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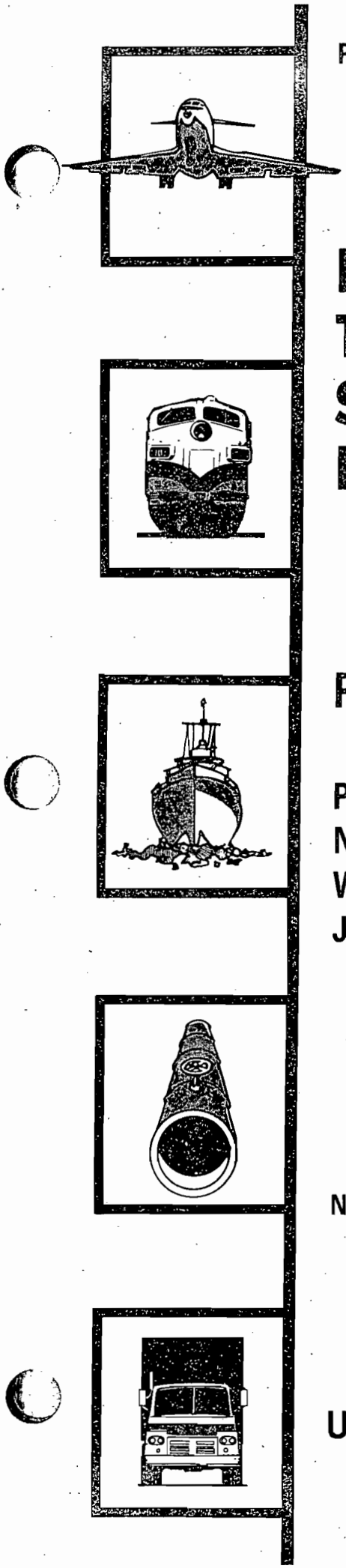

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

PIPELINE ACCIDENT REPORT

PIEDMONT NATURAL GAS COMPANY
NATURAL GAS EXPLOSION AND FIRE
WINSTON-SALEM, NORTH CAROLINA
JANUARY 18, 1988

NTSB/PAR-88/01

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

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15. Supplementary Notes

16. Abstract: On January 18, 1988, a natural gas explosion destroyed the building housing the K&W Cafeteria and the lobby of the Sheraton Motor Inn at 380 Knollwood Street, Winston-Salem, North Carolina. Two adjoining motel wings suffered structural damage. Of the four persons in the lobby/cafeteria building at the time of the explosion, three sustained minor injuries. The fourth person sustained a fractured ankle. One motel guest also sustained minor cuts but refused treatment.

The National Transportation Safety Board determines that the probable cause of the natural gas explosion was corrosion failure of the gas service pipeline at the north wall of the meter pit. Contributing to the explosion was the placement of the gas meter and piping in a pit that had direct openings into the building's boiler room. Contributing to the corrosion failure of the service line was the failure of the gas company to provide adequate direction and training for its inspectors to recognize conditions that adversely affected gas company equipment.

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The safety issues discussed in the report include the inherent danger of placing gas service regulator and metering equipment in enclosed pits adjacent to buildings openings, adequacy of gas company maintenance and inspection practices, effectiveness of gas company employee training and qualification, adequacy of gas company leakage and corrosion protection programs, adequacy of gas company notification procedures, and effectiveness of the enforcement of Department of Transportation pipeline regulations by the North Carolina Utilities Commission and the Office of Pipeline Safety.

CONTENTS

EXECUTIVE SUMMARY

On January 18, 1988, a natural gas explosion destroyed the building housing the K&W Cafeteria and the lobby of the Sheraton Motor Inn at 380 Knollwood Street, Winston-Salem, North Carolina. Two adjoining motel wings also suffered structural damage. Of the four persons in the lobby/cafeteria building at the time of the explosion, three sustained minor injuries. The fourth person sustained a fractured ankle. One motel guest also sustained minor cuts, but refused treatment.

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The safety issues discussed in the report include:

- Inherent danger of placing gas service regulator and metering equipment in enclosed pits adjacent to building openings;
- Adequacy of gas company maintenance and inspection practices;
- Effectiveness of gas company employee training and qualification;
- Adequacy of gas company leakage and corrosion protection programs;
- Adequacy of gas company notification procedures; and
- Effectiveness of the enforcement of Department of Transportation pipeline regulations by the North Carolina Utilities Commission and the Office of Pipeline Safety.

The report reiterates two previous recommendations: one to the American Society of Mechanical Engineers Piping and Standards Committee and the American Petroleum Institute, and one to the Research and Special Programs Administration. The report contains 11 new safety recommendations: 6 to Piedmont Natural Gas Company; 1 to the City of Winston-Salem; 2 to the North Carolina Utilities Commission, 1 to the Research and Special Programs Administration, Department of Transportation; and 1 to the American Gas Association.

PIPELINE ACCIDENT REPORT

PIEDMONT NATURAL GAS COMPANY
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JANUARY 18, 1988

INVESTIGATION

The Accident

About 1:30 a.m. on January 18, 1988, a security guard routinely checked the kitchen, break room, and maintenance shop in the basement of the building that housed the K & W Cafeteria and the lobby of the Sheraton Motor Inn at 380 Knollwood Street, Winston-Salem, North Carolina. (See figures 1 and 2.) The security guard said that he looked into the boiler room from the maintenance shop and that he did not see or hear anything unusual and that he did not smell gas. He had been instructed to stay out of the boiler room unless he noticed something unusual. According to the security guard, the lights in the lounge area were dimmed, the lights in the maintenance shop were off, and the lights in the boiler room and the hallway to the maintenance shop were on. Also, a floor fan that was located in the hallway at the entrance to the boiler room continuously blew air into the boiler room to keep steam from migrating into the hallway. Migrating steam had on several previous occasions activated the smoke alarm that was located in the ceiling of the hallway.

About 2:25 a.m., the cafeteria janitor was on a ladder near the ceiling of the serving area cleaning tiles with a commercial vacuum cleaner. He said that he heard a sudden noise that caused him to believe the vacuum hose had become disconnected. He climbed down the ladder, checked the hose which was still connected, and turned off the vacuum cleaner. He said that at that time he heard a very shrill, hissing noise, similar to that made by a steam radiator leak or a boiler "popping off," coming from the area of the plate glass windows along the north wall of the cafeteria. After moving a couch away from the north wall, he saw no visible steam lines, but he did smell gas. The janitor then went to the cafeteria office, where in accordance with his instructions, he notified the Sheraton Motor Inn desk clerk about the gas odor. He also smelled gas and heard the hissing noise in the cafeteria office. He requested the desk clerk to provide a key to unlock the cafeteria so that he could leave. (Between 10 p.m. and 4:30 a.m., the janitor was routinely locked inside the cafeteria without a key.)

The janitor then ran downstairs to the basement to retrieve his coat that was hanging in a room adjacent to, but isolated from, the boiler room. He said that the gas odor in the basement was very strong and and that his eyes burned. The janitor retrieved his coat and ran upstairs to the emergency door between the lobby and the south end of the cafeteria, where the the gas odor was as strong as it was in the basement.

The accounts of the desk clerk and the security guard differ regarding the sequence of events before the explosion. The desk clerk stated that about 2:27 a.m she was behind the lobby desk and a friend and the security guard were in the area of the desk when the smoke/fire alarm panel behind the lobby desk emitted audible and visual alarm signals. Upon hearing the signal and seeing the

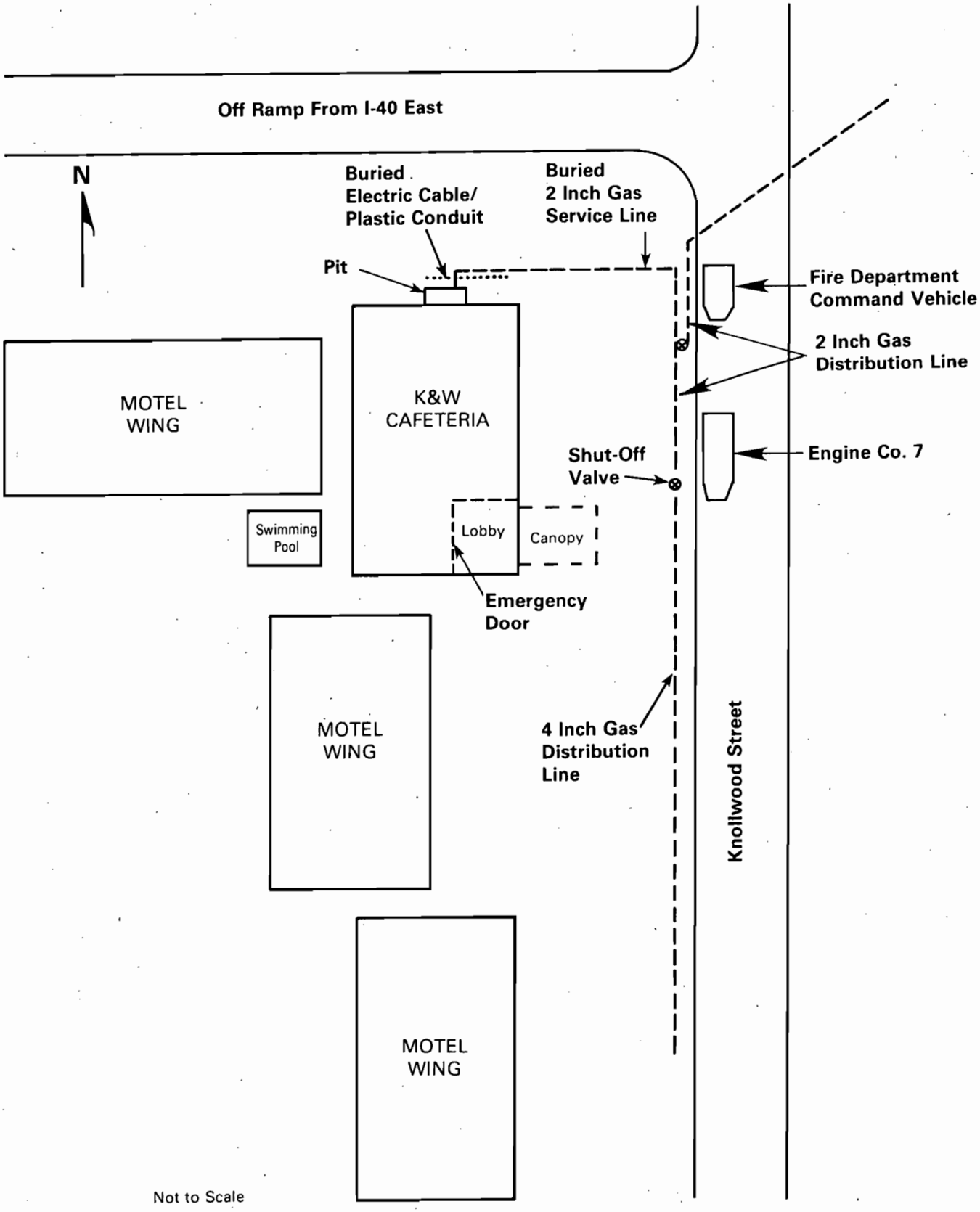

Figure 1.--Accident area.

