m. the gas company serviceman arrived on site, observed the old pipes and the deep, unshored ditch, which he refused to enter. However, he claimed he detected no odor of natural gas. The gas company supervisor who arrived moments later and was lowered into the ditch to look at the unidentified pipes, also claimed he detected no odor of natural gas; neither person used a CGI (although the CGIs were available in their vehicles) but relied on their sense of smell. Although the gas company procedures require the use of CGI's during leak search activities, both of the gas company personnel believed they had been called out to examine broken service lines not a gas odor complaint and, therefore, CGIs were, not needed.

The "gas odors," detected both inside and outside the restaurant from 7:30 a.m. to 11:30 a.m., probably were also odors of sewer gas since the sewer had been leaking effluent and accumulating since the late afternoon of the day before. In addition, Main Street had been opened up from Caroline Street to Minerva Street to install the new sewer and reconnect it to portions of the old sewer. This would have generated sewage gas which had been detected during the weeks before the accident. (It is possible that some odors of natural gas may have contaminated the soil as a result of previously repaired gas leaks caused by the sewer construction.) During the Safety Board's public hearing the restaurant owner stated, "The only thing that I can say is there was [sic] gas odors prevalent. It seemed like at the onset of construction, it seemed like there were a lot of odors of gas at that time." These odors (sewer gas and possibly some natural gas) were probably pulled into the restaurant through the front door which was continually opened and closed by customers. In addition, the kitchen exhaust fans located at the rear of the restaurant probably also pulled in the sewer gas odor generated by the broken sewer in the Caroline Street construction area. These odors could have readily entered the restaurant via the aqueduct in the restaurant basement. Odors were detected by persons both inside and outside of the restaurant; however, by the noon lunch hour, the odors had decreased; some of the restaurant customers did not smell any odors. If the 3-inch cast-iron gas main had been broken at that time, there would have been an increase not a decrease in the gas odors. Therefore, it is highly unlikely that by 2 p.m., when the restaurant owner talked to the resident engineer, the 3-inch diameter cast-iron gas main had been broken. In addition, the contractor had just begun to backfill the open sewer trench, and any significant gas leakage would have been detected immediately in the sewer trench.

About 10 minutes before 3 p.m., the Hopac operator, who was then compacting the sewer trench backfill, suddenly smelled gas odors so strong that he was afraid to light his cigar. The Hopac operator mentioned the heavy gas odors to another equipment operator at the site, but he did not tell anyone else. By 3:30 p.m., the compaction was completed and the Hopac was parked.

According to the Safety Board's metallurgical report, the force or forces that broke the cast-iron gas main, were inflicted above the cast-iron main at about the 1:30 o'clock position looking north. The Hopac, which had operated close to and over the cast-iron gas

main, had a bearing weight of only 5 pounds psi. This is not much more weight than a 200-pound man would exert (about 3.5 pounds psi) and not enough bearing weight to break the gas main, which had withstood truck traffic for 87 years without failure. However, the area close to the cast-iron gas main and its 87-year-old solid bedding had now been disturbed by the deep, unshored, sewer excavation. In addition, the heavy tamping forces of the Hopac were transmitted directly to the gas main via the stones and small rocks over the gas main. The backfill, had it been stone free, as it should have, might have helped cushion the Hopac blows instead of carrying the blows uncushioned directly to the gas main. The combination of the disturbed bedding, the backfill containing rocks, and the heavy forces transmitted by the Hopac, cracked the cast-iron gas main.

The contractor claimed that the 3-inch cast-iron gas main was neither uncovered nor undermined during the installation of the sewer pipe and that probably the gas main had been broken some days or weeks before the sewer construction had started. Several facts contradict this claim. During the careful excavation by the investigators around the failed gas main after the accident green grass and a paper cup were found immediately above and close to the gas main fracture. The grass and the cup would have had to have been buried during the recent backfill.

A survey taken after the accident showed that the pavement in Caroline Street above the gas main had been removed and, in the process, the yellow paint marks on the pavement locating the gas main also had been removed. This could explain why the Hopac operator did not see any paint marks on Caroline Street and would also indicate that even if nothing more was excavated from top or the side of the gas main, the protective macadam pavement had been removed and the gas main would have been more vulnerable to forces exerted from above, such as the force of the Hopac compactions.

The metallurgical examination of the pipe indicated that it had failed instantly and that a force from about the 1:30 o'clock position looking north had caused the break. The Hopac had been tamping during the compaction operation and had been delivering repeated blows on the stones laying on top of the pipe thus providing both the force and the direction to break the cast-iron gas main.

