

NATIONAL TRANSPORTATION SAFETY BOARD

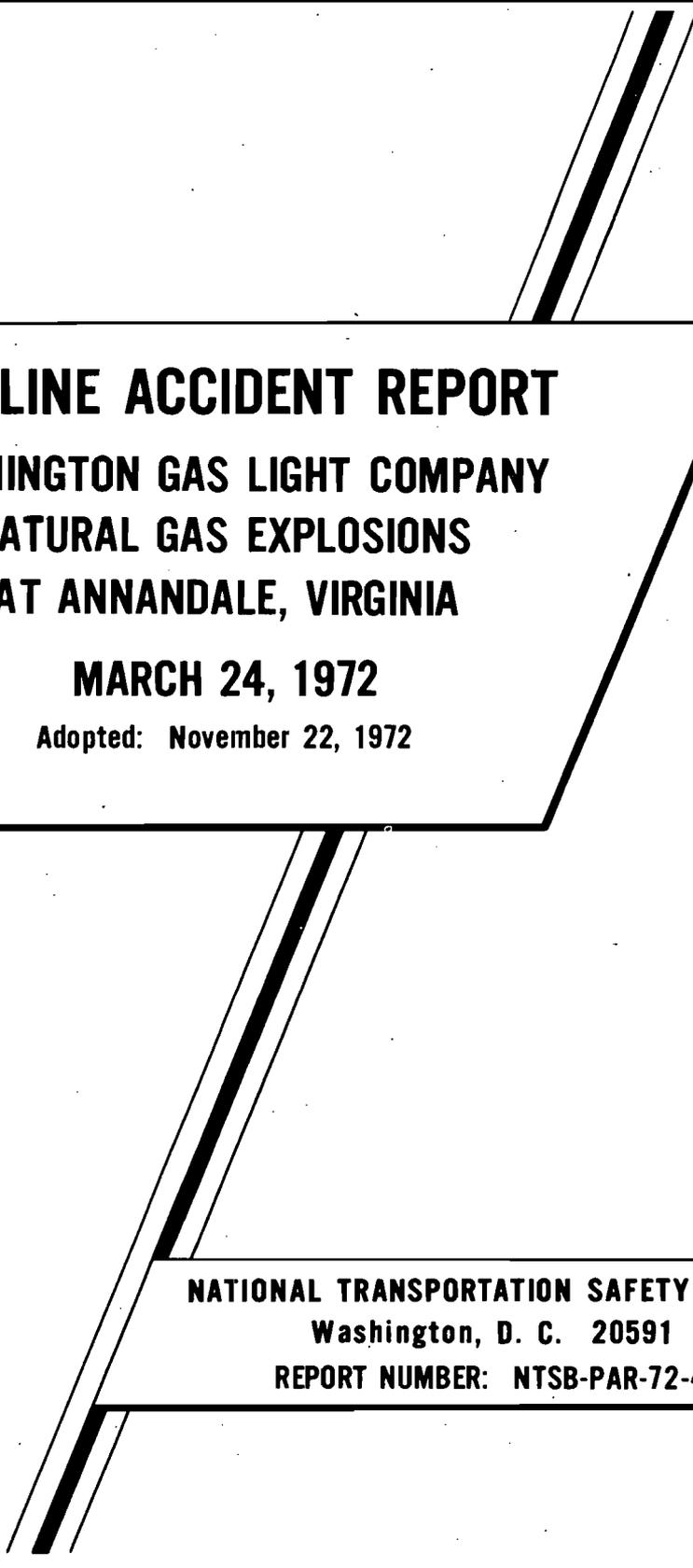
FOR RELEASE:
A.M.S OF FEB 2 1973

*the copy
not readable
#73-11*

**PIPELINE ACCIDENT REPORT
WASHINGTON GAS LIGHT COMPANY
NATURAL GAS EXPLOSIONS
AT ANNANDALE, VIRGINIA
MARCH 24, 1972**



**NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591
REPORT NUMBER: NTSB-PAR-72-4**



PIPELINE ACCIDENT REPORT

**WASHINGTON GAS LIGHT COMPANY
NATURAL GAS EXPLOSIONS
AT ANNANDALE, VIRGINIA**

MARCH 24, 1972

Adopted: November 22, 1972

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D. C. 20591

REPORT NUMBER: NTSB-PAR-72-4

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. NTSB-PAR-72-4	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle <u>Pipeline Accident Report</u> - WASHINGTON GAS LIGHT COMPANY, NATURAL GAS EXPLOSIONS AT ANNANDALE, VA., MARCH 24, 1972.		5. Report Date November 22, 1972	
		6. Performing Organization Code	
7. Author(s)		8. Performing Organization Report No.	
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Surface Transportation Safety Washington, D. C. 20591		10. Work Unit No.	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20591		13. Type of Report and Period Covered PIPELINE ACCIDENT REPORT March 24, 1972	
		14. Sponsoring Agency Code	
15. Supplementary Notes This report contains Pipeline Safety Recommendations P-72-40 thru P-72-62.			
16. Abstract On March 24, 1972, in the Annandale section of Fairfax County, Va., a contractor's backhoe snagged a 2-inch steel gas main, operating at 22 p.s.i.g., and pulled the main out of a compression coupling 22 feet away. Gas company personnel arrived on the scene about 40 minutes later and started to search for the break. The gas was not shut off and the nearby houses were not checked for the presence of gas. About 20 minutes after the gas company crew had arrived, a house, 240 feet away from the point at which the line was snagged, exploded. Within the next few minutes, two other houses exploded and burned. As a result of the accident, three persons died and one was injured; two houses were destroyed and a third was badly damaged; and \$153,000 worth of property was damaged. The National Transportation Safety Board determines that the cause of the explosions in the three houses was the ignition of gas that leaked from a main damaged by a contractor's backhoe. Contributing to the accident were the delay by the gas company in shutting off the flow of leaking gas, the failure to check for gas in houses, and the failure to notify police and fire officials. Also contributing were the failure of the area residents to report the presence of leaking gas in their houses, and the failure of the county to supply the contractor with the accurate gas main location which had been provided by the gas company.			
17. Key Words Pipeline accident, natural gas leakage, pulled main, pipeline safety standards, public awareness of gas emergencies, valve operation, gas migration through soils.		18. Distribution Statement Released to public; distribution unlimited.	
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 40	22. Price

FOREWORD

The accident described in this report has been defined as a major accident by the National Transportation Safety Board under the criteria established in the Safety Board's regulations.

The report is based on facts obtained from an investigation performed by the Safety Board. The investigation included a public hearing held in Washington, D.C., on April 5 and 6, 1972.

The conclusions, the determination of probable cause, and the recommendations herein are those of the Safety Board.

TABLE OF CONTENTS

	<i>Page</i>
FOREWORD	iii
I. SYNOPSIS	1
II. FACTS	1
Accident Site	1
Events Preceding the Accident	3
The Accident	4
Events After the Accident	8
Federal Standards	16
Guide for Gas Transmission and Distribution Piping Systems ..	18
WGL Standards and Practices	18
III. ANALYSIS	21
Delay in Shutting Down the Main	21
Notification Prior to Excavation	22
Hazard Warnings to Gas Users and General Public	23
Priority of Leak Reports	23
Notification of Public Officials	23
IV. CONCLUSIONS	23
V. PROBABLE CAUSE	24
VI. RECOMMENDATIONS	25
APPENDICES	
Appendix A: Operating Practices of Other Gas Companies ..	28
Appendix B: NBS Test Results	32
Appendix C: NBS Conclusions from the Field Investigation ..	33
Appendix D: WGL Operating Instructions, No. M & S-50, Investigation of Gas Leaks	35

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20591
PIPELINE ACCIDENT REPORT

Adopted: November 22, 1972.

WASHINGTON GAS LIGHT COMPANY
NATURAL GAS EXPLOSIONS
AT
ANNANDALE, VIRGINIA
MARCH 24, 1972

I. SYNOPSIS

On March 24, 1972, a construction firm under contract to Fairfax County was replacing a storm sewer in the Annandale section of the county. At about 7:50 a.m., the contractor's backhoe snagged a 2-inch, wrapped-steel gas main operating at 22 p.s.i.g. The main, which supplied five houses in the southern cul-de-sac of Magdalene Court, was not broken where struck, but was pulled out of a compression coupling 22 feet into the cul-de-sac. Leaking gas was detected at the job site almost immediately, and the Washington Gas Light Company (WGL) was notified. After some delay, the report of the pulled main was relayed to the gas company's field maintenance personnel, who arrived between 8:30 and 8:40 a.m. A number of residents in the area had detected the odor of gas, but only one called WGL.

Shortly before 9 a.m., an explosion occurred in a house 240 feet from the point where the line was snagged. A short time later, two neighboring houses also exploded, within a few minutes of each other. At 9:48 a.m., the last of four valves used to isolate the area was closed. A pipe squeezer was placed on the line at the point of the snag, and the flow of gas stopped at 9:52. As a result of the accident, the woman who had called WGL to report the leak and two of her

children died, and one WGL workman was injured seriously. Two houses were demolished completely, and a third was badly damaged.

The National Transportation Safety Board determines that the cause of the explosion in the three houses was the ignition of gas that leaked from a main damaged by a contractor's backhoe.

Contributing to the accident were the delay by the gas company in shutting off the flow of leaking gas, the failure to check for gas in houses, and the failure to notify police and fire officials. Also contributing were the failure of the area residents to report the odor of gas in their houses, and the failure of the county to supply the contractor with the accurate gas main location which had been provided by the gas company.

II. FACTS

Accident Site

This accident took place in a residential development, constructed in 1966, in the Annandale section of Fairfax County, Va. The houses in this development are served by underground sewer and water lines and by an integrated high-pressure gas distribution system operated at 22

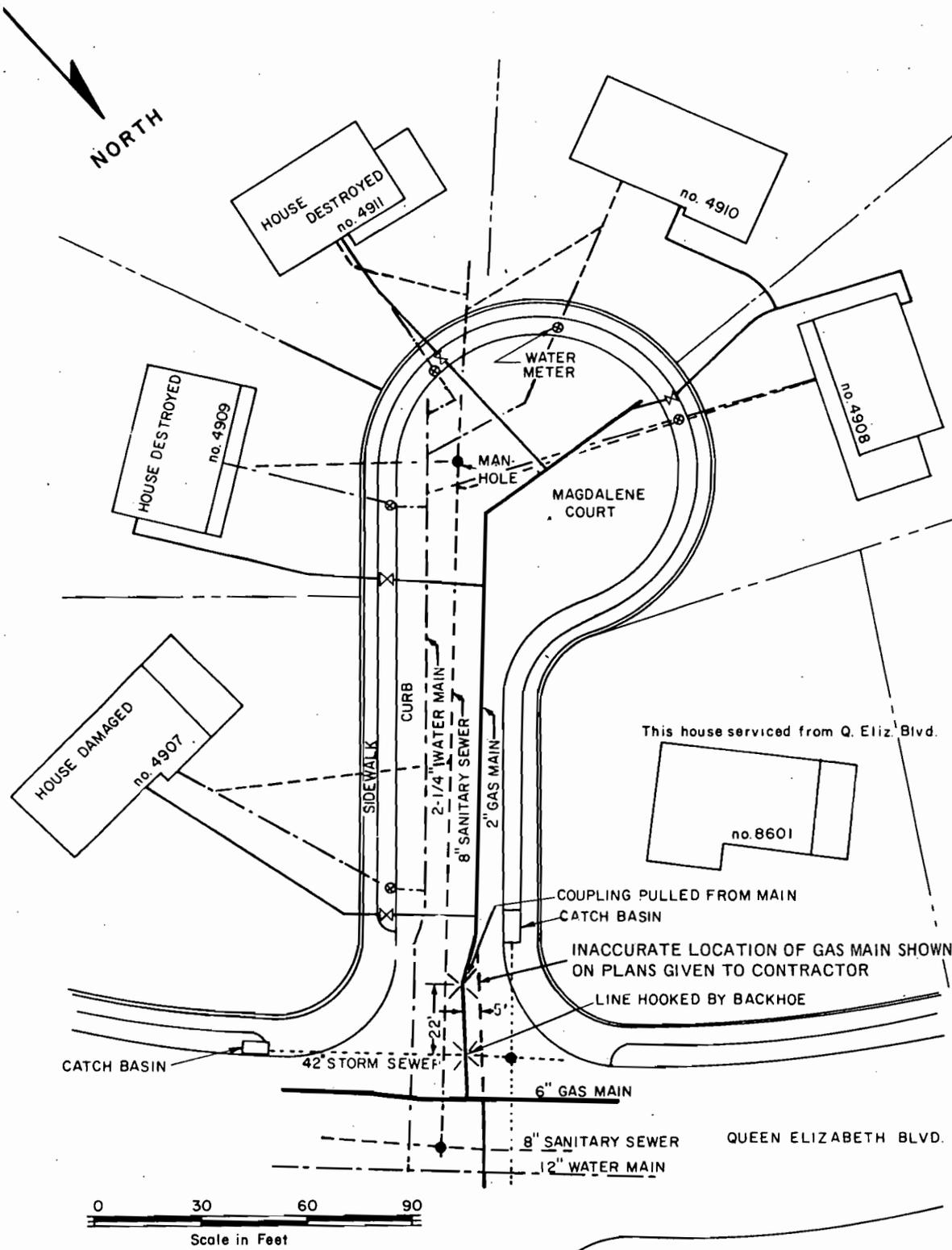


Figure 1. Accident site.

p.s.i.g. by the Washington Gas Light Company (WGL). A service regulator, which reduces the pressure to about $\frac{1}{4}$ p.s.i.g., a gas meter, and a shutoff valve are located in the basement of each house. A second shutoff valve is located at the curb.