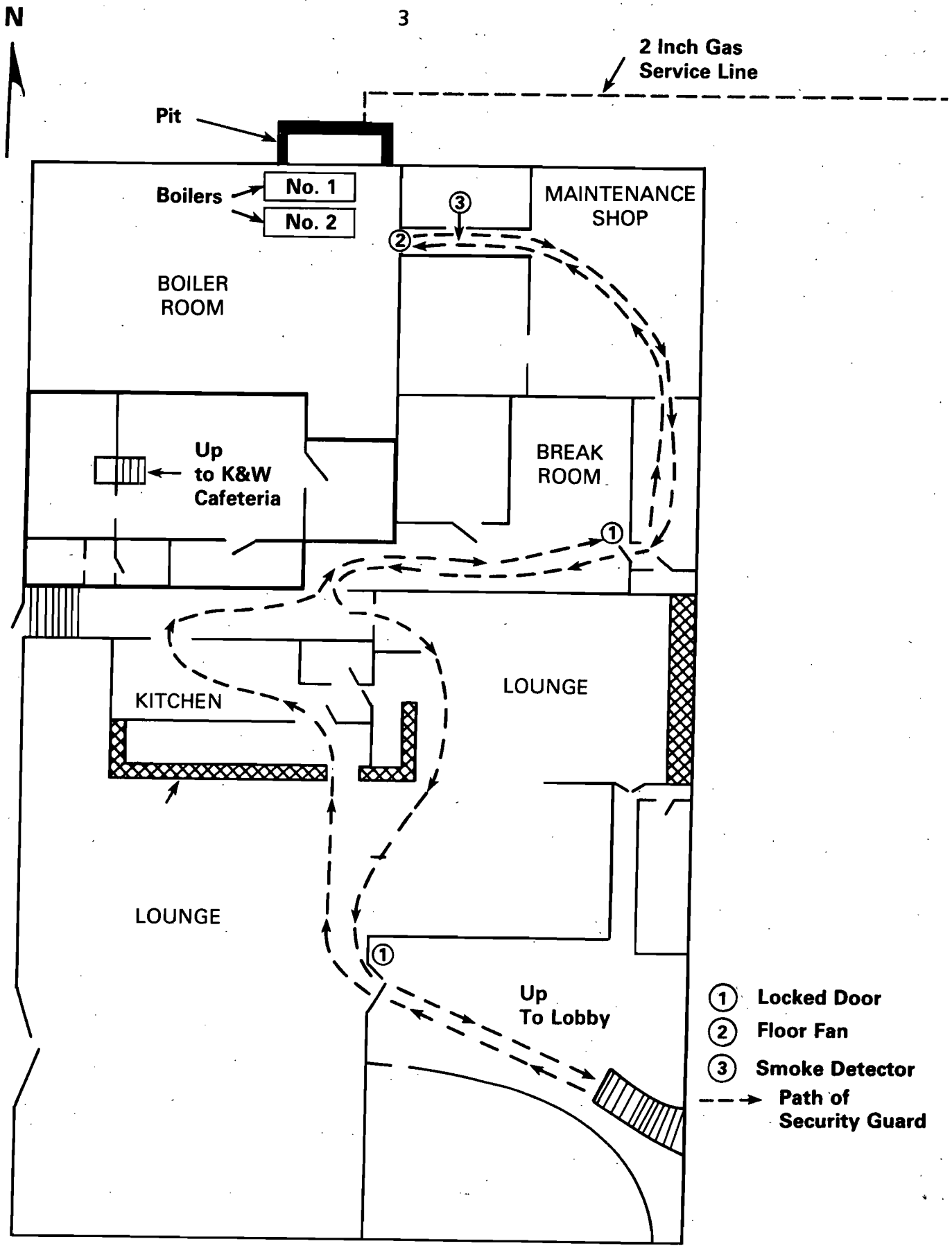

Figure 2.–Basement floor plan.

flashing yellow light on the panel, she said that she opened the panel box and pressed a button to silence the audible alarm. The alarm was for zone 4, an area at the entrance to the boiler room. The desk clerk said that she did not know the locations of the various zones; however, she knew the zones were in the basement and she directed the security guard to investigate the source of the alarm. The security guard and the desk clerk's friend then proceeded downstairs to the doors of the lounge. The desk clerk stated that shortly afterward, the janitor reported the gas odor and requested a key to open one of the cafeteria doors. She recalled contacting the security guard by portable radio and advising him of the janitor's report of a gas odor and request for a key. When she learned that the security guard did not have a key for the cafeteria, she advised the janitor who then told the desk clerk that he was going to come through the emergency door between the cafeteria and the lobby.

According to the security guard, the desk clerk received the telephone call from the janitor while the security guard and the desk clerk's friend were still in the lobby and before the alarm activated. He stated that when the alarm signals were received, he waited for the desk clerk to identify the alarm zone location, but after deciding that the desk clerk was unsure of the location, he and the friend, ran downstairs to investigate. (See figure 2.)

The security guard unlocked the doors to the lounge and he and the friend entered the lounge but separated once inside. The security guard proceeded through the bar and the kitchen to the locked door of the break room at the maintenance shop hallway. After unlocking and opening the door, he detected the odor of natural gas. The security guard proceeded through the maintenance shop to the doorway of the boiler room where he heard a very loud noise. He recalled looking up at the boiler room ceiling for the noise source, but he could not determine a location. He stated that the noise level was too loud for people to converse and that he did not recall hearing the noise of the floor fan at the entrance to the boiler room. (See figure 2.)

The security guard stated that as he ran from the maintenance shop to return to the lobby, he radioed the desk clerk to report that they needed help and that a pipe had ruptured. The noise level was so loud that he did not know whether the desk clerk had heard him. When the security guard reached the lobby, the desk clerk was attempting to telephone the motel maintenance man who was not at the hotel to report the problem. The security guard noted that the desk clerk's friend had returned to the lobby. The security guard did not recall any radio message from the desk clerk while he was in the basement.

The security guard and the friend went to help the janitor open the emergency door to the K & W Cafeteria. However, before they were able to help, the janitor opened the emergency door. The janitor said that he had proceeded about 5 feet into the lobby when an explosion occurred, the lights went out, and the walls and floor began to shake. The janitor estimated that 5 minutes had elapsed between the time he called the desk clerk and the time he entered the lobby through the emergency door. All four persons--the desk clerk, the security guard, the janitor, and the desk clerk's friend--escaped from the lobby following the explosion.

Emergency Response

After receiving a telephone call from a citizen about the explosion, the Winston-Salem Fire Department dispatcher notified the platoon supervisor of engine company 7 at 2:34 a.m. The company arrived on scene at 2:36 a.m. and positioned engine 7 on Knollwood Street heading south opposite the east side of the lobby/cafeteria building. (See figure 1.)

At 2:38 a.m., the incident commander arrived in the command vehicle and parked on Knollwood Street opposite the northeast corner of the lobby/cafeteria building, about 50 feet north of engine 7. The incident commander established the command post and switched to a common communications channel. He then directed the communications center to implement a designated

plan that required the mobilization of additional firefighting units and medical units and the notification of the electric and gas companies. The incident commander also specifically directed the dispatcher to contact the electric company and Piedmont Natural Gas Company (Piedmont). According to the incident commander, the dispatcher worked from a written checklist to make the proper notifications.

The fire department command post, a white van with a red stripe around it and the word "Fire" stenciled on the back door, was cordoned off by a fire line tape; a large sign was placed at the scene to identify the van as the command post. In accordance with fire department procedures, the flashing lights on top of the command post vehicle were operating to provide identification of the command post.

Shortly after arriving on scene, the engine company 7 platoon supervisor and his firefighters began to deploy hoses to extinguish a small brush/wood fire in the vicinity of the canopy at southeast side of the building. The platoon supervisor said that when he was about 100 feet from both the truck and the pit on the north wall of the cafeteria, he heard a loud hissing noise over the noise of the diesel engine. He later stated that due to the loudness of the hissing noise, he realized there was a sizeable gas leak.

Meanwhile, a hotel guest advised the platoon supervisor of a second fire burning in the west side of the basement. The platoon supervisor left his crew to extinguish the first fire while he proceeded around the south end of the building to the area of the swimming pool. He described the basement fire as having an orange flame, not generating much smoke, and not being forceful. He saw no signs that the basement fire was caused or sustained by flammable or combustible liquids, or natural gas.

Because of his concern about the stability of the building walls, the platoon supervisor decided to position hoses and apply water into the basement rather than send his men into the basement. About 2:56 a.m., engine company 7 had positioned hoses and was applying water to the basement fire. The platoon supervisor indicated that once water was applied to the fire, it was almost extinguished. A second hose was eventually deployed down the stairway at the southeast corner of the lobby. The fire was extinguished before the fire chief's arrival at the scene at 3:16 a.m.

A Piedmont serviceman, who was notified at 2:38 a.m. of the explosion, arrived on scene at 3:10 a.m. and reported to the command post. Between 3:16 a.m. and 3:19 a.m., additional Piedmont employees from the Winston-Salem district office were dispatched to the scene. A working foreman arrived at 3:32 a.m., and a service foreman arrived at 3:43 a.m.

Shortly after his arrival, the working foreman was directed by the incident commander to turn off the gas to the Sheraton. The working foreman said that he walked around the building to locate the meter and the pit, but that he could come only within 15 feet of the pit due to the debris from the building. He was not able to see the meter installation because of the rubble, and he did not see any dust or dirt blowing or hear any noise that he would associate with gas escaping under pressure from a broken gas service line.

Since the meter and pit were inaccessible, gas to the Sheraton could be stopped only by closing a valve on the 4-inch distribution line that ran under the sidewalk on the west side of Knollwood Street. (See figure 1.) The valve also controlled the flow of gas to additional customers downstream. The service foreman met with the incident commander to describe the proposed procedures to be used for shutting off the flow of gas and for severing the service line from the distribution line. Using one of Piedmont's vehicles, the service foreman established a communications post for Piedmont. At 4:07 a.m., about 1 1/2 hours after the explosion and 35 minutes after the arrival of a gas company foreman, the working foreman and the serviceman closed the valve thereby stopping the flow of gas to the building.

Using a combustion gas indicator (CGI), the working foreman began to survey adjacent buildings for the presence of gas. Between 4:10 a.m. and 5:35 a.m., Piedmont work crews and equipment needed to sever the service line arrived. Between 4:10 a.m. and 7 a.m., Piedmont service personnel conducted surveys of two adjacent small shopping centers, a restaurant, and a convenience store. No gas was detected.

The incident commander stated that he remained inside the command post van so that he could have maximum concentration directing the operation. Although the incident commander did not personally observe the scene, firefighters and Piedmont personnel kept him advised of the situation. With the exception of directing Piedmont to stop the flow of gas to the building, the incident commander did not direct Piedmont to take any other specific actions. The incident commander deferred to the advice of the Piedmont crews on the actions they believed necessary to secure the service line and to minimize the hazards of escaped gas.

Shortly after arriving on scene, the incident commander raised the level of response to three alarms, thus increasing the response to six pumper trucks and three aerial units. Extra personnel on these units were used to evacuate the motel guests and to check for the presence of gas in and around the motel complex. The incident commander also used fire department personnel to check other buildings in the vicinity. He expected these firefighters to detect any presence of gas by smell. He later stated that he was aware that gas can migrate long distances through the ground to other locations, but that he did not know that the odorizing agent in the gas can, under some circumstances, be removed in the process.