Calculations indicate that approximately 34,000 cubic feet of gas could have escaped each hour from the broken 3-inch diameter cast-iron gas main under 30-inch WC pressure if the natural gas was leaking directly into the open air and unimpeded by dirt around the pipes. However, considering that some dirt was packed around the buried pipe, an estimate of 17,000 cubic feet per hour was used to represent the volume of escaping gas of the buried pipe. The basement of the building in which the gas ignited measured approximately 58-feet long by 43-feet wide by 8-feet high; a volume of approximately 20,000 cubic feet. Only 1,000 cubic feet of gas would be required for a gas-in-air ratio of 5 percent (minimum percentage of gas-in-air required for ignition) and with gas escaping at a rate of 17,000 cubic feet per hour it would have required only 3.5 minutes to fill the restaurant basement with an explosive mixture. It is impossible to determine accurately the time needed for the gas to travel from the gas main through the aqueduct to the restaurant (nearly 40 feet). However, it is certainly reasonable to assume that if the 3-inch cast-iron gas main had been fractured about 2:50 p.m. (when the equipment operator detected heavy gas odors), gas could have migrated through the aqueduct into the restaurant basement (aided by the kitchen exhaust fans which created a slight vacuum), accumulated to a 5 percent gas-in-air mixture, and exploded at 3:55 p.m., one hour five minutes later.

It is not likely that the break in the cast-iron pipe occurred days or even hours before the explosion. Gas leaking at a rate approaching 17,000 cubic feet per hour located close to an open sewer trench would have either asphyxiated the construction crew or have been ignited by the construction equipment. The Safety Board concludes that shortly before 2:50 p.m. the 3-inch diameter cast-iron gas main was broken in an area weakened by graphitization by the considerable compaction force of the Hopac tamper.

This accident, which claimed the lives of 6 persons, injured 13 persons, and caused extensive property damage, could have been prevented had certain safety precautions been taken and had the contractor been more vigilant to his duties.

The contractor's superintendent knew that he was working close to a 3-inch diameter cast-iron gas main and at a preconstruction meeting, he had been cautioned to use care when working near cast-iron gas mains. The superintendent failed to alert his employees about the proximity of the cast-iron gas main and put a foreman in charge who was unaware of the existence, much less the proximity, of the cast-iron gas main and then left the construction site.

Either the contractor never fully understood the danger of working close to cast-iron gas mains or simply exercised poor judgment in his performance of the work in this area. Cast-iron gas mains are rigid, brittle, and will crack readily when subjected to external forces, but if the contractor had carefully shored the ditch (as was required by OSHA regulations), and then confined the backfilling and compacting operations to within that shored area, the 3-inch cast-iron gas main probably would not have been disturbed and probably would not have been fractured. Finally, the contractor should not have given responsibility for the job to a foreman without first making him aware of the location of the cast-iron gas main and the precautions necessary for working close to the facility.

Significantly, even the yellow paint marks which the gas company had used to identify the location of its gas main meant little to the contractor; the foreman was not sure which color paints indicated which utilities. The Hopac operator also stated that he didn't see any paint marks at all, although he said that he "wasn't looking for any marks" while compacting the fill in Caroline Street.

The Safety Board believes that the gas company, which had already planned to replace the 3-inch cast-iron gas main anyway, should have considered replacing it with steel pipe which would have been better able to withstand the forces of compaction. At the least, the gas company should have assigned an inspector to the site or taken other precautions to protect its cast-iron gas main. It also could have abandoned that portion of the gas main in Caroline Street from Main to First Street and supplied its customers from an alternate route. The gas company failed to take these actions even though its own policy for monitoring its system during construction projects emphasizes the fact that its cast-iron system should receive more attention than its steel or plastic systems.

Federal regulations for the protection of cast-iron pipelines, 49 CFR 192.755, require gas pipeline operators to take appropriate steps as soon as feasible to provide permanent protection for the disturbed segment from damage that might result from external loads. The gas company did not do this.

The ASME guide material for this Federal regulation suggests that an operator may use bridging, bracing, or cables to protect its cast-iron facilities. In the event that such

precautions are impractical or too expensive, the operator is advised to consider replacing the pipe "as an alternative to protecting and supporting a cast-iron main or service consideration may be given to its replacement."