A 6-inch wrapped-steel gas main runs in an east-west direction on Queen Elizabeth Boulevard. Two 2-inch steel mains connected to this 6-inch main supply gas to the two culs-de-sac of Magdalene Court, north and south of the boulevard. (See Figure 1.)

Events Preceding the Accident

In order to upgrade its storm-sewer system, Fairfax County undertook a project to replace a section of 42-inch storm sewer in the vicinity of Magdalene Court with 54-inch pipe. Prior to taking construction bids, the consulting firm designing the project for the county sent copies of the proposed plans to all area utility operators and requested that each operator mark the location of facilities that lay in the path of the storm sewer.

The plans sent to WGL erroneously indicated that the 2-inch gas main serving Magdalene Court ran in a north-south direction straight across the 6-inch main on Queen Elizabeth Boulevard. Actually, the 2-inch line which ran into the southern cul-de-sac of Madgalene Court was set 5 feet to the east of the line which ran into the northern cul-de-sac. (See Figure 1.) This 5-foot offset was marked on the proposed plans by WGL and the plans were returned to the consulting firm in August 1971. In the transmittal letter, the gas company explained that the new locations marked on the prints were approximate, and stated:

"We recommend that the contractor hand dig test pits to determine the exact location and depths of our facilities prior to any construction. If additional information is required, we shall be glad to furnish it."

In December 1971, the county forwarded to WGL two copies of the final plans, stating that

bids had been received and requesting that WGL review the plans and return them to the county. Like the earlier plans, these final plans showed the 2-inch gas main which ran south into Magdalene Court in the wrong position. On January 4, WGL advised the county that WGL planned to dig a test pit and would forward the results. Seventeen days later, the gas company returned one set of plans to the county, with the following remarks:

"We are returning one set of your plans on which we have shown the top of the 2" gas line to be 240.86 as obtained by digging a test pit.¹ The contractor will have to exercise extreme caution when removing the existing 42" storm sewer and installing the 54" storm sewer to prevent damage to this gas line. Should you require additional information we shall be glad to furnish it."

The test pit showed that the 2-inch gas main passed over the storm sewer which was to be replaced. Besides once again indicating the correct location of the main on the plans, WGL also provided the county with the exact depth of the main. County officials used this information to confirm that the sewer replacement could fit beneath the 2-inch main without requiring relocation of the main. However, they did not update the final plans.

In August 1971, after having received the first set of plans, WGL had painted G's and arrows on the pavement above the gas mains which lay under Queen Elizabeth Boulevard and south Magdalene Court. On January 14, 1972, when the location of the test pit was selected, WGL repainted these markings.

Preconstruction activities. The successful project bid was submitted in December 1971 by the William B. Hopke Company, Inc. On February 22, 1972, a preconstruction meeting was held in Fairfax. Representatives of the Hopke Company, the county department of public works, the county water authority, and the department of county development attended. The gas company

¹The number 240.86 represents the height above mean sea level in feet. (Footnote added by NTSB.)

was not invited, since the county had determined that their lines would not require relocation. No mention was made at the meeting of gas mains in the area; the minutes state that there would be "no conflict with gas lines."

Although the contractor was told neither the location nor the depth of the WGL gas mains, both the contract and the plans contained provisions regarding the location of such underground facilities. The plans warned that:

"Horizontal locations of existing water and gas mains shown on this plan are approximate. Contractor must verify location of these utilities in the field before proceeding with the work covered by these plans. Contact: water, FCWA 256-5500; gas, Washington Gas Light Company, 750-4706."

The contract cautioned that:

"The contractor will be held responsible for locating all underground structures such as water, oil and gas mains, water and gas services, storm sewers and telephone and electric conduits which may be encountered during the construction operation. He shall either dig test holes to determine the position of the underground structures or he shall arrange with the Owners of such underground structures to assign a representative to make the locations."

Before work on the project was begun, the Hopke superintendent went to the job site, where he noticed the G's and W's painted on the street. The contractor did not call WGL, because experience indicated that the gas company, if called, would only mark the street. Had the contractor known the depth of the gas main, this information would have been given to the foreman in charge of the project.

The foreman was provided with a copy of the final plans on March 15, the day before work was begun. In addition, the superintendent walked over the site with the foreman and cautioned him about the underground facilities. The foreman said that he was aware that the project would cross the path of water and gas lines and

was aware of the note printed on the plans in regard to the horizontal location of existing mains.

The contractor contacted the water company concerning the water line that ran into south Magdalene Court, because the water line was to be relocated. The foreman also requested that the contractor contact the gas and telephone companies and the water authority and find out the location of their lines in north Magdalene Court, since these locations had not been marked on the street. The foreman was aware of the G's marked on the street in south Magdalene Court and of the location of the test pit which had been dug there. However, he did not know if the gas main running into south Magdalene Court was above or below the sewer line to be replaced.

The start of construction. Work began on the south side of Queen Elizabeth Boulevard, east of Magdalene Court. Work stopped on March 23, because the project was approaching the water line in the intersection of Magdalene Court. The water was to be shut off the following day so that the water line could be relocated. Prior to this point, no other underground structures had been encountered.

On the morning of March 23, the foreman pointed out to the backhoe operator the markings and test pits for the gas and water lines in south Magdalene Court. The next morning, the foreman again cautioned the machine operator about the proximity of the water line, which the foreman knew lay beneath the sewer being replaced. The operator was not told about the gas main and he was not furnished with a copy of the project plans. Although he did notice the G's and the test pits, the operator paid no particular attention to them, because he was usually shown the exact location of an underground facility by a helper who directed his activities as he approached such a facility.

The Accident

National Weather Service records for National Airport indicate that, at 7:55 a.m. on March 24,

the temperature was 33°F and the wind was blowing at 17 knots, gusting up to 25. Since temperatures during the previous 2 weeks were well above freezing, there was no frost in the ground.

Upon arriving at the job site at 7 a.m., the backhoe operator was informed by the foreman that the water line had to be removed before work could start and that the representatives of the water authority would not be on the scene until 9:30 a.m. At 7:30, the operator moved his backhoe into position to begin excavating. A dump truck was positioned beside the backhoe in the intersection of Magdalene Court to receive removed blacktop. The foreman was in the excavation helping a workman set up a laser beam device which was used to obtain the proper alignment for the sewer.

The machine operator was taking light scoops to avoid breaking the 42-inch sewer. He did not realize that the gas main lay buried 3.14 feet below the surface of the street at that spot. At about 7:50, after making three passes with the backhoe, he realized that he had hit something "very heavy." He released the power and moved the bucket aside. The pipe was not broken where it was hit, but it was pulled. (See Figure 1.) Although workmen generally guide the machine operator when he is near underground facilities, when the line was snagged no one was directing the operator's work.

The foreman smelled gas almost immediately and contacted the contractor's office via a two-way radio in his pickup truck. After ascertaining the size of the snagged gas main, the contractor's estimator, who had taken the foreman's call, contacted WGL's planning section. At 7:55, the WGL dispatcher was informed by the planning section that a 2-inch gas main had been pulled.

The dispatcher immediately attempted to contact the WGL foreman assigned to that area. After two unsuccessful attempts, the dispatcher contacted the general foreman, who was at the office in Springfield, by telephone. The general foreman advised the dispatcher to continue to attempt to contact the foreman. The dispatcher made about seven more attempts to contact the

foreman, while simultaneously maintaining radio contact with approximately 135 other WGL vehicles in the metropolitan Washington area.

At some time prior to 8:20 a.m., one of the two crews assigned to the area foreman contacted the dispatcher. The crew had heard the dispatcher's call for the foreman, but had been unable to contact the dispatcher because of the heavy use of the radio by other personnel. The dispatcher advised the crew of the pulled main and its location.

Having departed from the company office, the foreman arrived at approximately 8 a.m. at a job site where he was to meet his second crew and check for gas leaks. In order to perform this work, the foreman left his car and its radio. When he returned, he received a call from the dispatcher, who informed him of the pulled main, and he asked the dispatcher to contact the crew which had already taken the call.

The dispatcher's records indicate that this series of transmissions with both the crew and their foreman was completed at 8:20. The dispatcher did not attempt to contact either fire or police officials, since the crew and foreman were proceeding to the scene and the problem seemed routine.

Shortly after 8 a.m., the resident of 4909 Magdalene Court detected an odor of gas in her home. She called her neighbor who lived on the corner of Queen Elizabeth Boulevard and Magdalene Court to inquire if the neighbor also smelled gas and to ask for advice. She then called the appliance-service department of WGL and reported the odor of gas. Another neighbor, at 4907 Magdalene Court, had also smelled gas, but did not call WGL.

The call from the woman at 4909 Magdalene Court was received by WGL at 8:36. The service order based on information supplied by the woman reported a "gas odor in house." The WGL clerk indicated on the order that the odor was slight and that the source of the odor was unknown. The order was dispatched to a WGL serviceman at 9:30.

The house at 4909 Magdalene Court is 165 feet from the point where the line was hit. The

machine operator and the contractor's foremen, soon after the line was caught, saw gas blowing up between the concrete curb and the street blacktop near a catch basin about 35 feet south of the point where the line was snagged.

A number of other residents east of Magdalene Court on Queen Elizabeth Boulevard, whose homes were located about 250 to 600 feet downwind of the accident site, also detected an odor of gas between 8:15 and 9 o'clock.² None of these people contacted the gas company or the police or fire departments. Some stated that they were aware of the activity going on at the corner of Magdalene Court and Queen Elizabeth Boulevard and assumed that the gas odor was due to the maintenance work being conducted.

The WGL crew arrived on the scene between 8:30 and 8:40 a.m., confirmed that a 2-inch main had been pulled and reported to their foreman by radio. After the foreman arrived on the scene, he was informed by the dispatcher that in order to shut off the affected area it would be necessary to close two valves to the east and two valves to the west of Magdalene Court.

When the crew arrived, the odor of gas was heavy, especially in the trench. The crew began to dig around the 2-inch main where it was snagged in order to confirm its size and to prepare to cut the line and place a 2-inch compression coupled valve on the end to stop the flow of gas. No attempt was made by the crew to check for the presence of gas in or around any of the nearby buildings or structures.

At this point, the WGL personnel on the scene did not know if the break in the 2-inch main was south, in Magdalene Court, or north, back toward the 6-inch main on Queen Elizabeth Boulevard. Responding to a request from the WGL foreman, the backhoe operator removed a few shovelfuls of the cover on top of the 2-inch main in a northerly direction toward the connection of the 2-inch main with the 6-inch main. The gas crew then got into the

trench and continued to uncover the 2-inch main. After the pipe was cleaned, it was decided that a compression coupled valve could not be slipped on the pipe because the pressure was too high and the escaping gas at the point of cut would have created further hazards. No additional crews or equipment were requested at this time. Also, about this time, the general foreman, who was enroute to the scene, spoke with the area foreman and instructed the crew not to turn off any valves.