Since the incident commander judged the building area too dangerous to permit safe access, he did not permit Piedmont crews to immediately conduct bar-hole tests.[1] He had them wait until there was sufficient daylight to safely perform the work. At 7:20 a.m., Piedmont crews were allowed to conduct the first gas detection tests over the gas service line from Knollwood Street to the pit. Six test holes, spaced about 20 feet apart, were made by the working foreman through the asphalt that covered the service line. All holes were tested; only one tested positive. A positive reading of 0.5 percent of the lower explosive level (LEL) was obtained in a bar hole located along the route of the service line about 88 feet east of the pit. A second test, which was immediately taken, resulted in a zero reading in the bar hole. Additional test holes away from the service line were not made to define an area of gas migration.

At 8:30 a.m., Piedmont received permission from the incident commander to sever the service line from the 2-inch distribution line. The service line was uncovered where it joined the distribution line. Piedmont crews cut the service line and installed a 2-inch compression coupling, nipple, cap, and strap on the end of the service line left joined to the distribution line. They then capped the end of the service line running to the Sheraton, finishing about 10:19 a.m. The incident commander was relieved from duty at 1 p.m.

[1] A bar-hole test is conducted by making a hole in the ground adjacent to and to the depth of a gas pipeline and then testing for the presence of gas in the hole using a CGI.

Injuries to Persons

	Gas Company Personnel	Civil Agencies	Employees/ Guests	Total
Fatal	0	0	0	0
Serious	0	0	1	1
Minor	0	0	4	4
Total	0	0	5	5

Damage Information

The building containing the Sheraton Motel lobby and the K & W Cafeteria was completely destroyed. The explosion caused the north half of the building to collapse. (See figure 3.) Several ground floor support beams were lifted from their supports in the basement walls causing the floor to fall into the basement. The floor of the south end of the building, including the lobby, did not collapse; however, the floors were buckled and weakened. Glass and debris were widely scattered to the north and east. The adjacent motel wings suffered structural and glass damage. Neighboring buildings also suffered some glass damage. A number of parked automobiles in the motel parking lot sustained varying degrees of damage and broken glass. Estimates from the property owner, the cafeteria, the gas company, and the fire department place property and other losses at $4,500,000.

Meteorological Information

At the time of the accident, the temperature was approximately 35° F, with fog. Winds were light, blowing in a northerly direction. The high temperature reported for January 17 was 45° F at 1 p.m., and a low temperature of 34° F reported at 6 a.m. for January 18. Rain also had been forecast for January 18 with a high temperature exceeding 50° F.

Postaccident Activities

The Fire Marshal's Office of the Winston-Salem Fire Department was responsible for conducting the city's investigation. The assistant fire marshal leading the investigation arrived on scene at 7:50 a.m. on January 18 and photographed the site and neighboring buildings sustaining damage. Between January 18-20, the assistant fire marshal interviewed the four individuals who were in the building when the explosion occurred.

Officials from the Fire Marshal's Office and the mechanical inspector from the Inspection Division of the City's Public Works Department entered the boiler room area on January 21. They reported that the No. 2 (south) boiler appeared to have been blown open. The No. 2 boiler door was found bent and the clamps that secured the door were found sheared. The spirals in the heat tubes of the boiler were found thrown toward the boiler door. The mechanical inspector said that he believed the explosion originated in the No. 2 boiler. He concluded that an enriched mixture of gas had entered the No. 2 boiler and that upon ignition of one of the two boilers, the explosion occurred.

On January 21, Piedmont recovered the gas meter, the security valve, the regulator, and piping from the pit. (See figure 4.) The fitting on the inlet side of the gas meter was damaged. The security valve was still connected to the gas meter but had been separated from the downstream piping. The security valve, which is designed to close if the gas pressure in the customer's piping exceeds the set pressure of the valve, was found in the open position. The regulator piping was separated at both ends, and the regulator valve body was fractured. The piping from the threaded elbow to the inlet side of the gas meter was not recovered. The fire department took custody of the gas meter, the security valve, the regulator, and sections of gas piping recovered from the pit.

Figure 3.--Lobby/cafeteria building looking west.
Drive-through canopy on left.

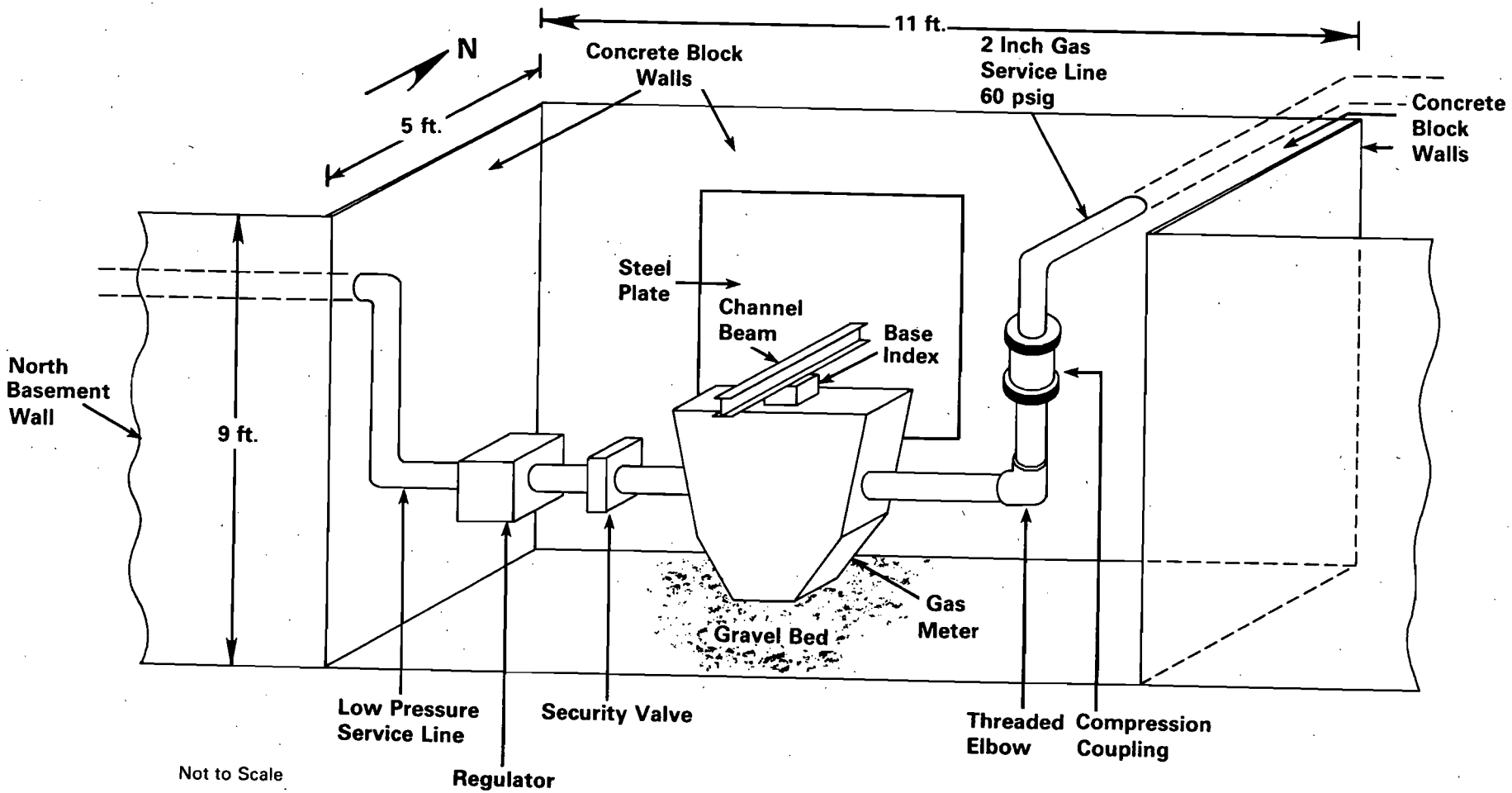

Figure 4.--Gas meter installation in pit.

The assistant fire marshal resumed his examination of the boiler room area on January 22. The electrical breaker for the No. 2 boiler was located in the electrical panel box on the north wall of the boiler room and was in the off position. The motel maintenance man confirmed that the No. 2 boiler was off when he left work on January 15. The maintenance man later stated that repair parts were on order and that the No. 2 boiler was inoperative.

Representatives from the fire department, Piedmont, Travco, and the City of Winston-Salem met on the afternoon of January 27, to test the operation of the security valve. A cameraman accompanied the Travco representatives to videotape the tests. During the testing a Piedmont serviceman from the Winston-Salem district office stated that a pressure drop of 2 or 3 psi was recorded from 2:30 a.m. when the 60 psig gas line "broke" to 4 a.m. when the gas flow was stopped.

When pressure tested, the valve closed automatically at a pressure of 42 inches water column (wc)(1.25 psi). The valve's set pressure was 22 inches wc, or 0.75 psi. The valve was then closed and pressured to 60 psig for approximately 5 minutes without any evidence of leaking.

After completing these tests on January 27, the fire department issued a statement that the cause of the explosion was a leak of natural gas into a confined area and ignited by mechanical equipment. The statement indicated that due to a leak inside the building, an explosion occurred in the No. 2 boiler. The fire marshal's investigative report did not identify a source of the leak or indicate the cause of the gas leak.

On February 1, a representative for Travco discovered that the 2-inch gas service line was corroded and cracked near the point where the service line entered the pit through the north wall. (See figures 5 and 6.) The area of corrosion was along an uncoated length of the service line extending about 2 inches into the concrete wall of the pit. The circumferential crack was located approximately 1 1/2 inches inside the concrete wall. The crack extended around the west half of the pipe, from the 10:30 o'clock position clockwise to the 6:30 o'clock when viewed from upstream. From the pit wall, the service line extended horizontally into the pit to a 90° welded elbow and then extended vertically downward. The downstream end of the vertical pipe section was connected to a Dresser Industries (Dresser) Series-90 compression coupling. The 2-inch pipe section that had been connected to the downstream end of the coupling was found separated from the coupling. The cracked service line section with the coupling was removed from the pit and placed in the custody of the fire department.

The assistant fire marshal returned to the accident site on February 2-3 and took custody of additional customer-owned gas service piping recovered from the basement in the vicinity of the boiler room. One of the items recovered was a 4-inch gas main tee located beside the No. 1 (north) boiler. A plug valve was attached to the end of a 3/8-inch pipe stem that in turn was welded to the 4-inch tee. The core of the plug valve was found on the basement floor. Evidence did not indicate whether the core was in or out of the plug valve when the explosion occurred.

On March 2, the National Bureau of Standards (NBS) visually examined seven pipe specimens recovered and in the custody of the fire department. Six specimens had been recovered from the basement of the building. The seventh specimen was the section of 2-inch gas service line with the corrosion area and the disengaged compression coupling. The NBS report, dated March 22, 1988, stated that, with the exception of the corroded piece of service line pipe, the remaining six pieces of pipe displayed severe mechanical deformation. The NBS report further stated that five of the six pieces failed by mechanical overload. The NBS report did not comment on the failure of the sixth piece.