Furthermore, 49 CFR 192.614, damage prevention programs requires that if a gas company is aware of construction activities close to its facilities it shall provide inspection "as frequently as necessary during and after the (construction) activities to verify the integrity of the pipeline." It further states that participation by the gas company in a one call system does not relieve the operator from compliance with this regulation.

Again, the ASME Guide Material for this Federal regulation recommends:

The operator should pay particular attention, during and after excavation activities to the possibility of joint leaks and breaks due to settlement when excavation activities occur near cast iron and threaded coupled pipe.

The Guide Material further recommends:

Where required, the inspection may include periodic full time surveillance and may include leakage surveys. The operator should consider maintaining field contact with the excavator during the excavation activities to avoid potential problems and to promptly resolve any problems that may arise.

The gas company did not take any of these Federally required or the ASME recommended steps to protect its cast-iron gas main in the face of construction work that involved deep excavation and backfill compaction.

The gas company also failed to patrol, adequately, its 3-inch diameter cast iron gas main. It did not even assign a permanent gas company inspector to that segment for the 2 or 3 days of sewer construction

Further, the gas company was aware that this contractor had already hit and ruptured gas service lines only days before. This is paradoxical since the gas company, at the preconstruction meeting, admonished the contractor about using care in working close to its cast-iron gas mains, but then ignored the regulations, guidelines, and its own procedures for the protection of the cast-iron pipe. The Safety Board is concerned about the gas company's lack of adequate attention to the integrity of its system during construction activities and to public safety.

Another area of concern to the Safety Board is the role that Genovese and Associates were contracted to fulfill. Genovese had been hired by the city of Derby to perform the engineering, prepare the construction plans and specifications, draw up the contract documents for the sewer project, and supply a Resident Project Representative (resident engineer) at the job site. At the Public Hearing held by the Safety Board in Waterbury, Connecticut, on February 11 and 12, 1986, the resident engineer stated that he understood his duties were "to observe the progress of the job and to try and see that the finished product is the same as what was laid out in the specs and the prints." He further pointed out that he had no authority over the contractor and could not direct the contractor to do something or to cease doing something even though the act was unsafe.

The contract between Derby and Genovese expressly stated that Genovese:

. . . shall not be responsible for the acts or omissions of any Contractors, any subcontractors or any of the Contractors' agents or employees or any other persons (except his own employees and agents) at the project site or otherwise performing any of the work on the project.

The contract further stated that the resident engineer:

. . . shall endeavor to provide further protection for the OWNER [Derby] against defects and deficiencies in the work, but the furnishing of such Resident Project Representative will not make the ENGINEER responsible for construction means, methods, techniques, sequences or procedures or for safety precautions or programs, or for the Contractor's failure to perform the construction work in accordance with the Contractor Documents.

The resident engineer did not caution the contractor or alert his company that the OSHA requirements for shoring trenches were not being adhered to. If he had done so and if, as a result, the contractor had driven shoring in the soil near the cast-iron gas main, the gas main might not have been disturbed and the compaction would have been confined to the area directly over the sewer pipe, not over the cast-iron gas main.

The resident engineer, because he had attended the preconstruction meeting, knew the location of the 3-inch cast-iron gas main and was aware of the gas company's admonition to use caution. However, he did not alert or caution the contractor or the gas company about the proximity of the sewer work on Caroline Streets to the cast-iron gas main.

The Safety Board believes that when a company is hired ". . . to provide further protection for the OWNER (municipality) against defects and deficiencies in the work. . ." it should be obligated to promote public safety. Apparently, this was not the case as the resident engineer was not explicitly required to and did not take any action to prevent this accident.

In this accident each of the three parties, the contractor, the gas company, and Genovese, apparently all assumed it was the other person's responsibility to protect the gas main. The contractor did not exercise sufficient care in supervising the operation and permitted the excavation, backfill, and compaction close to the cast-iron pipe without sufficient oversight and caution. The gas company did not take the steps necessary to protect its cast-iron pipe even though the pipe was one of the oldest in its system. The resident engineer, who knew the location of the cast-iron gas main and its proximity to the sewer construction, neither cautioned the contractor nor alerted the gas company to the potential hazard. No on-site communication took place among the three parties and as a result, the gas main was broken.