The resident of 4911 Magdalene Court, which is about 240 feet from the point where the line was hit, noted an odor in her home shortly after 8:30 a.m. She checked the gas stove to see if the pilot light had gone out but found it lit. She then went to the basement and found that the pilot light on the water heater was lit but could not locate the pilot light on the furnace and was unable to confirm if it was lit. She did note that the odor did not seem to be coming from the furnace.

Shortly before 9 a.m., there was an explosion in the house. The woman, in the dining room at the time, picked up her infant son and attempted to leave the house from the kitchen door. The door was jammed shut and could not be opened. The front door was also jammed shut. She then saw an opening in the front wall near the front door caused by the explosion and was able to leave the house by squeezing through the opening. The house did not appear to be burning at that time.

When the explosion occurred at 4911 Magdalene Court, both the foreman for the gas company and the foreman for the Hopke Company called their offices on their radios, reported the explosion, and requested assistance. At exactly 9 a.m. the county emergency operation center received a call from a resident in the area. Nine additional calls were received at 9:01. The foreman for the gas company ordered his men to turn off the gas meters at the houses on the Court and to evacuate the people. He had thought the meters were on the outside of the houses; however, they were on the inside.

² Residents of 8514, 8518, 8519, and 8521 Queen Elizabeth Boulevard detected gas odors.

A gas company employee and the machine operator ran into the court and were informed by the resident of 4911 that there was no one in the home except for her dog. They then attempted to evacuate the house at 4909. Finding the front door open, they entered the hallway and called to two children they saw in the basement, asking them if their mother was at home. The children, who were aged 3 and 1½ years, did not seem to understand and did not move. The machine operator felt a rumble beneath his feet, turned around, and ran from the house. As he reached the sidewalk, the house exploded violently. The machine operator threw himself to the ground, but the WGL employee was thrown back out into the street with his clothing burning.

The house was almost completely destroyed by this blast. The only other occupant in the house at the time, the mother of the two children, was blown out of the back of the house.

The house at 4907 Magdalene Court also exploded a few minutes later. This explosion was of a lesser magnitude and fire began in the southerly portion of the house. At this time, the house at 4911 started to burn.

The first fire company arrived at the site of the accident at 9:05 a.m. Firefighting equipment could not enter Magdalene Court because of live electrical wiring which had come down from the houses involved in the explosions. The first concern of the fire department was the safety of the people in the area. Ambulances, which had also been dispatched, picked up the resident of 4909 Magdalene Court and the injured WGL worker and took them to a nearby hospital.

Because of its condition, firemen could not enter the house at 4909 Magdalene Court. They did attempt to control the fire at 4911 Magdalene Court and to enter that house, but within a matter of minutes the firemen had to withdraw because the building began to collapse.

The house at 4907 Magdalene Court was intact and was burning in the carport and basement area. The firemen entered the building from the kitchen door on the ground level and from a basement door at the rear of the build-

ing. A combustible gas meter brought into the building indicated high concentrations of gas in the basement, and personnel withdrew from the building because of the danger of further explosions. While in the basement, firemen noticed that gas was burning from the top row of cinderblocks.

After leaving the building, the firemen were able to contain the fire. It appeared to them that an explosion which occurred in an ashpit located beneath the carport had blown out approximately five or six cinderblocks from their normal position. Small gas-fueled fires, which flared up and died down, were observed at the expansion joint where the carport at 4907 joined the driveway. Gas-fed flames were also observed in the wall area of the house at 4909 Magdalene Court and along the street in front of 4909 Magdalene Court where the blacktop joined the concrete curb. Gas was also detected coming up through cracks in the blacktop nearer to the excavation.

Police arrived on the scene shortly after 9 a.m. Because of the heavy odor of gas, the police and fire departments decided to evacuate all residents within a 1½-block radius of the explosions and fires. At 9:15 a.m. the evacuation began and, within 20 minutes, 75 homes were evacuated. The children at the nearby Canterbury Woods Elementary School, ¼ mile from Magdalene Court, were also evacuated. The police and fire personnel then began to vent the homes within a 1-block radius by opening doors and windows.

Fire-department personnel, using combustible gas indicators, checked the sanitary sewer manholes on Magdalene Court and Queen Elizabeth Boulevard and found no trace or indication of gas in the sanitary sewer system. Gas was detected in the water meter boxes at the curbs of the houses in the immediate area and some traces of gas were detected in the storm sewer in Magdalene Court.

After the explosions, the gas company dispatched two additional crews and a pickup truck equipped with various sizes of pipe-squeezing equipment. This truck is the only one in use by

WGL for the entire Washington metropolitan area. A foreman and crew in the pressure division were also dispatched to the scene to shut off the valves on either side of the pulled main.

The dispatcher, upon clearance from the pressure division, requested that valves 37 and 39, 800 feet to the east of the accident scene, and valves 49 and 50, 600 and 800 feet west of the scene of the accident, be shut off. (See Figure 2.) A crew at the accident scene was sent to locate these valves and make sure they were visible and not obstructed so that when the pressure crew arrived there would be no further delay in closing the valves. Preparations were being made simultaneously at the scene to place the squeezing device on the line as a second and independent method of stopping the flow of gas.

The pressure-division foreman and his crew, who arrived in two separate vehicles, shut off valve 37 at 9:30 a.m. and valve 39 at 9:31. The crew and the foreman then attempted to reach the two valves west of the accident, but were unable to proceed down Queen Elizabeth Boulevard because of the emergency equipment in the street. After going completely around the accident scene, the crew shut off the valves at 9:46 and 9:49.

Before the last valve was closed, mercury gauges were installed on either side of the valve to determine that the gas supply was being shut off in the affected area. While the last valve was being closed, the squeeze device was being applied at the scene of the accident and the flow of gas was stopped at 9:52 a.m.

With the gas supply shut off, the fires in the homes were extinguished, as were various small gas fires in the streets. The fire department estimated that all fires were out or under control by 10:30 a.m.

As a result of the explosions and fires, the woman occupant of 4909 Magdalene Court and her two children died, and the gas company workman was seriously injured. The estimated property damage was \$153,000. (See Figures 3, 4, 5, and 6.)

Events After the Accident

Locating the point of leakage. In order to determine where the pipe had been separated, the gas company cut and removed the pulled section of pipe, installed a 2-inch valve on the remaining piping leading into south Magdalene Court, and drilled holes over the pipe for a distance of approximately 40 feet. Compressed air, introduced into the end of the pipe, was detected blowing out of the holes in the pavement approximately 20 feet south of the point where the backhoe had snagged the main. The gas company excavated at this point and found that the pipe was separated 2-½ inches, at a point 22 feet from the point of snag, where it was joined to another section of pipe with a compression coupling. The coupling, 3.66 feet below the street, remained on the section of pipe that was snagged. (See Figure 7.)

Changes in Fairfax County procedures. Fairfax County is now formally inviting to the pre-construction meeting operators of all utilities that will be encountered during a planned construction project. The invitation is extended whether or not the underground structure requires relocation. The final plans provided to the contractor are now also given to the operators of all other utilities in the area. Any pertinent information provided to the county concerning underground utilities is given to the contractor, but the county still expects the contractor to make contact with each utility and discuss the information so that no misunderstanding exists on the part of the contractor concerning the exact location of underground structures prior to commencing work.

National Bureau of Standards tests. In order to determine the path of the leaking gas, the National Transportation Safety Board requested the National Bureau of Standards (NBS) to conduct a field investigation at the site of the accident.

In its investigation, NBS simulated natural gas flow underground by introducing a mixture of air and refrigerant R-12 tracer 6 feet south of

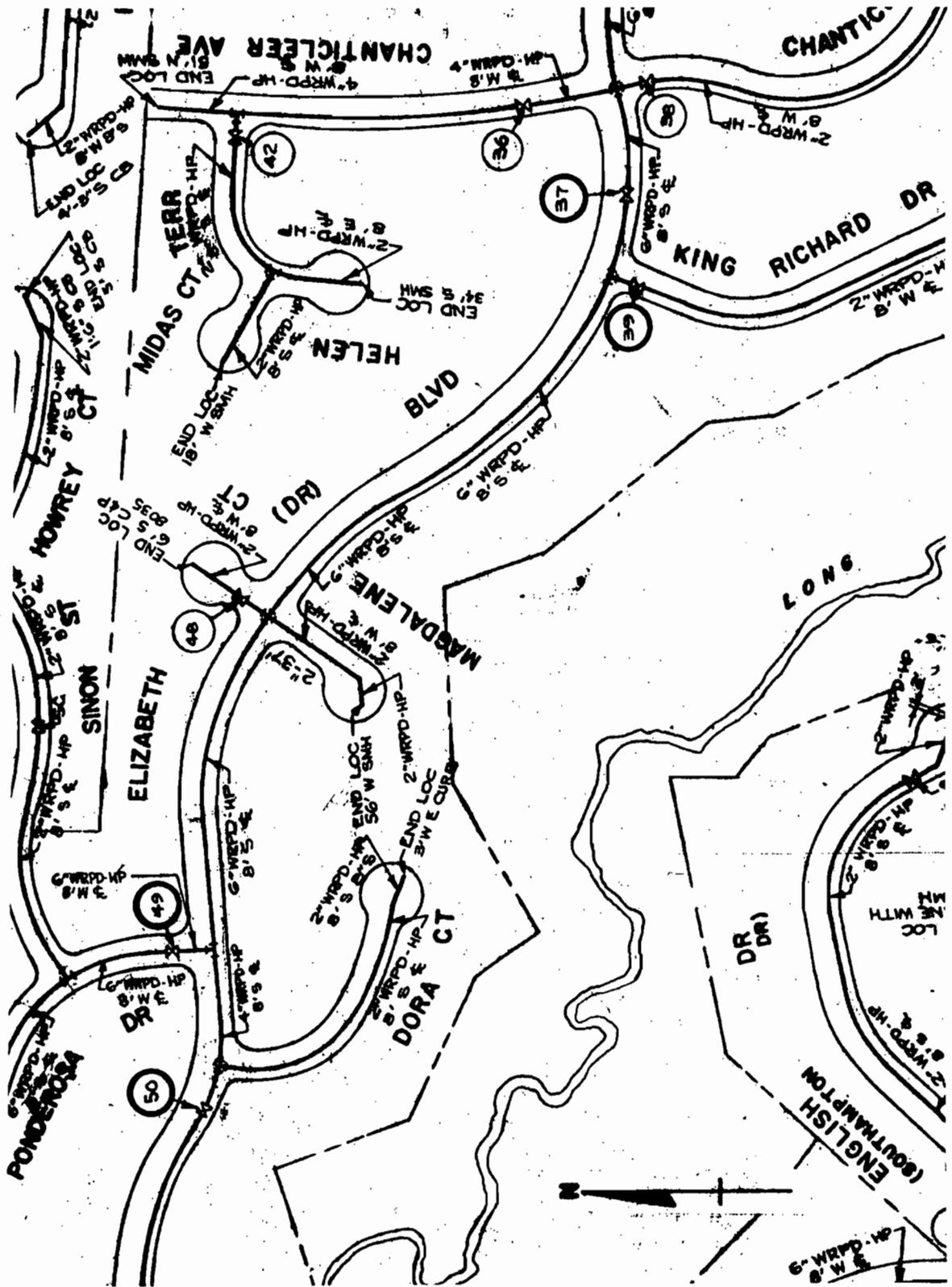


Figure 2. Location of the valves used to isolate the leak.



Figure 3. Aerial view of accident site (picture taken facing east).