On March 11 at the direction of the Safety Board, Piedmont pressure tested the buried portion of the service line in the presence of a field inspector from the Pipeline Safety Section of the North Carolina Utilities Commission (NCUC). The service line did not maintain pressure. A 1-inch-diameter

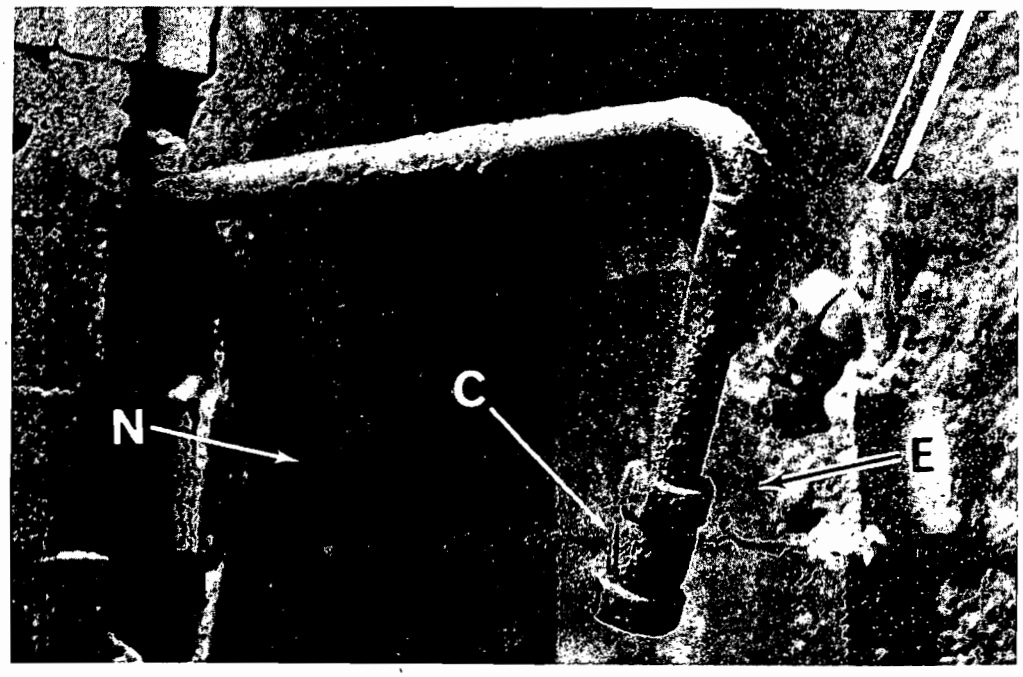

Figure 5.--View of the gas service line after the explosion at its entry point into the pit through the north wall (arrow "N"). The east wall of the pit (arrow "E") and the disengaged compression coupling (arrow "C") also are shown.

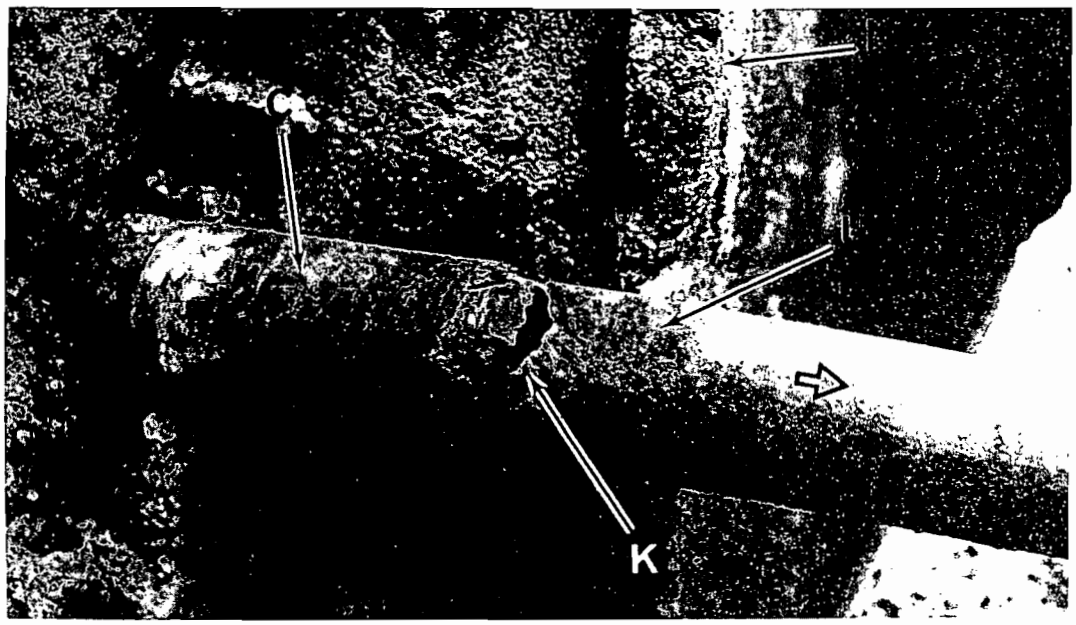

Figure 6.--View of the gas service line extending through the north pit wall (arrow "N"), showing the coated area (arrow "C"), the uncoated area (arrow "U"), and the crack area (arrow "K"). The unmarked arrow indicates the direction of flow.

corrosion hole was found in the service line approximately 9 feet 5 inches east of the bend leading to the pit, or about 10 feet from the northeast corner of the pit. The bend in the service line is located 7 feet 5 inches north of the north wall of the pit. The corrosion hole was found in a section of the service line about 9 feet long that had various gouges and damage to the pipe coating. A plastic electrical conduit had been laid adjacent and parallel to that section of the damaged service line. In January 1964, Duke Power Company installed an underground electrical cable through the plastic conduit to the Sheraton Motor Inn; however, there are no records indicating who laid the plastic conduit.

On March 10, 1988, Piedmont relocated a meter set at a hotel in Winston-Salem from a pit to an aboveground location and subsequently surveyed existing meter installations within its entire system. It found approximately 12 additional meter sets located in pits, but has no plans to relocate these additional meters.

Notification Actions

Piedmont notified the NCUC of an explosion in Winston-Salem about 6 a.m. on January 18. The NCUC inspector did not respond to the call because he was ill and the information provided by Piedmont suggested that a boiler had exploded. The NCUC pipeline section chief first learned of the accident from a news broadcast on the morning of January 18 . He telephoned Piedmont's offices that morning, but their offices were closed for the holiday. When the NCUC pipeline section chief contacted Piedmont about the accident on January 19, he was advised that Piedmont had tested the service line but had not found any leaks. The NCUC section chief assumed Piedmont had conducted a pressure test but later learned it was a bar-hole test. Due to illness, the NCUC section chief did not visit the accident site until January 22. At that time, he was told by the city mechanical inspector that "gas was not involved" and that the boiler had blown up.

On February 12 the NCUC learned that a corroded section of the gas service line to the Sheraton had been found and confiscated by the fire department. In a meeting with the assistant fire marshal on February 15, the NCUC section chief learned that the pipe would be tested at the NBS. Since the corroded section of service line was in the custody of the fire department, the NCUC section chief was not allowed to see the pipe. On February 22, the assistant fire marshal requested that the NCUC pay for the tests at the NBS. The NCUC section chief agreed providing that an NCUC inspector would be present for the tests and that any prepared reports would be sent to the NCUC.

The Safety Board first learned of this accident on February 29 when a representative for Travco called to inquire about the Board's investigation. After confirming with the National Response Center (NRC) that the accident had not been reported, the Board contacted the NCUC section chief who provided preliminary information about the accident. The NCUC section chief informed the Board about the tests scheduled at the NBS and agreed to advise the Board of the results.

After the NCUC section chief saw the corroded section of the service line for the first time on March 1, he recommended that Piedmont notify the NRC of the accident. Piedmont officials stated that they had not notified the NRC previously because the fire department had concluded that the source of the gas leak was piping in the basement. Since the piping in the basement was not part of Piedmont's pipeline system under Federal regulations, Piedmont determined that Federal notification requirements did not apply.

Upon receiving the NRC notification on March 2, the Safety Board contacted Piedmont for additional information. On March 3, the NCUC section chief briefed Safety Board staff members about the accident and then described the corroded section of the service line. After determining on March 4 that evidence sufficient to determine the probable cause of the accident likely still existed, the Board decided to investigate the accident.

Building Information

Design and Construction.--Travco has solely owned the Sheraton Motor Inn property since December 21, 1986. The owner of Travco had previously acquired a controlling interest in 1983. K & W Cafeterias leased the space for the cafeteria.

The motel complex was designed and constructed between October 1963 and May 1964. The original design and construction of the lobby/cafeteria building included a pit for locating the gas meter assembly. (See figure 4.) The pit was located along the north basement wall that also served as the south wall of the pit. The north basement wall was poured concrete, and the other three walls were made of concrete blocks. The concrete blocks in the north pit wall surrounding the entry point of the gas service line into the pit had been partially filled with concrete. The top of the pit was open to the air and covered with metal grates. The floor of the pit was gravel on top of earth.

When Safety Board investigators examined the pit on March 10 and again on April 1, all of the concrete block walls of the pit were cracked or crumbling into the pit. The east wall had almost completely fallen apart. The concrete blocks in the north wall of the pit and in the area where the service line entered the pit had either been removed or had crumbled in, thereby exposing a cross-section of a sidewalk extending along the north pit wall. The concrete sidewalk was approximately 7 inches thick and directly over a rock base approximately 4 inches thick. Clay below the rock base was measured to a depth of 18 1/2 inches from the top of the sidewalk. A second layer of concrete approximately 7 inches thick was found below the clay.

On June 2, 1986, Travco and a local construction company signed a proposal of work that included the fabrication and installation of steel plates in the pit to "reinforce existing concrete retaining wall in front of K & W." The contractor stated on the proposal that he "could not guarantee that this structural steel will keep other portions of this wall from cracking." Travco stated that the plate and channel beam supports were installed between June 18 and July 1, 1986. With the exception of the installation of the steel plate, the pit had not been altered or modified since its construction.

Boiler Room Ventilation.--The two openings to the pit through the north wall of the basement served as ventilation openings for the boiler room and combustion air intakes for the boilers. (See figure 7.) The two gas-fired boilers were mounted on raised concrete slabs adjacent to the ventilation openings from the pit. The ends of the boilers faced the entrance to the boiler room from the maintenance shop.

The motel maintenance man stated that the two ventilation openings in the basement wall were fitted with a series of louvered inserts. The upper ventilation opening also had a squirrel cage fan which drew fresh air into the boiler room from the pit. The maintenance man estimated that the fan ran approximately 90 percent of the time. One of the louvered inserts on the lower level was hinged on the right side to permit access to the pit. During cold weather, the louvered inserts on the lower level were covered with plywood to prevent cold air from entering the boiler room. The upper level vents were left open.

Boilers.--The two gas-fired steam boilers were used to heat the motel complex. The two boilers, both National Model No. 2590N-5, measured approximately 12 feet long and 5 feet in diameter. According to the maintenance man, each boiler was equipped with monitors for high- and low-water levels, a pilot, and a main burner. Each boiler also had an automatic purge cycle which ran for 30 to 45 seconds before the boiler would light. State inspection records indicate that the pressure relief devices were each set for 15 psig.

At the time of the accident, the No. 2 boiler was not operable. Repair parts were on order for the purging control cycle. The maintenance man stated that the pressure relief valve on the No. 1

Figure 7.--View of the ventilation openings (arrow "V") in the north basement wall to the pit and the concrete pads (arrow "P") for the heating boilers (arrow "B"). The boilers and water tank (arrow "T") were left after excavation.

boiler had been replaced in the late summer or early fall of 1987. He recalled that in the 3 1/2 years he had been at the Sheraton, occasionally the boilers had stopped automatically and required repair. Maintenance records and other documentation for the boilers were destroyed in the accident.