Emergency Response

The fire department's response was both rapid and effective. The fire chief received a radio call within 1 minute after the accident; he arrived on site 2 minutes later and firefighters and firefighting equipment followed immediately. The fire department together with the police department helped to evacuate 11 persons in the building, but was forced to leave the building due to its unstable condition. At that time, a crane was

positioned above the exploded building to evacuate anyone from above. One person was rescued when firefighters entered the basement of the restaurant from the west side through a common wall. Gas company personnel and contractor personnel identified themselves and cooperated with the fire department. In addition, they operated heavy equipment to clear away debris while rescue personnel searched for victims.

The Griffin Hospital Disaster Committee set up two triage units for the initial treatment of the injured; a trauma team with a medical helicopter aided in the treatment of the injured. Radio contact was maintained with area hospitals, which had been alerted and were ready to receive victims. The emergency response was very effective.

Public Awareness of the Hazards of Natural Gas

It appears that the natural gas was adequately odorized because the gas company had received gas odor complaints several days preceding the accident. The restaurant personnel and patrons knew the odor of gas and had detected the odor in varying amounts in and around the restaurant, but they did not report it to the gas company or to the fire department prior to the accident. Even though the gas odors detected in the early morning and through the lunch hour on December 6, 1985, were probably sewer gas from the old sewer which the contractor had broken the previous day, the restaurant owner through discussions with the resident engineer was advised that the gas company knew of the odors and believed the area to be safe. Nevertheless, the Safety Board believes that the restaurant owner should have reported his continuing concerns to the gas company for investigation to be certain that no present danger existed. In addition, gas company personnel had visited the neighborhood on several days before the accident and were highly visible and the area residents, the restaurant owner, and restaurant patrons probably thought that the gas company had the situation under control.

However, the Safety Board has investigated eight major accidents in which, unfortunately, gas odors detected before the accident were not reported to the gas company or to the fire department (see appendix C). While notification of gas odors to the gas company might not have altered the results in this accident, the Safety Board continues to be concerned about the public not informing gas companies or the fire department about gas odors.

Replacement of Cast-Iron Gas Mains

Cast-iron gas main failures often occur suddenly accompanied by the release of relatively large amounts of gas from a circumferential failure. Further, cast-iron gas main breaks most often occur beneath paved surfaces or below frost line (in winter) where escaping gas is unable to vent to the atmosphere and continues to build up below ground until it finds the path of least resistance (sewer pipe, electric conduct, water lines, etc.). The gas then travels along these paths, enters basements, crawl spaces, and foundations and is ignited. These accidents are very common and the Safety Board long has been concerned about the apparent frequency and seriousness of these failures.

On August 16, 1973, this concern about cast-iron failures prompted the Safety Board to issue a safety recommendation which asked the DOT to:

P-73-37

improve the accident reporting requirements in order to obtain a better understanding of the causes of failures of cast-iron mains.

This recommendation was issued as a result of the Safety Board's investigation of the explosion resulting from a gas leak from a failed cast-iron main in Atlanta, Georgia, on August 31, 1972. In response to this recommendation, the DOT stated on October 16, 1973, that the recommended improvements would be considered during its ongoing review of the pipeline data system. On April 3, 1978, the DOT further responded to this recommendation by stating:

OPSO recently completed a contract study to analyze the reported statistics and reporting procedures and to recommend appropriate revisions. The results of this study, along with comments and recommendations from NTSB and State regulatory agencies and the affected industry and industry associations, have been used by OPSO to develop new reporting forms which will provide data necessary to more clearly identify the causes of all types of accidents, including those caused from excavation damage and from cast iron mains. The revisions to the reporting forms will be proposed in an NPRM this Spring.

On March 21, 1983, the DOT responded further stating:

MTB (Materials Transportation Bureau) has now completely revised its methods of and upgraded its capability for analyzing and evaluating pipeline accident data. This has been accomplished primarily by a heavy investment in a computerized data entry, retrieval and analysis system, which has resulted in a better understanding of the causes of pipeline incidents, including failures involving cast-iron mains.

In the course of the Safety Board's evaluation of the DOT's actions, it determined that accurate records still are not available to determine the number of cast-iron gas main failures that occur nationwide each year. Also, the Safety Board determined that a majority of the gas distribution companies themselves do not know the causes of failures and extent of graphitization of their gas mains because they sleeve or clamp the majority of their cast-iron gas main failures without conducting any metallurgical analysis. Based on its evaluation that the intent of this Safety Recommendation had not been achieved and that it is not likely that the DOT would take effective action, therefore, the Safety Board classified Safety Recommendation P-73-37 as "Closed—Unacceptable Action."