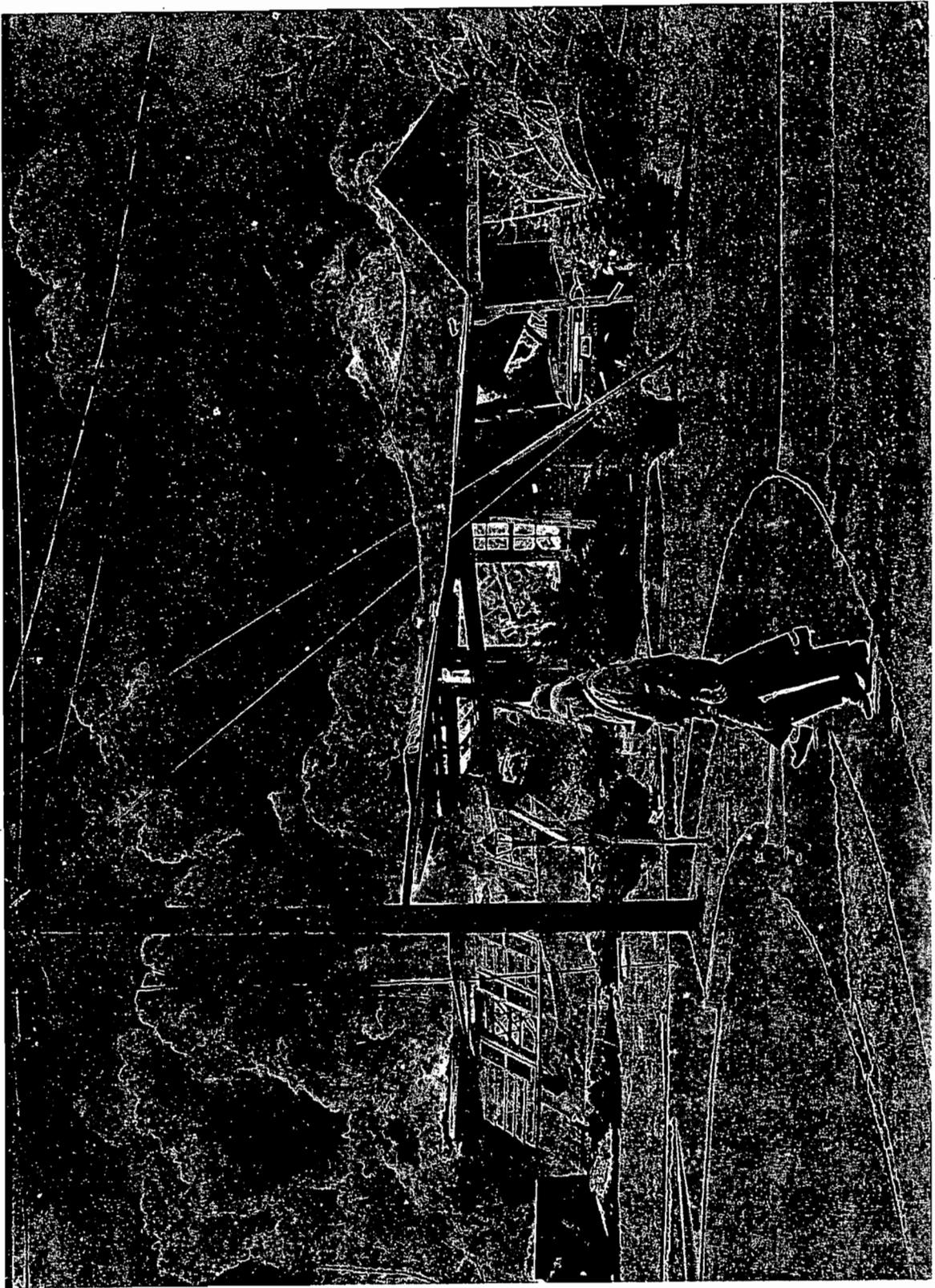


Figure 4. 4911 Magdalene Court (picture taken facing south).

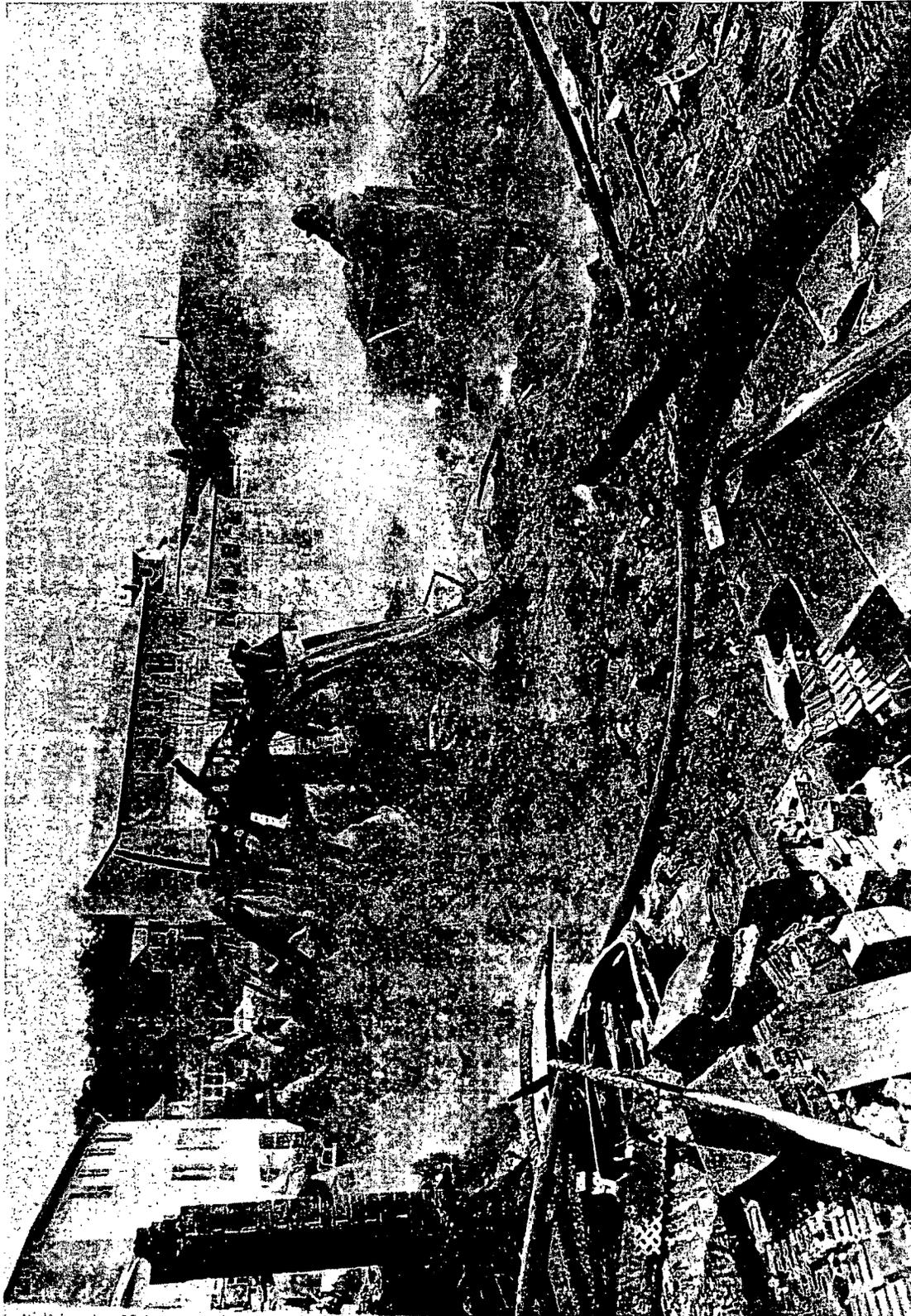


Figure 5. 4909 Magdalene Court (picture taken facing east).



Figure 6. 4907 Magdalene Court (picture taken facing west).



Figure 7. Pipe separated from coupling (picture taken facing north).

the separated coupling and by then checking for the tracer within houses and other locations. The premise of the NBS tests was that if the tracer could be detected at locations where natural gas was known to have escaped, then the underground paths followed by the gas at the time of the accident might still be intact. The test consisted of four phases:

- Determine if the air-tracer mixture could be detected at points where gas was known to have escaped during the accident.
- Take tracer readings at other locations at the accident site, particularly basement foundation walls and sewers, to attempt to reconstruct the pattern of gas leakage that occurred during the accident.
- Pinpoint the paths followed by the gas to the houses affected in the accident and, if possible, obtain quantitative estimates of the gas flow to these homes.

- Attempt to determine the means by which the gas entered the basement of 4911 Magdalene Court, which was destroyed in the accident.

Figure 8 shows the test setup used by NBS to inject the air-tracer mixture into the ground.

On the second day of tests, air-tracer mixture, flowing at a rate of 29.2 c.f.m. and at a pressure of 2.2 p.s.i.g., was introduced into the ground. Tracer was detected at many points at the accident site, including the points where natural gas was known to have been present during the accident. A complete list of the locations where tracer was and was not found is included as Appendix B.

As part of the field investigation, the utility trenches in front of 4909 and 4911 Magdalene Court were excavated. The trench dug for the water and sewer lines at 4909 revealed a 0.4-foot-deep cover of fine soil, under which lay a

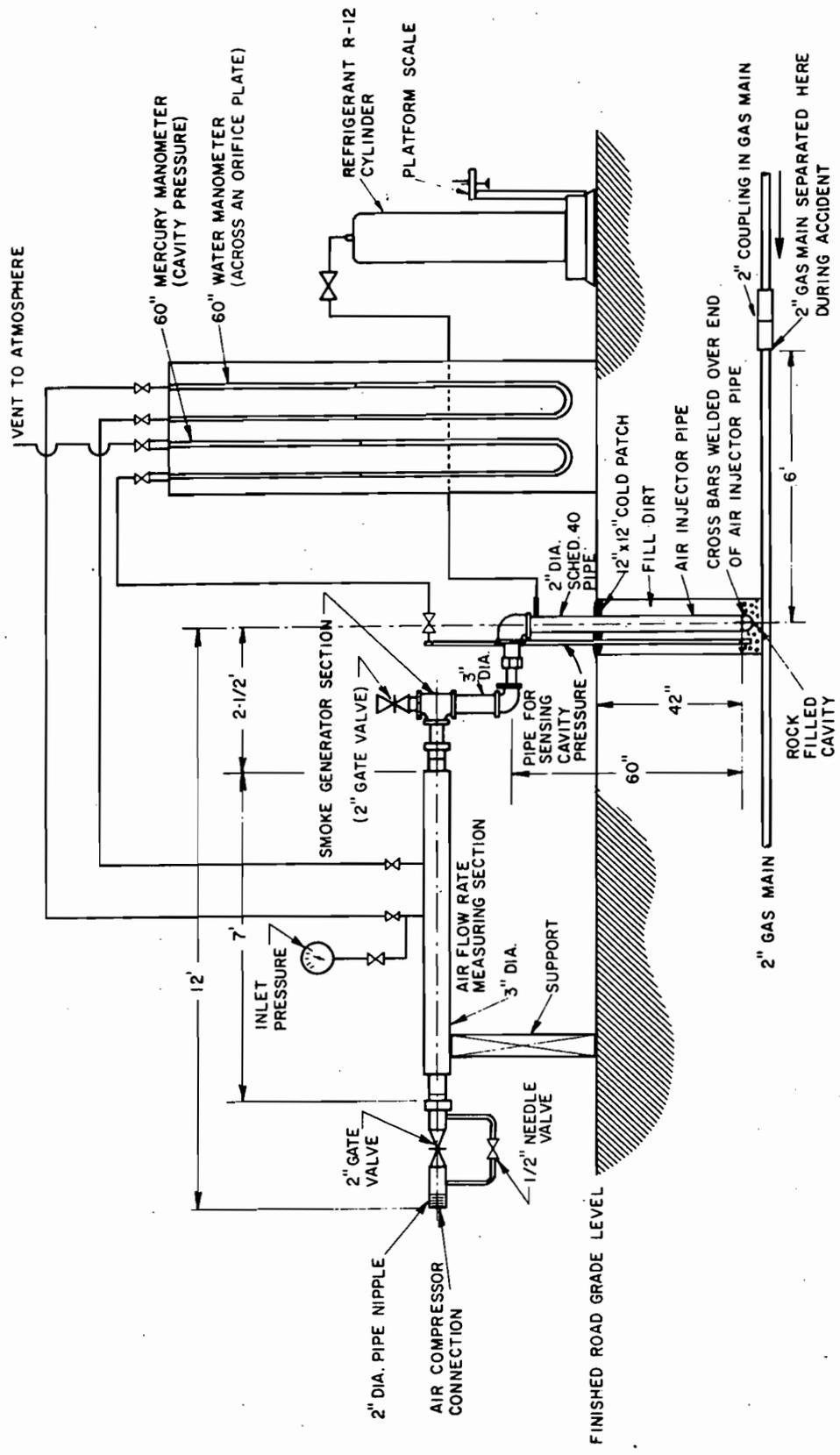


Figure 8. Set-up of National Bureau of Standards air-tracer injection.