Alarm System.--The alarm system was purchased from and installed by the ADT Company in accordance with the purchase order and service agreement dated November 29, 1983. The alarm system consisted of one fire alarm control panel located at the lobby desk and miscellaneous fire detection devices and alarms. The basement of the lobby/cafeteria building was separated into five zones. A sixth zone covered the laundry and employee lounge which were not located in the building.

A total of 15 smoke detectors, 22 fixed temperature/rate of rise thermostats, 4 horns, and 3 manual pull stations were installed within the basement area. Two fixed temperature thermostats were located in the boiler room. Five smoke detectors were located in the maintenance shop, including the steam-sensitive smoke detector in the hallway leading to the boiler room. The smoke detectors were photocells that are triggered by reflected light that can occur not only from smoke, but also from steam or dust in the air.

Service Line and Meter Set Installation

The gas service line to the Sheraton was installed in early 1964 and extended west from the distribution line along Knollwood Street to the north side of the lobby/cafeteria building before turning south and entering the pit. (See figure 1.) The service line was buried 30 inches deep under an asphalt driveway and parking lot. The service line entered the pit through the north wall and extended horizontally into the pit before turning vertically downward toward the gas meter assembly. (See figure 4.) The vertical length of pipe consisted of two pipe sections connected by a Dresser Series-90 compression coupling. Dresser's installation instructions that were provided in the

1960s warned, "When pipe movement out of the coupling or fitting might occur, proper anchorage of the pipe must be provided." The instructions did not indicate any coupling specifications for operating pressures or tensile loading. Current installation instructions contain the same warning concerning anchorage of the pipe and indicate the coupling has a pressure rating of 150 psi.

The 2-inch service line had an outer diameter of 2.375 inches and a wall thickness of 0.154 inch. Piedmont no longer had records indicating the grade of steel pipe used. The buried pipe was butt-welded, coated, and wrapped. The pipe exposed to the atmosphere in the pit was painted. The buried portion of the service line had never been cathodically protected.

The Rockwell 5000 model gas meter, serial No. 6016183, had a metering pressure of 60 psig. The base pressure index mounted on top of the meter was manufactured by American Meter Company, model BP-120, with a pressure range of 0 to 100 psi. The Fisher S201-443 regulator reduced the gas pressure from the 60-psig service pressure to the customer service pressure of 8 inches wc (0.3 psi). The meter set was installed and placed in service in March 1964.

The arrangement of the meter set and piping within the pit was not installed according to the approved design from Piedmont's General (corporate) Office. The approved plans show a meter set installed above ground rather than in a pit. The approved design shows that a single compression coupling should have been installed horizontally between the security valve and the regulator; however, the approved design does not indicate that a compression coupling was to be installed vertically upstream of the meter. Also, the gas meter was to be supported on a four-legged stand that in turn was to be positioned on a pad of unspecified material. During excavation of the pit on April 1, two badly corroded flanges that connected to pipe of the type commonly used as the leg supports for the meter stands were found. The pipe connected to each flange had corroded fully. However, there was no evidence in the pit of the meter stand or any type of pad.

Codes and Standards

When the meter set was fabricated and installed in 1964, Federal regulations did not exist for natural gas transmission and distribution systems. Standards for the gas pipeline industry had been published by the American Society of Mechanical Engineers (ASME) as the American Standard Code for Pressure Piping - Gas Transmission and Distribution Piping Systems (ASA B31.8). The 1963 edition of this code, ASA B31.8-1963, included the following provisions for pits and the location of gas meters.

> 847.1(a) Vaults and pits shall be designed and constructed in accordance with good structural engineering practice to meet the loads which may be imposed upon them.
>
> 847.1(d) . . . Where piping extends through the vault or pit structure, provision shall be made to prevent the passage of gases or liquids through the opening and to avert strains in the piping. Equipment and piping shall be suitably sustained by metal, masonry, or concrete supports . . .
>
> 848.1(a) Customers' meters and regulators may be located either inside or outside of buildings, depending upon local conditions . . .
>
> 834.4(a) All exposed pipe joints shall be able to sustain the maximum end force due to the internal pressure, i.e., the design pressure (psi) times the internal area of the pipe (sq in.); as well as any additional forces due to temperature expansion or contraction, or to the weight of pipe and contents.
>
> 834.4(b) If compression or sleeve-type couplings are used in exposed piping, provision shall be made to sustain the longitudinal forces noted in 834.4 (a). If such provision is

not made in the manufacture of the coupling, suitable bracing or strapping shall be provided; but such design must not interfere with the normal performance of the coupling nor with its proper maintenance . . .

Title 49 Code of Federal Regulations (CFR) Part 192 contains the minimum Federal safety standards for the transportation of natural and other gases by pipeline. The initial Federal regulations that became effective in 1971 incorporated the ASA standards in nearly identical form. Current Federal regulations do not prohibit or restrict the placement of gas meters in pits which also serve as ventilation inlets for combustion equipment.

During the 1960s, building contractors in North Carolina relied upon recommended industry practices adopted by organizations, such as the National Fire Protection Association (NFPA) and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) for heating and ventilation. These recommended industry practices, however, did not address the placement of boiler ventilation intakes in buildings with respect to gas meters and piping installations. State building codes for heating, ventilation and air conditioning that were adopted in September 1971 became effective in July 1972. Current building code requirements for heating and ventilation do not address the placement of combustion air intakes for machinery in the proximity of natural gas lines or meters.

North Carolina also has adopted the ASME Code for Boilers and Pressure Vessels as the design standard for heating boilers. While the ASME Code prescribes design standards for the boilers, it does not address the location of combustion air intakes. If the boiler is found to be in compliance with the ASME Code, the State will issue an inspection certificate authorizing the use of the boiler. If the boiler is not in compliance, the State will send a letter itemizing the action required to bring the boiler into compliance. The State had inspected both boilers at the Sheraton within 2 years of the accident; one boiler on April 10, 1986, and the second boiler on June 9, 1987. The State found both boilers to be in satisfactory condition when the inspections were conducted and reissued the inspection certificates.

Gas Company System

General.--Piedmont, which was formed in 1951, operates in the States of North Carolina, South Carolina, and Tennessee. Within the past 3 years, Piedmont purchased the Nashville Gas Company, which is currently operated as a separate entity. Piedmont eventually plans to fully integrate it into the company. Overall, Piedmont serves a total of 355,000 customers in three States. Within the State of North Carolina, Piedmont has seven districts that operate 264 miles of transmission pipeline and 4,124 miles of distribution pipeline and serves approximately 190,000 customers. There is also one liquefied natural gas facility.

Organization.--The senior vice president of operation services in the general office is responsible for all distribution operations for Piedmont within North Carolina and South Carolina. Within the general office, the Engineering Department, Maintenance and Safety Department, and Materials Management Department report to the senior vice president. The Engineering Department is responsible for system operations. The staff responsible for the leakage and corrosion programs is under the Maintenance and Safety Department but works closely with the Engineering Department. The Maintenance and Safety Department focuses on maintenance of facilities and occupational safety and is not involved with natural gas distribution and operations. The Materials Management Department is responsible for company inventory and supplies.

District managers also report to the senior vice president for operation services. Three managers are assigned to each district manager to oversee district operations, accounting, and marketing functions. The district superintendent of operations is responsible for the maintenance, installation, and inspection of distribution and service pipelines and metering equipment.

Servicemen, pipefitters, welders, and corrosion technicians work under the superintendent of operations. The office manager is responsible for customer accounts and billing. Meter readers, who are the only employees to see individual meter sets on a monthly basis, are under the supervision of the office manager. The sales manager is responsible for the marketing of services and appliances within the district.

Piedmont employs about 1,800 persons. Personnel turnover has been low, with many employees spending their working careers with Piedmont. Many of Piedmont's managers started as servicemen and have advanced within the organization.

Operating Policies and Practices.--Piedmont's operating policies and practices are consolidated in a series of corporate engineering letters. The Engineering Department has the responsibility to issue and update the letters. Piedmont management has directed that "Division and District personnel and operating people throughout our system are expected to become familiar and comply with all rules as interpreted and implemented by the Engineering Department."

The engineering letters contain complete reproductions of 49 CFR Part 191 (annual reports and incident reports), Part 192 (safety standards for gas pipelines), and pertinent sections from other Federal regulations addressing occupational health and safety practices. Additionally, the letters contain pertinent sections of North Carolina's and South Carolina's utilities laws and some sections of the ASME Guide for Gas Transmission and Distribution Piping Systems. The engineering letters also contain Piedmont's interpretations and instructions for implementing selected provisions of Federal and State regulations. For those regulatory provisions without added interpretation or instruction, Piedmont has determined that the provisions are sufficiently clear and further comment is not needed.

Piedmont has stated that the engineering letters constitute the company's Operating and Maintenance Plan required under 49 CFR 192.603, and copies are on file with the NCUC. However, the engineering letters contain no statement identifying them as such.

Maintenance and Inspection of Gas Meters

Engineering Letter No. 192.739 prescribes routine annual maintenance procedures for commercial customers, such as the Sheraton Motor Inn, that have meters with capacities of 5,000 cubic feet per hour or more. Under the annual maintenance schedule, district servicemen are required to look at the general condition of the meter set and exposed piping and paint as necessary. They are also required to check the setting of the regulator and security relief valve, the operation of filters and valves, and to visually inspect the "enclosure or area that contains the installation." Beyond listing these tasks, the engineering letter does not provide any instruction about completing the tasks or establish minimum acceptable standards.

Annual maintenance inspections for the Sheraton meter set were conducted in September 1986 and August 1987. Neither inspection report included any comments about the steel plate and channel beam bracing the north pit wall or other conditions in the pit. Both inspection reports indicated without explanation that routine maintenance checks had been performed on the filter, regulator, trip-over (security) valve, fences and buildings, and valves. The settings for the regulator and security valve were cited as 8 and 24 inches wc for 1986 and 8 and 22 inches wc for 1987. The 1986 inspection report also stated that the crew "touched up paint." The inspection checkoff list does not specifically include instructions for the crew to inspect the piping for corrosion.

Crews working under the general office test or "prove" the meter for accuracy in measuring the gas used by the customer. A hose with a regulator is connected to valves located on the high-pressure service line upstream of the gas meter and on the low-pressure customer piping downstream of the regulator. This arrangement isolates the gas meter while maintaining the flow of

gas to the customer. Test connections located on the high-pressure service line upstream and downstream of the gas meter connect measuring equipment for the tests. Using this arrangement for the by-pass hose and test connections, the prover tests are conducted without physically disconnecting the meter from the service line or otherwise disturbing the meter assembly. The meter prover tests are scheduled once every 2 years and are conducted independently of the annual maintenance inspections. Meter prover tests at the Sheraton Motor Inn were last conducted in May 1986.

Other than servicemen who conduct the annual maintenance inspections and the meter prover tests, the only other gas company employee to see an individual meter assembly on a regular interval is the meter reader. The observations of the monthly meter reader for the Sheraton differed from the actual layout of the pit. He stated that the basement wall was concrete block rather than poured concrete and that the remaining walls were poured concrete rather than concrete block. The meter reader could not recall how the service line entered the pit, how large the service line was, or if any wall of the pit was cracked and crumbling. He did remember that the channel beam installed to support the north pit wall did not provide enough clearance over the base index on top of the meter for him to raise the index cover and take readings. The meter reader did not know why the channel beam had been installed, nor did he notice any cracking, crumbling, or other unusual conditions in the north wall of the pit before the channel beam was installed. He stated that he advised the district office manager about the channel beam. He also stated that a Piedmont serviceman removed the index cover so that readings could be taken. However, the office manager did not recall the meter reader telling him about the channel beam. The district superintendent also stated that he was not aware that the index cover had been removed. The meter reader noted nothing unusual during his last reading on December 31, 1987.