Even though DOT does not have sufficient information concerning the specific failure causes or the extent of cast-iron gas main graphitization, the available data indicate that the number of miles of cast-iron gas mains is decreasing each year while the number of reportable cast-iron gas main failures remains relatively level; indicating that the numbers of leaks per mile is increasing. Further, cast-iron gas mains are steadily aging and, in many cases, the vehicular traffic (particularly heavy truck traffic) over these gas mains has increased in number as well as in weight. Because of these factors the Safety Board is concerned that the rate of failures of cast-iron gas mains may increase even further. While, to some extent, the same factors affect steel and plastic gas mains, they are more resilient, less brittle, and therefore, less apt to fail as a result of these factors.

Until now the Safety Board has addressed cast-iron gas main accidents on a case-by-case basis with recommendations generally made to the specific pipeline company involved in the accident. However, the Safety Board now believes that cast-iron gas mains, many of which have distributed natural gas to the public for well over 100 years, should be phased out in a planned, orderly, and economically feasible manner. The Safety

Board is aware that some large gas distribution companies are already engaged in cast-iron gas main replacement programs. Many of these large gas companies determine which cast-iron main is to be replaced based on the age of the cast-iron main, diameter of the cast-iron main, leak history of the cast-iron main, gas demand through the cast-iron main, depth of the cast-iron main, and vehicular traffic type and amount over the cast-iron main. In addition, many of the large gas distribution companies, on their own initiative, have systematically collected and recorded environmental information about their cast-iron gas main failures which can and should be used in their planned replacement programs.

However, no industry guidelines based on the available data, have been developed to provide direction to all gas distribution companies on how to develop replacement programs. Such guidance is needed to establish cast-iron gas main replacement programs with enough flexibility to accommodate the various needs of and resources available to large, medium, or small gas distribution companies. The Safety Board believes that if the gas distribution industry was required to initiate a program to replace its cast-iron gas mains through a well-planned, and well-executed program, this would result in a decrease in cast-iron gas main failures and a concurrent decrease in catastrophic accidents.

CONCLUSIONS

Findings

1. The contractor's superintendent left the site and put a foreman in charge of the job who was unaware of the existence of the 3-inch diameter cast-iron gas main.
2. The 3-inch diameter cast-iron gas main was fractured circumferentially by the sewer contractor's compaction activities during the afternoon of December 6, 1985.
3. Natural gas under 30 inches water column pressure escaped from the fractured 3-inch cast-iron gas main, migrated through an abandoned aqueduct into the River Restaurant, accumulated in the basement, exploded at 3:55 p.m., and then burned.
4. The sewer contractor did not use proper caution working around the 3-inch diameter cast iron gas main.
5. The gas company did not take prudent action to protect its 3-inch cast-iron gas main or to abandon it even though it was fully aware of the proximity of the sewer contractor's operations.
6. The resident engineer on site did not caution the contractor that they were working in close proximity to the 3-inch diameter cast iron gas main and that special care was needed in this work.
7. None of the three parties (gas company, contractor, or Genovese) communicated on site with each other concerning construction activities near the cast-iron gas main; none of the parties fulfilled their responsibility to take action which could have averted this accident.

8. Had the contractor's employee who was operating the compaction equipment reported his safety concerns to either his management or the gas company about the greatly increased odor, there would have been an opportunity to alert and evacuate people within the restaurant.
9. Because cast-iron is a brittle material susceptible to failure when subjected to impact or bending forces, special attention is required during excavation and other adjacent construction activities to prevent damage to cast-iron gas pipes.
10. Adequate data are available on which to establish cast-iron gas pipe replacement programs, however industry guidelines have not been developed.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the explosion and fire in the restaurant was the improper planning, execution, and supervision of the construction activities on the parts of the construction company and the gas company which resulted in the undetected fracture of the 87-year-old, 3-inch diameter, cast-iron gas main.