5.4-foot-deep layer of rockfill of 5 inches or greater sieve size. (See Figure 9.) The water and sewer lines, which were located under this layer of rockfill, were covered by 6 inches of rock-free fill, but rested directly on rockfill. The gas service line, buried about 24 inches deep, was bedded in rock-free fill and was covered by about 8 inches of rock-free fill.

The quantitative air flow tests at 4909 indicated that with an air flow rate of 41 c.f.m. at a pressure of 3.5 p.s.i.g. at the point of injection, the flow of tracer into the trench was in excess of 15 c.f.m. The air-tracer mixture readily passed through voids in the rock rubble from the injection point 150 feet away to the front of the foundation wall.

In the utility trench at 4911 Magdalene Court, rockfill was found in direct contact with water, sewer, and gas lines. Coarse angular rock fragments of 5 inches or greater sieve size were loosely placed around the water line.

Fragmentation and dismantling of the foundation wall at 4911 revealed coarse rockfill against the front wall surface in the utility trench. The water and gas lines did not have good seals at their penetration in the concrete block. However, since both showed evidence of having been sealed prior to the accident, it is likely that the foundation wall was moved by the explosion and fire. One of the concrete blocks did not have a mortar seal between its cut-shortened end and the adjacent block. The NBS report concluded that

"The air-tracer traveled through soil and rock rubble located in the utility trenches containing the individual water and sewer lines for the destroyed homes at 4909 and 4911."

The report surmised that the gas entered 4909 and 4911 through the front walls by way of piping penetrations and/or through the mortar and asphalt-coated concrete-block construction, and that gas could have traveled from the spot of the leak to the houses in less than 30 minutes. The report states that

"It is concluded that natural gas did not enter the sanitary sewer because tracer was not detected in the sanitary manholes servicing

south Magdalene Court or in sanitary sewer connections within the homes."

The report further concluded that gas flow at the time of the break through the same path could easily have been considerably in excess of the 12 c.f.m. required to form an explosive mixture within 30 minutes in an unventilated volume of 7,200 cubic feet, the approximate volume of the 4909 basement.

The NBS investigation found that 4907 was built on fill and concluded from test results that tracer must have traveled through this fill to the homes. The other houses on the cul-de-sac were built on excavated land, and, except for the utility trenches, little or no fill exists in the front yards of the destroyed homes. The rockfill in the trenches of 4909 and 4911 Magdalene Court probably resulted from the blasting required to form the trenches.

A complete listing of the conclusions made by NBS is presented in Appendix C.

Federal Standards

Applicable Federal safety standards in effect at the time of the accident are contained in 49 CFR 192. The provisions applicable to design, installation, construction, initial inspection, and initial testing became effective March 12, 1971. All other provisions became effective November 12, 1970.³

Each gas-utility operator is required by 49 CFR 192.615 to:

- "(a) Have written emergency procedures;
- (b) Acquaint appropriate operating and maintenance employees with the procedures;
- (c) Establish liaison with appropriate public officials, including fire and police officials, with respect to the procedures; and

³The Virginia State Corporation Commission, on January 8, 1971, adopted 49 CFR 192 as Virginia's minimum gas safety regulations.



Figure 9. Rock rubble in sewer and water service line trench in front of 4909 Magdalene Court.

- (d) Establish an educational program to enable customers and the general public to recognize and report a gas emergency to the appropriate officials."

The regulations (49 CFR 192.703) also require that "hazardous leaks must be repaired promptly," although there is no standard which defines what constitutes a hazardous leak. The regulations do not require that pipeline operators mark the location of their underground facilities prior to the start of construction work near those facilities or that the operators alert contractors or machine operators to the dangers of hitting a gas line. The Office of Pipeline Safety, however, considers these requirements to be covered by 49 CFR 192.605 ("Essentials of Operating and Maintenance Plan") and 49 CFR 192.615.

High-pressure distribution system valves are required by 49 CFR 192.181(a) to be spaced so as to reduce the time needed to shut down any section of main in an emergency. However, neither marking of the valves for positive identification nor preplanned procedures for shutting down affected sections of a distribution system is required by Federal standards.

In addition to the regulations embodied in 49 CFR 192, the Department of Labor's Safety and Health Regulations for Construction (29 CFR 1926.651) require that:

- "(a) Prior to opening an excavation, effort shall be made to determine whether underground installations; i.e., sewer, telephone, water, fuel, electric lines, etc., will be encountered, and if so, where such underground installations are located. When the excavation approaches the estimated location of such an installation, the exact location shall be determined and when it is uncovered, proper supports shall be provided for the existing installation."

Guide for Gas Transmission and Distribution Piping Systems

Representatives of the American Society of Mechanical Engineers (ASME), the organization which sponsored the American National Standard Code for Pressure Piping, Gas Transmission and Distribution Piping Systems, met with Department of Transportation officials after 49 CFR 192 was issued. Based on their discussions, ASME decided to form a Gas Piping Standards Committee, which would publish a guide for gas transmission and distribution piping systems. The first such guide, issued in December 1970, compared the standards existing in the National Standard Code with 49 CFR 192. The guide basically related applicable ASME specifications and recommended practices to specific DOT regulations. The ASME committee is now preparing "how to" specifications which will be related to DOT's "performance" regulations. A new edition of the guide will be issued shortly and will be updated continuously.

WGL Standards and Practices⁴

WGL serves 530,000 customers through a 5,700-mile distribution system in the Washington, D.C., metropolitan area. On a normal work day, WGL has operating in the field 62 crews and 33 supervisors equipped with mobile radio units. Other crews, not radio-equipped, are also assigned to leak-location and construction work. All of these crews are responsible for repairing leaks on WGL's piping system.

In addition to these field personnel, WGL has an appliance-service department which responds to customer appliance problems and checks leaks inside buildings. On a normal work day, WGL has 277 appliance-service units on duty, 85 of which are radio-equipped.

⁴In order to provide some perspective on the problems which were encountered in this accident, the practices of several other gas companies are described in Appendix A.

The pressure division, which is not included in any of the above figures, has 13 radio-equipped crews and supervisors.

When leaks and emergency conditions occur, WGL attempts to stop the flow of gas at the site of the leak or break. Distribution system valves are not closed unless the flow of gas cannot be stopped in other ways. When distribution valves have to be closed, it is WGL's policy that this work be performed only by personnel in its pressure division. The company requires that mercury gauges be installed before valves are operated. They feel that operation of a valve by an untrained employee could create situations far more hazardous than the particular incident requiring that the valve be closed. Under emergency conditions, however, other company personnel, with authorization from the head of the pressure division or his assistant, can close a valve. The company stated that such emergency conditions are rather rare.

When the closing of valves is required, the head of the pressure division or his assistant determines which valves should be closed to isolate the affected area. Records in the possession of pressure division personnel in the field show the precise location of these valves. Although each valve has a designated number for record-keeping purposes, the valves themselves are not numbered in the field. The maintenance crews have valve keys and appliance-service personnel have keys for service line valves that could also be used for distribution main valves.

Hazard warnings to gas users and the general public. WGL periodically prints a message on the back of its bills concerning notification of the company if a gas leak is detected. This message reads as follows:

"SMELL GAS? We give our gas a strong odor so that you'll know at once if any escapes.

If you ever should smell gas inside or outside your house, telephone us at 750-1000."

On two occasions before the date of the accident, this message appeared on customer's bills.

Investigation of gas leaks. As part of its operating and maintenance plan filed with the Office of Pipeline Safety, WGL includes an operating instruction, "Investigation of Gas Leaks," intended for use as a guide by the transmission and distribution department when dealing with leaks outside of buildings.⁵ This instruction, in setting forth "the fundamental principles which should be followed," cautions that "in leak situations there is no substitute for alert, intelligent, and careful action." More specifically, the instruction reads, in part, as follows:

"During normal working hours leak orders shall be dispatched immediately to the appropriate general foreman. . . .

"Immediately upon arrival at a location to investigate a leak complaint, the Foreman shall determine whether gas is entering any structures or confined spaces or whether any manholes in the vicinity contain explosive mixtures. If such conditions are found, prior to an attempt to locate the source of leakage, they shall be relieved by opening windows or doors, removing manhole covers, stuffing ducts, turning off valves or stopcocks, excavating outside building wall or by any other method indicated."

WGL witnesses testified at the Safety Board hearing that considering the circumstances of the pulled main, when the foreman and crew arrived on the scene there was no need to follow the instruction for the investigation of gas leaks. The break in the line appeared to be close to the point where the line had been hit. Also, it appeared to the WGL personnel on the scene that gas was coming out into the open trench and was not traveling underground. For these reasons, no checks were made in any of the underground structures or in any of the houses.

⁵ A copy of this operating instruction is included as Appendix D.

WGL's operating and maintenance plan did not include additional instructions concerning the proper actions to take when confronted with a broken main or other conditions of this type. In addition, no guidance was given as to when to notify police and fire officials that a potential hazard existed because of gas leakage.

WGL's appliance-service department has a manual which prescribes the priority for orders originated in the office. The highest priority, code A-1, includes explosions, very strong odor of gas, broken gas line, house or building full of gas, etc. The manual requires that this type of order be dispatched immediately. The second highest priority, code A-2, includes a strong gas leak and a report of a loss of gas service to a commercial establishment or hospital. An A-2 order must be dispatched within two hours from time of receipt. The A-3 code, the lowest priority, includes a slight gas leak, loss of gas service to a premises, no heat, etc. An A-3 order must be dispatched the same day it is received. The code on the leak report made by the resident of 4909 Magdalene Court was A-3.

The code assigned to each report of a leak is determined by the WGL employee who receives the call. He bases his decision on the information provided by the caller. WGL personnel answering these calls generally have had experience in other company departments before progressing to this job. In training, they listen to more experienced clerks talking to callers, and after starting work, their calls are monitored by supervisors. No written guidelines, however, are issued to help these workers determine the proper coding of leak reports.

WGL's leak record. In 1971, WGL received 85,756 leak reports, 50 percent of which turned out to be actual leaks. In addition to the leaks reported to WGL by people outside the company, WGL also discovered the location of almost 1,000 leaks through its own surveys.

In its 1971 report to the Office of Pipeline Safety, WGL indicated that it repaired 11,608 leaks on its distribution system, 2,791 of which were caused by damage to WGL's facilities dur-

ing construction activities. Although this represents an average of 54 damage-type leaks per week, the daily rate varied. One day, for example, 25 lines were damaged by construction activities. About 96 percent of the damage-type leaks involved piping 2-inches or smaller.

Of all the leaks reported in 1971, there were 18 instances of fire and 10 instances of explosions resulting from the escape of gas.

Although WGL keeps a record of each leak reported and the action taken concerning that leak, these records do not readily show the chronology of the company's response to the leak reports it receives.

WGL's damage-prevention program. As part of its program to prevent damage to its underground pipelines WGL distributes a pamphlet entitled "Before You Dig Check!" Developed by the American Gas Association, this pamphlet was sent in March 1965 and again in June 1967 to contractors who damaged WGL's facilities. The pamphlets were also given to contractors at preconstruction meetings to which WGL was invited. The pamphlet describes the problems involved in hitting a gas line, explains the basic elements of gas piping systems, and offers information to the contractor concerning working around gas facilities. The central message in the pamphlet is to call the gas company before commencing work.