Leakage and Corrosion Programs

Piedmont's leakage and corrosion protection programs are the responsibility of the Corrosion and Leakage Department which is under the Manager of Maintenance and Safety in the general office. The Corrosion and Leakage Department is under the supervision of the superintendent of corrosion and leakage. The department staff includes a corrosion engineer, a leakage supervisor, and several leak technicians who work in the districts. The superintendent of corrosion and leakage has the overall responsibility of Piedmont's leakage and corrosion programs, which are currently conducted independently of one another. The leakage survey programs are administered directly by the Corrosion and Leakage Department; the corrosion control program is primarily administered at the district level by the district superintendent of operations.

Leakage Survey Program.--According to Engineering Letter No. 192.723, the Corrosion and Leakage Department will maintain records, prepare annual leakage reports, train leakage personnel, and use outside consultants as necessary to audit all areas of the program. To define the scope and work of this program, the department has developed a leak survey manual which includes Engineering Letter No. 192.723 and information about properties of natural gas, gas detection equipment, leak grading, and types of surveys and reports. Piedmont also has adopted, as part of its leakage control program, the gas leakage control guidelines in Appendix G-11 of the ASME Guide for Gas Transmission and Distribution Piping Systems.

Leak technicians are assigned to the Corrosion and Leakage Department in the general office but work independently within the districts. Piedmont conducts annual surveys of business districts, shopping districts, schools, and other places "where large numbers of people congregate, including theaters, hospitals, churches, and multi-story apartment complexes." Business districts are further characterized as outlying areas with "large paved areas covering natural gas pipelines where the paving goes up to the building walls such that leaking gas could not vent to the atmosphere." The remaining areas within the district are surveyed once every 5 years.

Piedmont did not classify the Sherton Motor Inn as being within a business district because the presence of vegetation, planting strips, landscaping, and medians was sufficient to keep the area from being "wall-to-wall" pavement. Consequently, leak surveys for the Sheraton were scheduled for 5-year intervals. The last leak survey of the service line to the Sheraton was conducted in December 1984.

Title 49 CFR 192.465(e) requires each operator at intervals not exceeding 3 years to reevaluate its unprotected pipelines and to cathodically protect those pipelines in areas of active corrosion. In 1977, Piedmont had indicated to the NCUC that one corrosion leak would constitute an area of active corrosion. The distribution line along Knollwood Street was part of an isolated section of the gas distribution system. In 1979, a leak was reported in this section and was found to have been caused by corrosion. In 1984, a second leak was reported near the location of the 1979 leak. When the second leak was repaired in May 1988, seven holes were found in the distribution line. Since the last leak survey in 1984, Piedmont had not reevaluated the distribution line and service line to the Sheraton by an electrical survey, leak survey, or other procedures.

The determination that a particular area meets the criteria for an annual or every fifth year survey is made by the district superintendent who may seek the advice of the leak technician. If the leak technician disagrees with the classification, he can attempt to resolve the disagreement with the district superintendent. Failing this, the leak technician can approach the superintendent of corrosion and leakage to work with the district superintendent and resolve the problem. The superintendent of corrosion and leakage acknowledged that these procedures are not in written form and have only been passed verbally. There are no written procedures or guidelines that define the responsibilities of the district superintendent and the leak technician for determining leakage survey frequencies.

Leak technicians submit leak reports to the district superintendent and to the Corrosion and Leakage Department. The district has the responsibility to repair leaks and notify the general office of the repairs. District servicemen, rather than leak technicians, resurvey the repairs to assess the adequacy of the repairs. Leak technicians do not follow up to verify that previously reported leaks have been repaired or otherwise monitor the adequacy of district repairs and leak survey work.

Cathodic Protection Program.--The Corrosion and Leakage Department develops the cathodic protection plans for large construction projects within each district and approves each district's budget for cathodic protection. However, other than these two specific functions, the Corrosion and Leakage Department has left the implementation and administration of cathodic protection programs to the district superintendents of operations. While the Corrosion and Leakage Department receives the cathodic protection data, corrosion technicians within the district offices carry out the cathodic protection programs. Unlike the leak technicians who work under the Corrosion and Leakage Department, the corrosion technicians work under the district superintendent of operations. The corrosion technician is responsible for placing pipelines within the district under cathodic protection, conducting annual pipe-to-soil potential tests, and taking corrective action as necessary to maintain pipe-to-soil potentials at negative .85 volt.

In placing an existing pipeline under initial cathodic protection, the corrosion technician determines the location and number of test points and provides them to the Corrosion and Leakage Department. The department uses these test points to generate a monthly list of test points to be surveyed by each district. The same test points within a district are surveyed from year to year. From the survey results, the department develops two listings, one for cathodic protection units that are "down" or are not meeting the negative .85 volt standard and one for cathodic protection units test points not "read" or tested. If the number of failed or unread test points is considered excessive, the superintendent of corrosion and leakage will follow up with the district superintendents.

The corrosion technician checks these test points and takes corrective action that he deems necessary to maintain the pipe-to-soil potentials at the negative .85 volt standard. If the corrosion

technician encounters a problem with maintaining the negative .85 volt pipe-to-soil potential, he will confer with the district distribution foreman for leakage and corrosion. If the two cannot resolve a problem, they can seek assistance from the Corrosion and Leakage Department.

Engineering Letters Nos. 192.463 and 192.465 contain Federal regulations addressing cathodic protection programs and monitoring of cathodically protected pipe. Neither engineering letter offers guidance about performing survey tests, criteria for selecting the location and number of test points, or seeking assistance from the Corrosion and Leakage Department to resolve problems or disagreements within the district. The corrosion technician for the Winston-Salem district was not aware of any other manual providing such guidance.

Records for pipe not under cathodic protection are maintained within the districts, with no reporting requirements to the general office. The distribution line along Knollwood Street was the only remaining pipeline section within the Winston-Salem district that had not been cathodically protected on January 18. The service lines branching off this distribution line, including that to the Sheraton Motor Inn, also were not cathodically protected.

Atmospheric Corrosion Control.--Piedmont has no formal program to inspect for atmospheric corrosion. The engineering letters simply include 49 CFR 192.479, the general atmospheric corrosion control standards.

The superintendent of corrosion and leakage acknowledged that he was responsible at the corporate level for atmospheric corrosion control, although his written position description does not specifically identify atmospheric corrosion as an area of responsibility. At the district level, no one has been designated for developing and implementing an atmospheric corrosion control program.

Piedmont does not have a written program that defines the scope and goals of controlling atmospheric corrosion. Management expressed the view that atmospheric corrosion control involved painting meters and exposed piping on an as-needed basis. Work of this nature is performed by district servicemen as they conduct routine annual maintenance work, or by crews sent out strictly to paint.

Corporate management also indicated that meter readers are expected to inspect for atmospheric corrosion since they see meter installations on a regular basis. The Winston-Salem district office manager who supervises the meter readers stated the meter readers are not trained to inspect for atmospheric corrosion, but they are trained to report gas leaks immediately. The office manager also expects the meter readers to report obvious problems, such as meters that need painting, have been tampered with, or have been covered over. The office manager said that he would not expect a meter reader to inspect the gas piping for the complete meter assembly or to notice conditions, such as a shifting wall in a meter pit.

In October 1986, Piedmont began training meter readers on the use of computerized meter reading equipment. The meter readers enter their readings into a hand-held computer which has a dedicated key to indicate that a meter set and piping need paint. Piedmont stated that use of this dedicated key was included in the training given on the use of the computer. Piedmont also stated that the meter readers were instructed to look at exposed piping and meters for signs of atmospheric corrosion in conjunction with the computer training. However, Piedmont could not provide documentation about the training given. Also, the computers are not used for commercial meters, such as the one installed at the Sheraton. Although the individual meter readers read both commercial and residential meters, the personnel/training records of the meter reader for the Sheraton did not indicate whether he has received the computer training. Since the accident, Piedmont has specifically emphasized to the meter readers to look at exposed piping for signs of atmospheric corrosion.

Gas Company Employee Qualification and Training

Managers, supervisors, and other nonunion employees, such as leak and corrosion technicians, each have a written position description. In addition to describing overall responsibilities, the position description also includes the employee's immediate supervisor and the number of employees supervised. Position descriptions do not specify minimum qualifications in terms of experience, education, or training. Statements from employees interviewed indicate that their position descriptions accurately describe their duties and responsibilities.

Nonunion employees receive written evaluations annually. Whether the supervisor discusses the evaluation with the employee and identifies and recommends additional training appears to depend upon the supervisor. The leak technician stated his supervisor did discuss his evaluation; however, the corrosion technician stated his supervisor did not. There was no indication that Piedmont has a definitive policy requiring supervisors to review evaluations and training needs with the employee.

Union employees include servicemen, meter readers, working foremen, utility technicians, machine operators, distribution regulator servicemen, and other general workers. Due to contractual considerations with the union, Piedmont does not have written position descriptions for union employees. However, the company has implemented an apprenticeship program for entry level employees in the service department. The program has been defined by written goals and procedures that address required classroom training, minimum experience for various service activities, on-the-job training, and passing a written examination.

Under the apprenticeship program, new service employees must complete a total of 78 hours of classroom instruction covering such topics as general service, appliances, electricity, and residential boilers. Employees also spend a minimum of 18 months working in different operational areas, such as service work, appliance installation, and distribution work. During this period, the employees serve as helpers to pipefitters or servicemen and also may work without supervision. Upon completion of the field service requirements and classroom instruction, the service employee must successfully pass the "Serviceman/Pipefitter" examination with a grade of 85 percent. From the service department, an employee can be promoted into other departments, such as distribution. Since Piedmont has traditionally had a low employee turn-over, foremen in the distribution department generally have 12 to 15 years of experience.

With the exception of the serviceman apprenticeship program, Piedmont does not have any written policy regarding the on-the-job training program, overall training goals, minimum training required for specific positions, recurrent training needs, and evaluation of training. Corporate training for both nonunion and union employees is scheduled through the manager of technical training (training manager), who works within the Engineering Department. The training manager meets monthly with district superintendents to discuss training programs within the districts. The training manager also coordinates some training for employees within the general office. Piedmont and the union agreed under the current contract to establish a joint training committee that will formulate and maintain a training program. Each district superintendent is responsible for identifying the training needs of the service and operations employees. The superintendent in the Winston-Salem district assesses the training needs in his department by conferring with various foremen and supervisors under his supervision.

Piedmont relies heavily on the districts to provide on-the-job training for the initial qualification and training of all union employees. In the course of accompanying other servicemen in their daily activities, trainees are expected to learn what the responsibilities are for a particular job. The manner in which on-the-job training is conducted is left to individual district superintendents and trainees' supervisors.