RECOMMENDATIONS

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

--to the National Utility Contractors' Association:

Notify its member companies of the circumstances of this accident and urge them to be sure, when conducting excavation operations near buried gas lines, that their construction crews are alerted to the existence and proximity of the gas lines. (Class II, Priority Action) (P-86-16)

--to the American Gas Association and to the American Public Gas Association:

Develop, in conjunction with the American Society of Mechanical Engineers, Gas Piping Standards Committee, specific guidelines for the replacement of cast-iron gas mains in large, medium, and small gas distribution companies. The guidelines should include, but not be limited to such factors as pipe age, pipe diameter, soil corrosivity, buried depth, and external loading. (Class II, Priority Action) (P-86-17)

--to the city of Derby, Connecticut:

Establish in contracts that involve excavation activities specific authority and responsibility for detecting and correcting any unsafe activities and specifically provide for stopping all excavation-related work until the unsafe conditions are corrected. (Class II, Priority Action) (P-86-18)

--to the Northeast Utilities Service Company:

Emphasize in its training of operating personnel the importance of following the company procedures for patrolling and protecting its gas mains in proximity to excavation projects. (Class II, Priority Action) (P-86-19)

Consider the abandonment of cast-iron gas mains prior to any excavation work in their proximity. Where abandonment is not practical or feasible prior to the excavation work, assign inspectors to the job site to monitor the excavation work. (Class II, Priority Action) (P-86-20)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ JOHN K. LAUBER
Member

/s/ JOSEPH T. NALL
Member

November 14, 1986

APPENDIXES

APPENDIX A

INVESTIGATION

The National Transportation Safety Board learned of this accident by telephone from the National Response Center duty officer at 10:20 p.m. e.s.t. on December 6, 1985. Two investigators were dispatched from the Safety Board's Washington, D.C. headquarters and arrived on-site at 11 a.m., December 7, 1985.

Parties to the investigation were the Northeast Utilities Service Company, the New England Railroad Construction Company, the city of Derby, Connecticut, the Connecticut Bureau of State Fire Marshal and Safety Services, and the Connecticut Department of Public Utility Control.

A technical review of the factual section of the report was held in Hartford, Connecticut, on June 23, 1986; all parties attended.

APPENDIX B

**PIPELINE ACCIDENTS WHERE GAS ODORS WERE DETECTED
BUT NOT REPORTED BEFORE THE ACCIDENT OCCURRED**

1. Northern States Power Company, Lake City, Minnesota, October 30, 1972
NTSB/PAR-73/1
2. Southern Union Gas Company, El Paso, Texas, April 22, 1973
NTSB/PAR-74/2
3. Columbia Gas of West Virginia, Inc. Charleston, West Virginia, December 2,
1973
NTSB/PAR-74/4
4. Consolidated Edison Company Explosion at 305 East 45th Street, New York,
New York
NTSB/PAR-76/2
5. Kansas Public Service Company, Inc. Explosion and Fire, Lawrence, Kansas,
December 15, 1977
NTSB/PAR-78/4
6. Columbia Gas of West Virginia, Inc. Explosion and Fire South Charleston, West
Virginia, October 17, 1983
NTSB/PAR-84/4
7. Arizona Public Service Company, Natural Gas Explosion and Fire, Phoenix,
Arizona, September 25, 1984
NTSB/PAR-85/1

APPENDIX C
SAFETY PROCEDURES

The following excerpts are taken from safety guidelines, procedural manuals, and Federal requirements established for the safe operation around pipelines.

1. Gas Company Underground Plant Damage Prevention-GO 190

<u>Revised</u>	<u>Date Effective</u>
May 1, 1982	May 1, 1982

I. APPLICATION

A. This procedure establishes the company's participation in a damage prevention program to reduce the risk of excavation damage to buried gas facilities.

* * * * *

B. Each area superintendent is responsible for providing for inspection of pipelines that he has reason to believe could be damaged by excavation activities. These inspections should be carried out in accordance with policy and procedure (GO 330).

2. Gas Company Distribution System Patrolling and Reporting (GO 330)

<u>Revised</u>	<u>Date Effective</u>
August 1, 1985	June 1, 1981

I. APPLICATION

A. This procedure establishes methods for patrolling and reporting conditions found on Northeast Utilities gas systems.

* * * * *

II. GENERAL INFORMATION

A. It is Northeast Utilities' policy to operate and maintain its gas facilities in good working order and to eliminate the development of any conditions which may become a hazard due to leakage or uncontrolled escape of gas from its facilities. Accordingly, it is Northeast Utilities' policy to patrol distribution gas mains to locate and identify conditions which could cause failure or leakage and consequent hazards to public safety. In addition to regular surveys required under Gas Operating Instruction 310, Leak Surveys, patrols the distribution system to include observation and reporting potential hazards such as the following will be conducted:

1. Excavation, grading, demolition or other construction activity which could result in:
 - a. damage to the pipe;
 - b. loss of support due to settlement or shifting of soil around the pipe;
 - c. undermining or damage to pipe supports;
 - d. loss of cover;
 - e. excess fill; or
 - f. damage to protective pipe coatings.