In early 1971, the utility companies serving the suburban Maryland area formed a utility service protection committee in order to determine methods of reducing the number of damages to their facilities. A small flyer entitled "Call Before You Dig" was mailed in June 1971 to approximately 1,400 plumbers, excavators, and contractors working in the Washington area. This flyer listed telephone numbers to be called before construction work to obtain the location of sewer and water facilities. The flyer was considered an interim step. Planning was instituted to establish a one-call system which would enable a person planning to excavate to call the one phone number and thereby notify the operators of all the underground facilities in the

area. This system, named the Miss Utility program and modeled after similar programs operating in other parts of the country, became effective for the Maryland counties on April 17, 1972.

The contractor involved in this accident claimed neither he nor his employees had ever seen a copy of the "Before You Dig Check!" pamphlet.

On April 18, 1972, the Board held a Government-Industry symposium on the prevention of damage to pipelines. All aspects of the problem were reviewed and discussed. The Board is planning to issue a special study reporting on the symposium and its findings, including recommendations to help prevent these types of accidents. Because of the planned study, the damage-prevention aspect of this accident will not be covered in greater detail in this report.

III. ANALYSIS

Delay in Shutting Down the Pulled Main

WGL handled the report of the pulled main as a routine matter. This is quite understandable when the number of times that WGL's facilities are damaged during construction work is considered. The unusual aspects of this accident were that the line was not broken where it was hit and that escaping gas entered the ground and did not vent entirely into the atmosphere. Because they thought that the leaking gas was being vented to the atmosphere, the WGL personnel on the scene did not check for the presence of gas in the nearby buildings and underground structures, although their operating instruction required them to do so.

The exact time of arrival of the crew at the scene of the accident could not be determined. However, since the crew was on the scene for approximately 20 to 25 minutes prior to the explosion, it appears reasonable the WGL personnel could have taken steps prior to the explosion to stop the flow of leaking gas or to reduce the hazard to the public. Had the crew been

equipped with apparatus to squeeze off the line, upon arrival they could have shut off the flow of gas approximately 5 minutes after the pipe was accessible. Or, if the crew had been directed or authorized to proceed directly to the valves which were subsequently closed and to close these valves, the gas flow conceivably could have been shut off before the first explosion occurred. Time was also available to check the houses for the presence of gas.

Because of the unusual way in which the pulled main was reported to the company, a representative of the appliance-service department was not dispatched to the scene. If the original call from the contractor had been channelled through the company's telephone service department, the appliance-service department would have dispatched an appliance serviceman in addition to the transmission and distribution department dispatching its personnel. The customer serviceman would have conceivably checked the nearby homes for the presence of gas.

Another factor having an effect on the length of time necessary to respond to the report of a pulled main was the workload of WGL's dispatcher. This dispatcher was in communication with many radio-equipped vehicles and could not direct his full attention to dispatching necessary personnel to this accident site. (Shortly after the accident an assistant dispatcher was assigned to help the dispatcher with his work.) In addition, his guidelines and instructions were not specific enough to allow him to react promptly when he was unable to reach the area foreman to whom he was requested to assign this job.

Other elements in WGL's methods of operation inherently contributed to the delay in stopping the flow of leaking gas. These practices, which are generally accepted in the industry, can be modified to provide for a quicker response to an emergency situation. For instance, two radio-equipped appliance servicemen were in the immediate area at the time the line was snagged. However, because they had not been trained to respond to problems of this nature, they were not utilized. In addition, once the crew arrived

on the scene and verified the conditions, the dispatcher had to notify a representative of the pressure division at the operations center, who then had to refer to maps and charts and decide which valves should be closed. A quicker response could have been made if preplanned shutdown procedures had been available at the time of the accident, and if the first personnel on the scene had been used to implement the shutdown.

One of the reasons for WGL's reluctance to allow personnel not in its pressure division to operate valves is the fear that a valve not intended to be operated will be opened or closed inadvertently. If all valves had the numbers used for record-keeping purposes placed on or in the valve boxes to identify them positively, the chance of operating the wrong valve would be greatly reduced. Thus, if a decision is made at the company's operation center that certain valves should be operated to control an emergency situation, the dispatcher could then provide the closest personnel with the valve numbers and the actual location of these valves.

Another operating problem which contributed to the delay was the inability of a dispatcher of one department to be in contact with the crew and workmen of another.

Additionally, dispatching both the pressure division foreman and crew to the same valve location rather than directing the foreman to close the valves on one side of the break and the crew the valves on the other added further delay.

The problems involved in stopping the flow of gas when a pipeline fails were discussed by the National Transportation Safety Board in February 1971 in a study of the shutdown of failed pipeline systems.⁶ In that study the Board concluded that

“By reducing the time required to shut down a failed pipeline system to minimize the

⁶National Transportation Safety Board. *Special Study of Effects of Delay in Shutting Down Failed Pipeline Systems and Methods of Providing Rapid Shutdown*, NTSB-PSS-71-1.

loss of material, the hazardous effects to the public, to persons working near a pipeline, and to property can be minimized or eliminated. Equipment and procedures are currently available which if utilized, could drastically reduce the shutdown delay cited in the accidents discussed in this study.”

The Board pointed out the lack of standards or guidelines for the rapid shutdown of failed pipeline systems and recommended to the Office of Pipeline Safety of the Department of Transportation that a study be conducted to develop such standards. The Office of Pipeline Safety has issued a request for proposals to conduct this study. Proposals have been submitted and are currently being evaluated.

Notification Prior to Excavation

WGL had accurately marked the location of the 2-inch main on the street and had provided the county with the exact location and depth of the underground facility. Since both the contractor and WGL agreed that nothing further would have been done had the contractor called WGL prior to commencing work, the lack of notification was not a major factor in this accident. A more important factor was the failure of the county to provide the contractor with the information it had received from WGL. The call for the location of the gas service lines in north Magdalene Court 2 days prior to the accident indicated that the contractor was not attempting to evade his responsibility to determine the location of underground facilities near his planned excavation.

Although the contractor's foreman was aware that a gas line crossed the path of the storm sewer, he did not know whether the gas line passed under or above the storm sewer being replaced. Had the information provided by the gas company to the county been subsequently provided to the contractor and made available to the foreman, the location of the line would have been pinpointed and the foreman would have been more aware of its presence. Reviewing the

plans with the machine operator would not have been useful in this instance, since the plans incorrectly showed the line 5 feet away from its actual location.

Hazard Warnings to Gas Users and the General Public.

The potentially hazardous consequences of not reporting a gas leak were apparently not effectively portrayed by WGL's education program. The program is deficient for several reasons. First, the portion of the bill on which the message appears is returned to the company when the bill is paid. Second, the message is restricted to those persons in the WGL service area who receive gas bills. Residents of condominiums, townhouses, and apartment developments may have gas appliances and piping but may not be billed directly by WGL. Third, the message did not clearly indicate the potentially hazardous consequences of not reporting a gas odor in the house or in the area. If the residents who detected gas odor had been aware of the risk of explosion and fire, they may have taken more effective action.

If any of these residents had contacted the WGL personnel on the scene prior to the explosions, steps could have been taken which might have prevented the explosions from occurring. The action required to be taken by WGL personnel is quite definitive if gas is known to be present in buildings or other structures.

Priority of Leak Reports

When the resident of 4909 called to report a leak in her house, the WGL clerk assigned the leak a code requiring dispatch the same day (the lowest priority leak). Since the house exploded violently less than a half hour after the call, this was not a proper interpretation of the problem.

The practice of assigning a priority to a leak report received from customers by telephone creates an imperfect system at best. People calling to report a leak do not have the same sense of smell, the same analytical capability, or the

same descriptive ability. A clerk answering such a call may not interpret the information the same way as the clerk at the next desk.

The situation is made even worse, because the clerk is not provided with specific questions to ask the caller to help obtain the information necessary to make a decision. For example, had the leak order required the clerk to ask the woman at 4909 Magdalene Court whether construction work was going on in the area, the clerk could have better determined the type of response which should be made. The clerk should also be able to give instructions to the caller to reduce the hazard until a serviceman can arrive, and should know when to contact local police and fire officials.

Notification of Public Officials

The police and fire departments were not notified until after the first explosion occurred. By not requesting assistance from local authorities, WGL assumed responsibility for assistance from local authorities, WGL assumed responsibility for assessing the hazard that existed to the public. Fire and rescue personnel have only one responsibility, i.e., to protect life and property. Gas company personnel, on the other hand, have responsibilities at the scene of a gas emergency in addition to protection of the public.

Although Federal regulations require pipeline operators to establish liaison with fire and police officials with respect to emergency procedures, there are no requirements to notify police and fire officials and coordinate activities during actual emergencies. The required liaison usually takes place during routine meetings, and generally results in an understanding by both public officials and the pipeline operator concerning contacts that can be made during emergencies. Almost no guidance, however, is generally offered as to when this contact should be made.

IV. CONCLUSIONS

The National Transportation Safety Board concludes that:

1. Pipeline operators are required by Federal regulations to have emergency plans; however, the regulations do not control or specify problems or emergency measures to be covered in such plans.

2. The plans for the sewer project provided to the contractor by the county showed the 2-inch pipeline that was subsequently hit to be 5 feet west of its actual location. A correct location, including the depth of the line, was provided to the county by WGL prior to the letting of the contract.

3. The warning given to the county by WGL that the contractor would have to exercise extreme caution to prevent damage to the gas line was not passed along to the contractor.

4. The gas mains to be encountered during this project were not discussed at the county's preconstruction meeting with the contractor.

5. The contractor and his foreman at the job site were aware that the gas main was in the path of the sewer replacement being undertaken. They were not aware, however, whether the gas line passed above or below the 42-inch sewer being removed.

6. The backhoe operator was not being guided adequately at the time that he pulled the gas main with the backhoe. Neither the foreman nor other workmen were observing conditions in the excavation to advise the operator of the presence of other facilities.

7. The workload of the WGL dispatcher was such that he was unable adequately to direct and coordinate the activities of WGL's field forces to respond promptly to the report of the pulled main.

8. WGL's program to educate its customers and the general public to recognize gas emergencies was not effective, in that it did not reach the general public or adequately point out the possible hazards or consequences of not reporting gas odors.

9. Since gas was observed emanating from the crack between the blacktop and concrete at the catch basin, the WGL personnel on the scene prior to the explosions should have realized that

all of the gas was not venting to the atmosphere but was traveling through the ground.

10. Even though the line was separated, the gas continued to flow through the separation and into the main that supplied the homes in Magdalene Court. The sources of ignition are unknown but could have been gas-stove flames or pilot lights.

11. Tests performed by the NBS indicate that the gas which leaked from the separated coupling flowed rapidly through rock-filled utility trenches to the front walls of 4909 and 4911, and the front and side walls of 4907 Magdalene Court. The gas entered the buildings through the mortar and asphalt-coated concrete blocks and/or through spaces where utility piping entered the buildings.

12. WGL's personnel did not follow their operating instruction, Investigation of Gas Leaks, which required them to determine whether gas is entering any structure before attempting to locate the source of leakage. Although this instruction concerns leak complaints and is not for large failures of this nature, no additional instructions were issued to its employees.

13. The practice by WGL of restricting the operation of valves to pressure division personnel increased the time taken to shut off the flow of gas.

14. The marking of valves in the field would allow them to be positively identified in emergency situations.

15. The methods used by WGL to classify the leak reported by telephone by the resident of 4909 Magdalene Court was inadequate and incomplete, in that the true hazard that existed was not determined.

16. Although 96 percent of the construction-caused damages that occur on WGL distribution system affect lines 2-inch in size or smaller, the equipment to squeeze off lines of this size was not readily available in the field.

V. PROBABLE CAUSE

The National Transportation Safety Board determines that the cause of the explosions in

the three houses was the ignition of gas that leaked from a main damaged by a contractor's backhoe.

Contributing to the accident were the delay by the gas company in shutting off the flow of leaking gas, the failure to check for gas in houses, and the failure to notify police and fire officials. Also contributing were the failure of the area residents to report the odor of gas in their houses, and the failure of the county to supply the contractor with the accurate gas main location which had been provided by the gas company.