Training sessions or lectures for the district operations employees are given on "rainy days" when no outside work can be performed. The district superintendent also determines the employees who are to attend. Topics covered in the training sessions have included general discussions of the engineering letters, Federal regulations, gas service equipment, and district emergency plans. The training sessions, lasting between 1 and 1 1/2 hours are conducted by a training supervisor who works within one or more districts, but reports to the training manager in the general office. After conducting a training session, the training supervisor prepares a memorandum for the district and general office identifying those employees present and the topics discussed. There are no provisions for rescheduling training sessions for employees who might be absent. The memoranda have not included an outline of the presentation or otherwise described in any detail the information covered. A copy of the memorandum also would be placed in each employee's training jacket.

Additionally, technical classroom training by recognized industry experts, such as Heath Consultants, Southern Cross, West Virginia University, and individual consultants have been provided for leak technicians, corrosion technicians, and service and distribution employees. Classroom training is scheduled when new products and equipment are introduced into the system, or when the district superintendent expresses a need. Courses of this nature have included graded examinations of the course material.

Video training tapes are available for employees to review individually. The tapes include classroom training conducted by an independent consultant on leak detection practices and a series of company produced training tapes on the engineering letters. On the engineering letter tapes, specialists from the general office stand before a lectern and read individual engineering letters verbatim. Occasionally, the reader stops to offer editorial comments and from time to time the camera is directed to the printed text of the engineering letter being read or the item of equipment being discussed.

To evaluate the effectiveness of the emergency response training of the district operations department, the general office conducts mock emergency drills within each district annually. General office evaluators arrive unannounced at the district office and present the operations department with a simulated gas system emergency. The operations department is then evaluated on the response measures taken as a demonstration of the knowledge and training of the operations employees. The general office critiques the drill to identify areas that require additional training and instruction. The mock drills are conducted during normal business hours and without the participation of the local fire department or other emergency management officials.

Gas Company Sponsored Training for Firefighters

Winston-Salem firefighters have received training sponsored and conducted by Piedmont about the hazards of natural gas. Piedmont has traditionally initiated the offer for training and coordinated the scheduling, both locally and regionally. On a local level, a Piedmont employee will present slides illustrating different types of meter installations, regulator stations, and relief valves. Past training has included demonstrations of equipment to pinch off gas lines during an emergency, instructions for closing valves, and descriptions of the different pressure systems. Also, Piedmont has sponsored regional training at the Charlotte Police and Fire Training Academy for fire departments within Piedmont's area of operation. The regional seminars, lasting approximately 4 1/2 hours, include a classroom presentation of the properties and hazards of natural gas, followed by a field demonstration of a natural gas fire.

The Winston-Salem Fire Department receives notices from Piedmont two or three times a year about training for firefighters. The training agenda and subject content are finalized by Piedmont. The fire chief was not aware of anyone within the fire department requesting Piedmont to include particular subject matter or of anyone advising Piedmont of any specific training needs of the fire department.

The platoon supervisor and incident commander had some knowledge of natural gas and its hazards. Both were aware that natural gas has flammability limits, is odorized, is less dense than air, and can migrate through soil. However, neither man provided the correct flammability range or knew that natural gas can lose its odor after migrating through soil. The incident commander knew that Piedmont servicemen at the accident scene had gas detection equipment but he stated he was not familiar with bar-hole testing, i.e., testing for gas in air samples drawn from holes in the ground over a gas line. Beyond turning the gas off, the incident commander did not have any specific expectations about the assistance Piedmont employees could have provided during the emergency response efforts.

Gas Company Liaison with the Fire Department

Under 49 CFR 192.615(c) each gas pipeline operator is required to establish and maintain liaison with fire, police, and other public officials to (1) learn the resources of the public organization that may respond to a gas pipeline emergency; (2) acquaint the officials with the operator's ability in responding to a gas pipeline emergency; and (3) plan how the operator and officials can engage in mutual assistance. Piedmont's Engineering Letter No. 192.615 tasks each district with this responsibility. The superintendent of operations indicated that he was responsible for establishing liaison with the fire department for the Winston-Salem district.

To fulfill these responsibilities, the district superintendent has asked the fire chief and other members of the fire department to advise Piedmont of any assistance the fire department would want or need from Piedmont. Piedmont servicemen, upon arriving on-scene, have been instructed to report to the incident commander and to be available to the fire department. On-scene servicemen are required to conduct gas detection surveys of the surrounding area in accordance with the district's emergency plan. The district superintendent stated that he has conveyed this information to the fire department.

The incident commander and the fire chief both indicated that they expect Piedmont to stop the flow of gas and provide support to the fire department in a natural gas emergency. The fire department depends on Piedmont to take the necessary action to minimize the threat of natural gas, even though no fire department official mentioned specific actions other than stopping the flow of gas. The fire chief viewed Piedmont as the recognized experts and expects Piedmont employees on scene to consult with the incident commander and provide advice and information. The fire chief could not identify any other capabilities that Piedmont could provide. The fire department and Piedmont do not have a written understanding that describes the availability and capabilities of equipment or employees in the event of a natural gas emergency. The fire chief acknowledged that Piedmont has always cooperated and assisted the fire department to the extent requested. The fire chief also acknowledged that he was not aware of any previous natural gas emergencies that involved Piedmont property.

North Carolina Utilities Commission

Responsibilities and Organization.--The Pipeline Safety Section of the Transportation Division of the NCUC has been certified by the U.S. Department of Transportation (DOT) to implement and enforce the Federal pipeline safety regulations, 49 CFR Part 192, within the State of North Carolina. The pipeline section also enforces State regulations and will process violations for consideration by the NCUC.

The pipeline section has two full-time inspectors and a chief, who also performs some field inspections, to oversee the operations of 4 intrastate operators, 8 municipal gas systems, and 38 master meter operators that are subject to the jurisdiction of the NCUC. In terms of facilities, this amounts to over 1,500 miles of transmission pipelines, 11,000 miles of distribution pipelines, and

500,000 services that are organized into 86 "inspection units." Inspection units are defined arbitrarily and may be a transmission line, a distribution line, or some other designated grouping of equipment. The section conducts a comprehensive inspection of each inspection unit at intervals not exceeding 15 months.

Annual Inspections.--The NCUC inspections for 1986 and 1987 of Piedmont's Winston-Salem district included a review of the files and monitoring of field work of company employees. The NCUC inspection reports noted minor problems and generally commended the district office's compliance with State and Federal regulations. Both inspection reports noted, however, that Piedmont had not yet cathodically protected all street distribution lines that were installed before August 1, 1971. Under 49 CFR 192.457(b), buried steel distribution lines installed before August 1, 1971, must be cathodically protected in areas of active corrosion.

Enforcement and Compliance with Federal Regulations

Cathodic Protection.--With the implementation of new pipeline safety regulations in 1971, the NCUC asked operators in August 1972 to submit their plans for complying with the cathodic protection requirements for pipelines installed before August 1, 1971. Piedmont complied with the NCUC request in September 1972. Piedmont received no response from the NCUC about its plan and assumed that it was acceptable to the NCUC. In September 1975, at a seminar sponsored by the NCUC, comments by a DOT official suggested that Piedmont's plan did not meet the intent of the Federal regulations. Between September 1975 and March 1976, Piedmont and the NCUC held discussions about the corrosion protection plan. In April 1976, the NCUC advised Piedmont that its original cathodic protection plan did not meet the intent of the corrosion protection requirements of 49 CFR Part 192.

On May 11, 1976, Piedmont filed a petition with the NCUC seeking a waiver of the requirements of 49 CFR 192.457(b), which then required buried pipelines installed before August 1, 1971, to be cathodically protected in areas of active corrosion not later than August 1, 1976. When filing the petition, Piedmont also submitted a revised corrosion protection plan that defined an area of active corrosion as one with a single corrosion leak. By defining areas of active corrosion in this manner, Piedmont estimated that 50 percent of its entire pipeline system in North Carolina would require cathodic protection. Piedmont advised the NCUC that it could not meet the August 1, 1976, deadline and requested an extension to August 1, 1979. The NCUC issued an order on June 15, 1976, granting Piedmont the 3-year extension. However, on August 13, 1976, the Office of Pipeline Safety (OPS), as part of the Research and Special Programs Administration (RSPA) of the DOT, stayed the NCUC order granting the extension, citing that Piedmont appeared not to have made an effort to meet the 1976 deadline due to a "variety of excuses, such as costs and lack of qualified personnel," and that none of the excuses justified a waiver.

Under the order dated June 15, 1976, the NCUC also required Piedmont to file a report listing its progress in achieving cathodic protection on or before September 1, 1976. The report was received by the NCUC on October 11, 1976. In an order dated March 23, 1977, the NCUC determined that Piedmont had failed to designate areas of active corrosion on pipelines installed before August 1, 1971, and to protect these pipelines by August 1, 1976. Consequently, in the March 23, 1977, order, the NCUC assessed Piedmont a $1,000 penalty for failure to comply with 49 CFR 192.457(b). The NCUC further ordered Piedmont to submit within 30 days a detailed budget, a listing of projects by district, and the proposed expenditures by year from August 1, 1976, to August 1, 1979, for the cathodic protection of 192 miles of mains in downtown service areas and 1,460 miles of mains in residential service areas. Piedmont stated that the 1,460 miles of residential mains was the total number of miles of pipeline to be under cathodic protection by August 1, 1979, rather than the number of miles to be placed under cathodic protection during the 3-year period.

Piedmont submitted a budget on May 11, 1977, that was accepted by the NCUC as meeting the conditions of the NCUC order. Under the budget, Piedmont planned to place 706 miles of distribution pipeline under cathodic protection. This included 111 miles in the Winston-Salem district. Piedmont has indicated that the distribution line along Knollwood Street was not included under this plan. As of June 30, 1979, Piedmont had protected 702 miles of pipeline, including 123 miles in the Winston-Salem district. The NCUC has stated that since the end of this 3-year period, Piedmont has cathodically protected all of its steel-coated and wrapped pipelines.

Piedmont's detection of a leak in the Knollwood Street area in October 1979 indicated this area to be one of active corrosion. Piedmont repaired the leak in February 1980. A second leak was detected in July 1984 but was not repaired until May 1988. Piedmont originally planned to place the distribution line along Knollwood Street under cathodic protection in 1985. However, the distribution line was not under cathodic protection at the time of the accident. Piedmont stated that the delays occurred because the company identified other areas as having a higher priority and, therefore, scheduled to place these areas under cathodic protection before the Knollwood Street distribution line.

Telephonic Notification.--On May 18, 1988, the Southern Regional Office of the OPS issued Piedmont a notice of probable violation and proposed civil penalty for failing to notify the DOT by telephone about the January 18, 1988, accident as required by 49 CFR 191.5. In giving notice, the OPS stated that it had reviewed the circumstances and supporting documentation involved and had decided to assess Piedmont a civil penalty of $1,000.

In a response dated June 7, Piedmont stated that on the basis of an investigation conducted by several parties shortly after the accident, the "general conclusion" was that the accident did not result from the release of gas from a pipeline as defined in 49 CFR 191.3. Piedmont's response further indicated that it had immediately notified representatives of the NCUC "who have the responsibility for investigating and administering pipeline safety rules." Piedmont stated that a company official had asked the NCUC pipeline section chief whether it was necessary to notify the DOT. Piedmont claimed that the NCUC section chief had advised that, under the circumstances, no such notice was required. Piedmont's response did not indicate the date on which Piedmont contacted the NCUC about the need to notify the DOT, about the information it had provided the NCUC on the accident, or the date the NCUC section chief had given his advice. To avoid the time and expense of a hearing, Piedmont submitted with its response a check for $500 as compromise without an admission of guilt.