3. Gas Company Protection and Maintenance of Cast Iron Pipelines (GO 370)

Revised

Date Effective

October 1, 1981

October 1, 1981

I. APPLICATION

- A. This procedure establishes methods for the protection and maintenance of cast iron pipelines.

II. GUIDELINES

- A. This procedure is consistent with the Title 45, Code of Federal Regulations, Part 192, paragraphs 703 and 755.

III. PROCEDURES

- A. When an Area Superintendent has knowledge that a segment of varied cast-iron main is to be excavated, he shall determine whether the pipeline should be replaced under GE 201, or shall remain in place and be protected against damage.
- B. If the pipeline is to remain in place, it must be protected as necessary against damage during the disturbance by:
1. vibrations from heavy construction equipment, trains, trucks, buses or blasting;
 2. impact forces by vehicles;
 3. earth movement;
 4. apparent future excavations near the pipeline; or
 5. other foreseeable forces which may subject that segment of pipeline to bending stress.

* * * * *

- F. Where an exposed cast-iron main or service is located in proximity to conduit, duct, sewer line or similar structures, the potential for the structure to provide a path for migration of leaking gas should be considered.
- G. Patrolling may be necessary along cast iron mains or services during and after the disturbance to ensure adequacy of support methods and to ensure that the integrity of the system is maintained.

4. Federal Regulations for Damage Prevention Program (49 CFR 192.614)

Section 192.614, Damage Prevention Program (4/1/83)

(a) Except for pipelines listed in paragraph (c) of this section, each operator of a buried pipeline shall carry out in accordance with this section a written program to prevent damage to that pipeline by excavation activities. For the purpose of this section, "excavation activities" include excavation, blasting, boring, tunneling, backfilling, the removal of above ground structures by either explosive or mechanical means, and other earth moving operations. An operator may perform any of the duties required by paragraph (b) of this section through participation in a public service program, such as a "one-call" system, but such participation does not relieve the operator of responsibility for compliance with this section.

* * * * *

(6) Provide as follows for inspection of pipelines that an operator has reason to believe could be damaged by excavation activities.

(i) The inspection must be done as frequently as necessary during and after the activities to verify the integrity of the pipeline.

5. Gas Industry Safety Guidelines

The American Society of Mechanical Engineers, Gas Piping Standards Committee, Guide for Gas Transmission and Distribution Piping Systems lists the following procedures to be used to conform to 49 CFR 192.614.

Guide Material

1. Scope

Note 192.614(c) which lists pipelines excluded from the requirements related to damage prevention programs.

2. Written Program

Written procedures should state the purpose and objectives of the damage prevention program, and provide methods and procedures to achieve them. Applicable state and local requirements should be reviewed.

* * * * *

2.8 Inspecting pipelines.

(a) Need and schedule. Each notification should be evaluated to determine the need for and the extent of the inspection. Where required, the inspection may include periodic or full-time surveillance and may include leakage surveys. The operator should consider maintaining field contact with the excavator during the excavation activities to avoid potential problems and to promptly resolve any problems that may arise. The following factors should be considered in determining the need for and extent of inspections.

- (1) The type and duration of the excavation activity involved.
- (2) The proximity to the operator's facilities.
- (3) The type of excavating equipment involved.
- (4) The importance of the operator's facilities.
- (5) The type of area in which the excavation activity is being performed.
- (6) The potential for a serious incident should damage occur.
- (7) The past experience of the excavator.
- (8) The potential for damage occurring which may not be easily recognized by the excavator.

(b) Cast-iron and threaded-coupled steel pipelines. The operator should pay particular attention, during and after excavation activities, to the possibility of joint leaks and breaks due to settlement when excavation activities occur near cast iron and threaded-coupled steel.

* * * * *

6. Federal Regulations for Protection of Cast-Iron Pipelines (49 CFR 192.755)

When an operator has knowledge that the support for a segment of a buried cast-iron pipeline is disturbed:

- (a) That segment of the pipeline must be protected, as necessary, against damage during the disturbance by:
 - (1) vibration from heavy construction equipment, trains, trucks buses, or blasting;
 - (2) impact forces by vehicles;
 - (3) earth movement;
 - (4) apparent future excavations near the pipeline; or
 - (5) other foreseeable outside forces which may subject that segment of the pipeline to bending stress.
- (b) As soon as feasible, appropriate steps must be taken to provide permanent protection for the disturbed segment from damage that might result from external loads.