VI. RECOMMENDATIONS

The National Transportation Safety Board recommends that:

1. The Office of Pipeline Safety

- (a) Amend 49 CFR 192 to require onsite identification of all valves on high-pressure distribution systems which may be necessary for the safe operation of the system. (Recommendation No. P-72-40)
- (b) Amend 49 CFR 192 to require that each pipeline operator prepare pre-planned shutdown procedures so that any section of a high-pressure distribution system can be shut down in an emergency. (Recommendation No. P-72-41)
- (c) Amend 49 CFR 192 to require that each operator maintain a log which shows the receipt and handling of each leak or emergency report received. Information concerning the time that the report was first received, that a crew was first dispatched to the scene, that such a crew arrived, and that the condition was considered safe should be included. In addition, each pipeline operator should be required to analyze his performance in respond-

ing to gas-leak emergencies and reports. Both the logs and the analysis should be made available to State agencies and the Office of Pipeline Safety. (Recommendation No. P-72-42)

- (d) Amend 49 CFR 192 to require that each pipeline operator have on duty a sufficient number of dispatching personnel to effectively coordinate emergency situations. A study may be required to determine the relationship between various conditions and the number of dispatchers necessary. (Recommendation No. P-72-43)
- (e) Amend 49 CFR 192.615 to include an explicit requirement that each pipeline operator notify and coordinate his activities with local fire and police officials when gas leaks create hazardous conditions.⁷ (Recommendation No. P-72-44)

2. The American Public Works Association

develop guidelines for preconstruction meetings, which should include methods of preventing damage to underground utilities to be encountered during the proposed construction work. Such preconstruction meetings should be attended by all operators whose facilities are involved. (Recommendation No. P-72-45)

3. The American Society of Mechanical Engineers Gas Piping Standards Committee

- (a) Recommend methods of numbering or marking valves in the field so that they can be readily and positively identified. (Recommendation No. P-72-46)
- (b) Develop guidelines to be used by pipeline operators in establishing pre-planned sectionalizing programs to shut down any section of main in an

⁷ Same as Recommendation 1(b) in Board report, "Lone Star Gas Company, North Richland Hills, Texas, October 4, 1971."

emergency. (Recommendation No. P-72-47)

- (c) Develop guidelines to assist pipeline operators in preparing their emergency plans. These plans should indicate the action to be taken by the first gas company employee arriving at the scene of an emergency. (Recommendation No. P-72-48)
- (d) Develop guidelines to assist pipeline operators in educating customers and the general public in the proper action to take if gas leaks are detected. (Recommendation No. P-72-49)
- (e) Develop guidelines in cooperation with the National Fire Protection Association to assist pipeline operators in determining the conditions under which local fire and police officials should be notified. (Recommendation No. P-72-50)
- (f) Develop guidelines for classifying and responding to leaks reported by the public. (Recommendation No. P-72-51)

4. The National Science Foundation, the Office of Emergency Preparedness, and the National Bureau of Standards initiate a research project, under their cooperative program, "Building Practices for Disaster Mitigation," to study the flow of natural gas through various basement wall materials and types of construction. This project should also include effective methods of sealing the space around underground utility lines where they enter a building. The effects of aging, settlement, and exposure to water should be considered. (Recommendation No. P-72-52)

5. The American Gas Association study the flow of gas through various construction fill media and recommend methods and types of fill to be used in the installation of underground utility lines. (Recommendation No. P-72-53)

6. The Washington Gas Light Company

- (a) Extend, in cooperation with other utility companies and governmental

agencies, the Miss Utility program to receive reports of proposed excavation work in the entire Washington metropolitan area. (Recommendation No. P-72-54)

- (b) Develop a sectionalizing program of its high-pressure distribution system so that preplanned procedures are available to isolate any section of its system in an emergency. (Recommendation No. P-72-55)
- (c) Train and equip all appropriate radio-equipped field personnel to locate and operate main line valves under the direction of knowledgeable office personnel. (Recommendation No. P-72-56)
- (d) Expand its customer education program so that its customers and the general public can be made aware of the proper action to take if gas leaks are detected. (Recommendation No. P-72-57)
- (e) Maintain a leak log which will give appropriate information relative to all aspects of receiving and responding to reported leaks. This information should be analyzed periodically to provide information which will readily point out problem areas in WGL's response. (Recommendation No. P-72-58)
- (f) Identify all valves in the field to permit positive identification. (Recommendation No. P-72-59).
- (g) Realign its dispatching facilities so that one dispatcher can contact all field personnel capable of responding to an emergency when such a situation is encountered. (Recommendation No. P-72-60)
- (h) Coordinate the activities of the transmission and distribution department dispatcher with the customer ap-

pliance dispatcher so that an appliance serviceman is dispatched to the scene of any reported leak in the distribution system. (Recommendation No. P-72-61)

(i) Provide all maintenance foremen with the equipment necessary to squeeze off 2-inch and smaller gas lines. (Recommendation No. P-72-62)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

Louis M. Thayer, Member, was not present and did not participate in the adoption of this report.

November 22, 1972.

Intentionally Left Blank

APPENDIX A

OPERATING PRACTICES OF OTHER GAS COMPANIES

Preplanned Shutdown Procedures.

A number of gas pipeline operators have reevaluated their procedures and developed comprehensive plans which made possible quick and efficient response to a gas distribution system emergency and prompt isolation of the affected facilities. The main concept that these operators espouse is that the first representative of the company to arrive at the scene of an accident should be able to operate valves in order to make safe any hazardous condition that is encountered. These operators do not depend on a few highly skilled but widely scattered "pressure crews" to operate valves while other company employees at the scene are standing by. Some companies have equipped and trained their maintenance crews and customer servicemen to locate and operate main-line valves under the direction of a dispatcher. For example, one company with 5,560 miles of mostly high-pressure distribution piping, serving 386,000 gas customers in an area similar to the Virginia and Maryland suburbs, has only five pressure-control crews and one foreman equipped with mobile radio units available during normal working hours. It has, however, 222 maintenance crews plus foreman, and between 191 and 216 (depending on the time of year) gas customer servicemen and foreman radio-equipped and available to respond to an emergency and operate valves if required. During the night hours and on weekends, no pressure-control crews are on duty (crews are available on a callout basis), but maintenance crews, servicemen, and foremen are working throughout the service area. This company, a combination gas and electric utility, has even trained and equipped its electric servicemen and light patrolman to operate gas main valves in emergencies. This greatly increases the number of men that can be dispatched to the scene of any emergency.

A second company, supplying more than 1,000,000 customers in a mainly urban setting through a largely low-pressure system, also trains and equips its customer servicemen and maintenance crews to operate valves under the direction of a dispatcher. During normal working hours, this company uses 26 radio-equipped crews and supervisors on duty in its pressure section to operate valves. However, by training and equipping maintenance and customer service personnel, the company can call upon 201 additional units (262 during winter months) to operate valves in emergencies.

To be further prepared to respond to any emergency, these two companies have sectionalized their systems so that any necessary shutdown has been preplanned. The plan for the first company includes records that have been developed to show exactly which valves should be operated to shut off the flow of gas or reduce the pressure to any of the 800 sections of its 4,500 mile high-pressure system. These records also indicate the number of customers in each section that would be affected by a shutdown and the number of servicemen necessary to restore gas service in a 10-hour period. The second company has a sectionalizing plan for its 650 miles of high-pressure system. There are 619 preplanned shutdown procedures; one for each section of its system. Each procedure indicates the action necessary to isolate a section of main or to reduce the pressure in that section.

The preplanned procedures for both companies are maintained by a dispatcher who can communicate with workmen from various departments, even though they have different radio frequencies. These companies also conduct frequent tests of their systems. An emergency is simulated at a certain location and all necessary company forces are mobilized to respond and take

action just as if a real emergency existed. This allows evaluation of the effectiveness of the programs, points out weaknesses, and provides excellent training for personnel who do not usually operate valves.

Analysis of Response to Leaks

The time required by a pipeline operator to respond to a report of a leak and to render the condition safe is a composite of the time required for a number of various steps. The report must be received by the company, and directed to the proper dispatcher. The dispatcher must advise appropriate field personnel; the field personnel must travel to the scene of the reported emergency; and after arrival the crew must take appropriate action to make the conditions safe. Individual operators have different problems which depend on the type of area which they serve and the various conditions of their operations. Generally when a leak or other emergency is reported to a pipeline operator, a service order or ticket is filled out by the representative answering the call. This form records information concerning the subsequent activities of the company's personnel. A review of the tickets for any period of time would give a complete chronology of the chain of events that follows each of the reported leaks. This procedure does not provide a convenient means by which a pipeline operator's supervisory personnel can obtain an overall picture of the company's performance on any particular day. If a daily log were maintained to furnish information such as the location of the leak, the time the report was first received by the company, the time it was responded to, the time that the crew or representative arrived at the scene, and the time that the emergency was made safe, both the company's management and a regulatory agency, such as the Office of Pipeline Safety or a State Commission, could readily see the factors involved in any delay. The information in the logs could be analyzed statistically to determine where problem areas exist.

Since 1968, the New York State Public Service Commission has required all gas companies in New York State to keep a log of all leak calls received and to submit monthly analyses of the response to emergency reports. The current form used in New York is shown in Figure 10.

The analysis shows clearly the performance of each company under various conditions, such as weekdays during business hours, weekdays after normal business hours, and Saturdays, Sundays, and holidays. This information has been very useful to the companies in New York State and has pointed out problem areas which have been corrected subsequently. In addition to providing a basis for determining performance, each company was able to compare the performance of each of its operating districts. For example, one utility found that one of its divisions was able to respond to 68 percent of its leak reports within 15 minutes, while another division was only able to respond to 16 percent of its cases within this same interval. Analysis located the problem.

Hazard Warnings to Gas Users and the General Public

While there are no specific industry standards or guidelines, a number of pipeline operators have undertaken comprehensive educational programs. For example, advertisements have been placed in newspapers, (see Figure 11), announcements have been made on local radio stations, and special inserts that actually contain the gas odor have been sent with customer's bills. In areas where a language other than English is spoken by a significant portion of the population, the announcements and newspaper advertisements have appeared in these languages. Other forms of advertising that have been utilized by the industry include sending telephone stickers with the emergency number listed and listing an emergency number on the front cover of telephone directories.

Figure 10. New York State form for analysis of response to emergency reports.

Gas corporation _____

Month _____, 19____

Emergency Calls

Response Time* (minutes)	<u>Weekdays-during normal business hours</u>		<u>Weekdays-after normal business hours</u>		<u>Sat., Sun., & hol.</u>		<u>Total</u>	
	<u>No. of calls</u>	<u>Percentage of calls</u>	<u>No. of calls</u>	<u>Percentage of calls</u>	<u>No. of calls</u>	<u>Percentage of calls</u>	<u>No. of calls</u>	<u>Percentage of calls</u>
0-15								
16-30								
31-45								
46-60								
More than 60 min.								
Total		100%		100%		100%		100%

*Total elapsed time from receipt of report to time of arrival.

Signature of gas corporation officer

Title



What to do if you smell gas.

Pick up the phone and call the nearest Niagara Mohawk Office.

Any hour of the day or night. Our servicemen will promptly make an inspection and do whatever is necessary to correct the situation.

While waiting for our servicemen to arrive, ventilate the area. While natural gas is nontoxic and contains no poisonous ingredients, a leak can become hazardous if combustible gas pockets are allowed to form.

The important thing to remember, though, if you do smell leaking gas, is to call us immediately.

In fact, it would be a good idea to put the paper down for a minute, look up the telephone number of our nearest office and jot it down with other emergency numbers.

NIAGARA  MOHAWK

Figure 11. Example of a newspaper advertisement used to educate the public about the hazards of leaking gas.

APPENDIX B

NATIONAL BUREAU OF STANDARDS

TEST RESULTS

Tracer *was detected* at the following locations:

- a. Blacktop and concrete gutter interface near the catch basin at the corner of South Magdalene Court.
- b. Driveway/carport concrete slab expansion joint at 4907.
- c. Crack in the concrete gutter and curb in front of 4909 water meter box.
- d. At the front inside basement walls of 4907, 4909, 4911, where the water lines enter.
- e. Within concrete blocks at the front basement wall next to the utility trench for water, sewer, and gas at 4911 and within the same area for the utility trench serving water and sewer at 4909.
- f. Within the rock rubble located below the carport and adjacent to the fireplace foundation wall at 4907.
- g. At the gas line where it penetrates the concrete block wall in the basement of 4911.
- h. In all water meter boxes located on South Magdalene Court.
- i. In the gas curb box for 4911. (This curb box had been dug up for repairs so this indication of tracer does not necessarily mean natural gas was in the box at the time of the accident.)
- j. At many positions along concrete gutter and curb, including curb joints near several water boxes, and curb joints adjacent to driveways at 4907 and 4911.
- k. At the interface between the sanitary sewer manhole rim and surrounding blacktop located in the South Magdalene Court cul-de-sac.
- l. In catch basins located at (a) Queen Elizabeth Boulevard in front of 4907 South Magdalene Court, (b) Queen Elizabeth Boulevard in front of 8526 (at the corner of North Magdalene Court), and (c) the north corner of South Magdalene Court and Queen Elizabeth Boulevard.

Tracer *was not detected* at the following locations:

- a. Interior of homes at 4908 and 4910 South Magdalene Court and the home at 8601 Queen Elizabeth Boulevard. The slab on grade home at 8601 was not entered but was judged to be free of tracer because a check for tracer at the front foundation wall, the gas curb box, and the water meter box at 8601 did not reveal tracer.
- b. The gas curb box for 4908 and 4910. It was not possible to check the gas curb box at 4907 since it had been removed by the gas company when gas was shut off to 4907 after the accident.
- c. Gas line at the point of basement entrance and gas curb box at 4909.
- d. Gas line at the point of basement entrance at 4907.
- e. Water and gas valve boxes located in the right-of-way at the intersection of North Magdalene Court and Queen Elizabeth Blvd.
- f. The sanitary sewer in 4907, 4909, 4911, and street manholes. At 4907 normal water seals were in all traps. At 4909 and 4911, measurements were made in the open basement commode drain line. The commodes had been removed and there were no water seals. No tracer was detected either in or around the sanitary drain lines.
- g. Two one-inch holes, six inches deep, drilled in cul-de-sac surface.
- h. Curb joints adjacent to driveway at 4908 and 4910.

APPENDIX C

NATIONAL BUREAU OF STANDARDS CONCLUSIONS FROM THE RESULTS OF THE FIELD INVESTIGATION

The following is concluded from the results of the field investigation.

- a. The air-tracer traveled through soil and rock rubble located in the utility trenches containing the individual water and sewer lines for the destroyed homes at 4909 and 4911.
- b. The investigation showed that tracer did not flow on the outside of any particular pipe, per se, but rather, traveled through soil and rock fill. It was not possible to determine precisely how gas actually entered the houses through their foundations from the rock-rubble-fill that was found in the utility trenches. The water lines, gas lines, and concrete block walls had been disturbed by the explosions, fires, and fire-fighting and clean-up activities in the homes. Repair work carried out on 4907 prior to the tests further altered the test simulation in this home. As a result it is surmised that the gas entered 4909 and 4911 through the front walls by way of piping penetrations and/or through the mortar and asphalt coated concrete block construction. Because tracer was detected at the apparently undisturbed water line at its penetration in the front wall and at the fireplace foundation wall under the carport of 4907, it is assumed that gas entered this building in the same manner. Soil tests and drilled hole tracer tests at 4907 indicated that possibly more than one rock fill path exists between the injection area and the house.
- c. The undamaged homes at 4908 and 4910 South Magdalene Court and the home at 8601 Queen Elizabeth Boulevard did not experience explosion or fire during the accident and did not receive tracer during the air-tracer test.
- d. Natural gas could flow again into or to the same homes if another natural gas leak were to occur in the vicinity of the leak of March 24 unless the rock rubble paths are eliminated.
- e. In the tests conducted, it was not possible to duplicate enough conditions to pinpoint the time required for natural gas to travel from the leak to the homes at the time of the accident. However, it was established, based on the following two facts, that the gas could have traveled to the homes in less than 30 minutes. It was documented at the public hearing that the odor of natural gas was detected by residents of 4909 and 4911 in their homes at about 8:30 a.m. on the day of the accident, and air tracer traveled from the injection point to the front wall of 4909 in less than 30 minutes during the tests on May 17. Secondly, during the test, air tracer injection began at 11:00 a.m. and tracer was detected inside the front wall of 4909 in the vicinity of the water line at 11:31 a.m. Further, because this wall position had not been monitored before 11:31 a.m., the tracer could have arrived at the wall in less than 30 minutes.
- f. The quantitative air flow test at 4909 showing more than 15 cfm of air tracer flowing from the point of break on the gas main to the trench in front of the foundation wall with a source (cavity) pressure of $3\frac{1}{2}$ psig indicates that gas flow at the time of the break through this same path could easily have been considerably in excess of that required (12 cfm) to form an explosive mixture (5% by volume) in one half hour in an unventilated volume of 7200 cubic feet, the approximate volume of the 4909 basement, if the cavity or source pressure was sufficiently high. The source pressure at the time of break could possibly have approached 22

psig, far in excess of the 3.5 psig source pressure used in the quantitative air flow test. The actual volume of the 4909 home is not known, nor is the ventilation/infiltration rate existing at the time of the explosion.

- g. Although tracer was detected in the storm sewer, tracer was not detected in the sanitary sewer. The storm and sanitary sewers are not interconnected. It is concluded that natural gas did not enter the sanitary sewer because tracer was not detected in sanitary manholes servicing South Magdalene Court or in sanitary sewer connections within the homes. If natural gas had existed in the storm sewer at the time of the accident, the gas in the storm sewer could not have contributed to the accident since the storm sewer does not extend up the Court.

Examination of drawing no. 4, as listed in Appendix 7.2, shows that the home at 4907 is built on fill and also that the entire front yard of this home is fill. It is concluded from test results that the tracer must have traveled through this fill to the home. The rest of the houses on the site, including the destroyed homes at 4909 and 4911, were built on excavated land and not on fill. Except for the utility trenches, little or no fill exists in the front yards of the destroyed homes. The middle of the cul-de-sac area is about 14 feet lower than the original land grading indicating that considerable material had been removed. It may be that the removal of this material exposed bed rock since the service trenches at 4909 showed the existence of solid rock. It appears that some blasting must have taken place in order to form the trenches. The rock rubble found as fill in the trenches at 4909 and 4911 was probably produced by the blasting.

APPENDIX D
WASHINGTON GAS LIGHT COMPANY
OPERATING INSTRUCTIONS
NO. M & S-50
INVESTIGATION OF GAS LEAKS

I. General

This procedure is a guide to the handling of leak complaints and sets forth the fundamental principles which should be followed. It should be noted, however, that in leak situations there is no substitute for alert, intelligent and careful action.

II. Classification & Originating Orders

Orders are originated for every leak detected and are noted with combustible gas indicator readings obtained from the manhole, bar test or other. Indicators are calibrated periodically to guarantee accuracy and consistency in order that readings designated on each order may be used as a priority number. All Leak Locator crews are instructed as follows:

- A. "A" orders which represent trace of leakage to 4.9% gas in air, except leaks at building walls, are turned into the Dispatcher at the end of the work day.
- B. All leak orders, within 20 feet of building walls, as well as all "B" leak orders which represent 5.0% to 50% gas in air in telephone and electric vaults or other underground structures that include devices capable of producing ignition, are phoned or radioed to the Dispatcher immediately upon discovery. All other "B" leaks are reported at the end of the day.
- C. A "C" leak which represents 50% or more gas in air are phoned or radioed to the Dispatcher immediately.

For all outside leak orders where Appliance Service is unable to detect leakage they shall pressure test the service from outside shut-off to meter in accordance with Appliance Service's Operating Procedures and Technical Field Manual. Where the stopcock is inoperable or there is no stopcock on the service, the order should be referred to T&D. T&D will repair the stopcock and pressure test to the meter or where no stopcock exists will bar test over the service from property line to building wall.

III. Priority

Because of the hazardous conditions that may exist, leak orders shall be given priority over all other non-emergency street work. Prompt and complete investigation of each leak order shall be made.

IV. Dispatching

During normal working hours leak orders shall be dispatched immediately to the appropriate General Foreman. Should the number of orders on hand exceed the capacity of the maintenance gangs on duty, it shall be the responsibility of the General Foreman to arrange for the temporary use of available gangs that are engaged in other than emergency work.

During hours other than those normally scheduled, leak orders shall be dispatched to the Foreman on duty or to the General Foreman concerned. Should the number of said orders exceed the capacity of gangs on duty, it shall be the responsibility of the General Foreman to obtain sufficient off duty employees to perform the work at hand.

V. Open Flames Forbidden

Smoking or the use of other open flames in an atmosphere where natural gas or other flammable gas may be present is dangerous and is forbidden.

VI. Investigation Procedure

Immediately upon arrival at a location to investigate a leak complaint, the Foreman shall determine whether gas is entering any structures or confined spaces or whether any manholes in the vicinity contain explosive mixtures. If such conditions are found, prior to any attempt to locate the source of leakage, they shall be relieved by opening windows or doors, removing manhole covers, stuffing ducts, turning off valves or stopcocks, excavating outside building wall or by any other method indicated.

If gasoline, cleaning fluid or other screening odors are present, it shall be assumed that such odors are either flammable or toxic and immediate steps shall be taken to turn off the gas at the meter or stopcock and vent the building completely. No open flames shall be used.

When steps to remove screening odors or minimize the accumulation of gas have been completed, the foreman shall direct the tracing of the leakage to its source through the use of a combustible gas indicator or, where exposed piping is involved, by use of a soap solution.

VII. Assistance

If the foreman feels either his equipment or manpower is insufficient, he shall contact his General Foreman.

VIII. Work Within Buildings

If it becomes necessary to work inside a building and there is any possibility of gas escaping within the building, the meter must be turned off and all open flames extinguished. Where coal or oil furnaces are involved, special attention shall be given to the provisions of adequate ventilation. Except where a stoppage is indicated, the cap or plug at the blow-out tee should not be removed. All pressure testing should be done at the meter or at an appliance with a pressure testing device. See O.I. No. M&S-24. If it becomes necessary to remove the cap or plug from the blow-out tee and the service is equipped with a stopcock or fire valve, the shut-off shall be

closed before any work is performed at the tee. If no shut-off is available the amount of gas permitted to escape into the building when the cap or plug is removed must be kept to a minimum. Precautions should be taken against open flames and inadequate ventilation.

IX. Other Gases

During leakage investigation work if the foreman feels that gases other than natural gas are present, he shall arrange through his General Foreman to have the Laboratory secure a sample of the atmosphere for analysis and report. In no instance shall it be reported that suspected gas leakage was from one of these other sources without a positive Laboratory report.

X. Repairs

When the source of leakage is determined every effort shall be made to effect permanent repairs. If impossible owing to lack of material or volume of work, temporary repairs in line with Company standards may be made provided the job can be left in a safe condition. Leak Orders for such temporary repairs must be referred by the Foreman to the General Foreman as early as possible in order that the necessary arrangements for final repairs can be made.

Upon completion of a leak repair, combustible gas indicator tests shall be made in order that the Foreman may be assured that leakage in the area has been eliminated.

XI. Making Job Safe

When a foreman is requested to leave a leak location prior to completion of the job in order to investigate another leak complaint it shall be the foreman's responsibility to determine whether, by venting manholes, barricading, etc., he can make his first job safe. If such is not possible he should notify his General Foreman who shall arrange for coverage of the new leak location by another gang.

XII. Leak Work Order Report

The foreman shall enter on the Leak Work Order a complete job report which report shall include information with regard to what was done and condition in which the job was left.

XIII. Checking

Leaks that are referred for Carbosealing shall be checked, after completion of the required number of pourings, by a Leak Locator Crew and Leak Work Orders shall not be filed as completed for these locations until the check tests indicate that all leakage has been eliminated. Leak Work Orders that originate as a result of explosions in manholes shall also be referred to the Leak Locator group, for checking at 24 hour intervals after repairs have been made. Testing shall be continued until it is indicated that all leakage in the area has been eliminated.