The American Society of Mechanical Engineers, Gas Piping Standards Committee, Guide for Gas Transmission and Distribution Piping Systems lists the following procedures to be used to conform to 49 CFR 192.755.

Guide Material

1. General

In addition to the conditions outlined in 192.755(a) and 3.1 of the Guide Material under 192.703, consideration should also be given to conditions such as water leaks and sewer failures, excavations for construction work, and excavations for repair or replacement of other underground facilities which can also remove or undermine the support.

* * * *

3. Replacement of Cast-Iron Mains or Services

As an alternative to protecting and supporting a cast iron main or service, consideration may be given to its replacement. (See 3.1 of the Guide Material under 192.703 and the Guide Material under 192.489.)

4. Adjacent Underground Structures

Where an exposed cast-iron main or service is in close proximity to a conduit, duct, sewer line, or similar structure, including abandoned facilities, the potential for the structure to provide a path for migration of leaking gas should be considered.

5. Patrolling

Patrolling may be necessary along a cast-iron main or service during and after the disturbance to insure the adequacy of support methods and the integrity of the system (see 192.721).

7. The Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor regulations:

Section 1926.652, Specific Trenching Requirements.

(a) Banks more than 5 feet high shall be shored, laid back to a stable slope, or some other equivalent means of protection shall be provided where employees may be exposed to moving ground or cave-ins. Refer to Table P-1 as a guide in sloping of banks. Trenches less than 5 feet in depth shall also be effectively protected when examination of the ground indicates hazardous ground movement may be expected.

* * *

(c) Sides of trenches in hard or compact soil, including embankments, shall be shored or otherwise supported when the trench is more than 5 feet in depth and 8 feet or more in length. In lieu of shoring, the sides

* * *

of the trench above the 5-foot level may be sloped to preclude, collapse, but shall not be steeper than a 1-foot rise to each 1/2-foot horizontal. When the outside diameter of a pipe is greater than 6 feet, a bench of 4-foot minimum shall be provided at the toe of the sloped portion.

(h) When employees are required to be in trenches 4 feet deep or more, an adequate means of exit, such as a ladder or steps, shall be provided and located so as to require no more than 25 feet of lateral travel.

APPENDIX D

CAST-IRON GAS MAIN FAILURES 1970 THROUGH 1983
OFFICE OF PIPELINE SAFETY
DEPARTMENT OF TRANSPORTATION

<u>Pipe Diameter</u>	<u>Number of Failures</u>	<u>Percent of Total</u>
1.000		
1.200	12	1.0
1.250		
2.000		
2.199		
2.250	103	8.1
2.380		
2.500		
3.000	31	2.4
3.500		
4.000		
4.620	491	38.7
4.800		
4.899		
5.000	3	0.2
6.000		
6.625		
6.899	361	28.4
6.900		
7.100		
8.000	146	11.5
9.049	1	0.1
10.000	16	1.3
12.000	58	4.6
13.000	2	0.2
13.200		
16.000	18	1.4
20.000	8	0.6
24.000	9	0.7
30.000	1	0.1
36.000	2	0.2
40.000	6	0.5
48.000	1	0.1
60.000	1	0.1
	<u>1,270</u>	<u>100.0*</u>

*Does not add to 100.0 percent due to rounding.

APPENDIX E

**MAJOR PIPELINE ACCIDENT REPORTS CONCERNING
CAST-IRON GAS MAINS**

1. Atlanta, Ga. Atlanta Gas Light Company August 31, 1972
NTSB/PAR/73-03
2. Missouri Public Service Company, Clinton, Missouri, December 9, 1972,
NTSB/PAR/74-03
3. UGI Corporation, Natural Gas Explosion and Fire, Allentown,
Pennsylvania, August 8, 1976
NTSB/PAR/77-02
4. Atlanta Gas Light Company, High Pressure Gas Main Rupture, Atlanta,
Georgia, December 1, 1977
NTSB/PAR/78-03
5. Philadelphia Gas Works Pipeline Rupture, Explosion and Fire,
Philadelphia, Pennsylvania, May 11, 1979
NTSB/PAR/79-03
6. Northeast Utilities Service Company, Explosion and Fire, Derby,
Connecticut, December 6, 1985
NTSB/PAR/86-02

END

DATE

FILMED

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NITIS