In a June 24 memorandum, the chief of the Southern Region, OPS, stated that he had verified Piedmont's claim with the NCUC section chief. The memorandum advised that the NCUC section chief had indicated that, based on the information available at the time, he had told Piedmont that he did not believe it necessary to notify the NRC about the accident. Consequently, the OPS region chief recommended that Piedmont's compromise offer be returned and the case be closed by a warning letter. On August 25, the deputy chief counsel for the OPS notified Piedmont that its compromise offer had been rejected. The OPS returned the $500 submitted by Piedmont, withdrew its notice, and closed the case. In closing the case, the OPS did not offer any explanation of the reasons prompting it to take this action but simply stated that no further enforcement action was contemplated.

The OPS case file contained no other documentation indicated that the OPS had attempted to interview Piedmont officials about company policy, obtain copies of Piedmont policies, or determine when Piedmont had reason to suspect its service line was involved in the accident.

Tests and Research

The Safety Board took possession of four gas pipe specimens; three specimens were from Piedmont's service line to the Sheraton and the fourth specimen was from the gas piping system within the building. The Safety Board performed a variety of metallurgical, pressure, tensile and noise tests to assist it in determining the failure mechanisms and the most likely sequence of events leading to the explosion. Appendix B contains the details and results of these tests.

Additional Information

Gas Flow Calculations.--Calculations were made to estimate the flow rate of gas through (1) an orifice having an area equal to the combined area of the two corrosion perforations, (2) an open-ended pipe that would have occurred with the pipe disengaging from the compression coupling, and (3) a 3/8-inch stopcock valve with the plug removed. With these flow rates, the approximate time required to generate an explosive concentration of gas (5 percent by volume in air) in the boiler room and maintenance shop was then calculated. The combined volume of the boiler room and maintenance shop was estimated to be 22,960 cubic feet. Flow rates were calculated at operating line pressures of 50, 55, and 60 psig for the orifice and open-ended pipe. The flow rate through the stopcock valve was calculated at an operating pressure of 8 inches wc. To obtain the worst-case conditions, all of the gas was assumed to be drawn into the boiler room. The gas temperature was assumed to be 60° F, or standard temperature since the actual gas temperature cannot be determined. A difference of 20° F will cause a variation of less than 2 percent in the calculated values.

Gas flow rates through an orifice having the same area as the corrosion perforations ranged from 5,800 standard cubic feet per hour (scfh) at 60 psig to 5,000 scfh at 50 psig. The time to create an explosive concentration of gas in the boiler room and maintenance shop at these flow rates would be approximately 12 to 14 minutes. Gas flow rates through an open-ended, 2-inch pipe ranged from 330,000 scfh at 60 psig to 286,000 scfh at 50 psig, and would generate an explosive concentration in approximately 15 seconds. According to the calculations, the flow of gas through an orifice of equivalent area of the corrosion perforations or through the open-ended pipe occurs at sonic velocities.[2]

Flow rates through the stopcock valve ranged from 34.7 to 347 scfh, depending upon assumed friction losses. Generation of an explosive concentration at 34.7 scfh would have taken 661 hours and, at 347 scfh, 66 hours.

Forces on Compression Coupling Joint.--If the gas meter had not been supported by a pad or plate, the downstream half of the compression coupling joint would have been the primary support for all of the weight of the meter set assembly under worst-case condition. For the joint to hold, the friction force between the coupling seal and the inserted pipe would have to equal or exceed the downward weight being supported, the equivalent downward force from the gas pressure against the elbow downstream of the coupling, and any force that developed through thermal contraction of the pipe length connected to the coupling.[3] The cumulative weight of the gas meter, the regulator, the security valve, and piping that was located downstream of the compression coupling was approximately 284 pounds. The downward force of gas against the cross-sectional area of the pipe at the downstream elbow was approximately 188 pounds. Since the temperature on the day of installation is not known and the length of pipe whose contraction could exert forces on the coupling/pipe connection is very short, the force from thermal contraction is considered negligible.

[2]The sonic velocity is the maximum possible velocity of gas in a pipe.

[3]Forces from thermal contraction occur at pipe joints and fittings when the joints and fittings are exposed to temperatures that are below the temperature of the pipe at installation.

The total friction force required to support the metering equipment at the service pressure of 60 psig would be approximately 472 pounds.

ANALYSIS

The Explosion

Based on the pattern of destruction of the lobby/cafeteria building, particularly at the north end, the explosion originated in the boiler room. The gas meter and piping were exposed to the full force of the explosion because the ventilation openings for the boiler room opened directly into the pit.

The explosion occurred because natural gas accumulated in the boiler room and was ignited by one of several available sources. The Safety Board looked at four conditions that could have led to the gas leakage and explosion:

1. Gas escaped from the corroded area along the uncoated length of the service line that extended 2 inches into the north concrete wall of the pit. Prolonged corrosion had reduced the pipe wall thickness until two or more perforations of the pipe wall developed and severely weakened the pipe. Stress induced in the corroded area resulted in a catastrophic failure and the release of gas into the pit. Gas was then directed toward the boiler room by the pressure in the pipeline and drawn into the boiler room by the squirrel cage fan.

2. Gas escaped from the downstream separation of the compression coupling when the partially inserted pipe end pulled out of the coupling, or when the rubber coupling gasket lost its seal and leaked. Gas that was released into the pit was drawn into the boiler room by the squirrel cage fan.

3. Gas escaped underground from a hole caused by corrosion in the buried service line north of the building. Gas that was released through the corrosion hole migrated through the soil along the path of the service line into the pit and then was drawn into the boiler room through the squirrel cage fan.

4. The core of the stopcock valve on the 4-inch gas main in the boiler room was dislodged for unknown reasons, thereby releasing gas directly in the boiler room.

The noise levels reported by the security guard and the cafeteria janitor indicate that the leaking gas escaped under high pressure and at high velocities. Such a flow rate and noise level could be achieved only by a leak on the high-pressure system. Only gas leaking from the corroded area within the pit wall or the failed compression coupling joint could occur at sonic velocities sufficient to generate the extremely loud noise and flow rates needed to produce an explosive concentration of gas within the few minutes indicated by the witnesses. Gas leaking through the stopcock valve on the 4-inch main could not generate noise levels during tests comparable to those reported nor were the calculated flow rates through the valve sufficient to generate an explosive mixture in the time-span of interest.

Gas leaking through the corrosion hole of the buried service line also would not have generated the noise described by two witnesses. The flow rate of gas that migrated through the soil along the service line cannot be estimated with any degree of accuracy. However, the Safety Board does not believe that the flow rate into the pit from this source would have been sufficient to generate an explosive mixture in a short time and it would not have generated the noise heard by the two witnesses. Consequently, both the stopcock and the underground corrosion leak possibilities were determined not to have been the source of gas leakage that fueled the explosion.

Although the unthreaded pipe to the downstream compression coupling half had only been partially installed and was slightly offset, the physical evidence and tests support a conclusion that the coupling joint was intact when the explosion occurred. The compression coupling joint normally is the last joint to be connected during installation of the meter set. The partial insertion and the offset of the pipe in the downstream coupling half suggest that Piedmont had difficulty aligning and inserting the pipe when the meter set was installed. This evidence is supported by the markings on the unthreaded pipe end and the coupling's rubber gasket. The presence of a single distinct paint line at the insertion end of the pipe strongly indicates that the paint line marked the original insertion depth and that the pipe did not gradually pull from the coupling. The cuts and marks on the rubber coupling gasket align with the point of minimum pipe insertion in the coupling. Since the pipe was also slightly offset, the pipe end at the minimum insertion point would be pressing up and into the rubber seal. The cuts and marks could easily have been made as the pipe was inserted and the coupling nut tightened during its 1964 installation.

Also, the arc-shaped mark at the edge of the paint line on the unthreaded pipe end likely occurred when the pipe disengaged from the coupling as a result of the explosion. The downstream end of the partially inserted pipe was connected to a threaded elbow and horizontal pipe section that in turn was connected to the gas meter. Since the gas meter presented the most surface area to the force of the explosion, the net force on the meter and the horizontal pipe would have pushed them toward the north wall of the pit, generating a downward motion toward the north basement wall on the partially inserted pipe end in the coupling. The net explosive force against the meter then overcame the resistance of the coupling joint against rotation, and the unthreaded pipe end disengaged from the coupling. The arc-shaped mark on the partially inserted pipe end was made when the pipe was pressing against the coupling before the pipe disengaged from the coupling. The oval deformation of the pipe end occurred initially during the disengagement of the pipe end from the coupling. Similiar results were obtained by Dresser in its deflection tests. Additional deformation of the pipe end likely occurred when the pipe end struck another object, possibly the north wall of the pit. The abrasion marks on the flattened side of the pipe indicate the impact of the pipe occurred along the length of the pipe, including the pipe end.

While the tensile and pressure tests that were conducted on the fabricated coupling joint do not provide direct information about the partially inserted coupling joint in the pit, the tests do provide a relative comparison. The test coupling joint held a pressure that exceeded the pressure of the service line. The tensile force to pull the pipe from the test coupling was approximately 50 percent greater than the maximum calculated load that could have occurred on the actual joint from gas pressure and support of the total weight of the meter and the downstream piping.

Metallurgical examination of the crack faces of the service line at the pit wall indicated that both corrosion penetration and tensile shear overstress cracking had occurred. Since the corroded area of the service line was uncoated and exposed to the air, the corrosion was likely caused by atmospheric conditions. The corrosion also may have been aided by electrolytic action. Corrosion had severely reduced the thickness of the pipe wall over a prolonged period and had penetrated the pipe wall in at least two areas well before the explosion. Even though gas had leaked through these perforations long before the explosion occurred, the leaking gas likely migrated through the concrete wall into the pit and vented through the metal grates to the atmosphere.

The gas leak which fueled the explosion likely occurred when the corroded section of the service line catastrophically failed. When viewing the cracked and corroded area from upstream, the top half of the service line from the 10 o'clock position clockwise to the 3 o'clock position was heavily corroded and contained areas where the pipe wall had been reduced to a knife-edge. (See figure B-1, appendix B.) Since the gas meter was not supported by a firm support, such as a concrete pad, the weight of the meter was supported by the gravel bed of the pit and the ground beneath the gravel. As the ground in the pit bed settled, the support for the meter was reduced, thereby

transferring a portion of the meter's weight to the service line. Corrosion of the meter support resulted in a complete transfer of the support for the weight of the meter from the meter support plate or ground to the service line. Much of the load imposed on the service line by the weight of the meter was transferred through the piping to the horizontal piping that penetrated the pit wall. The transfer of weight to the service line induced a tensile stress in the top of the horizontal piping. The shifting of the north pit wall also may have created a downward force on the top of the service line as it came through the pit wall and induced additional tensile stresses on the top of the piping where corrosion had occurred.

Continued corrosion eventually reduced the wall thickness of the service line within the pit wall until the noncorroded thickness of the pipe wall could no longer withstand the stresses imposed by the weight of the meter and piping, the pressure of the gas against the threaded elbow, and possibly the shifting pit wall. Consequently, the service line fractured circumferentially at the top, releasing gas at 60 psig directly into the pit and the opening to the basement. The flow of gas through such a fracture would be similar to the operation of a whistle and could therefore be expected to produce a loud noise as reported by two witnesses.

When the concentration of gas reached its lower explosive limit in the boiler room and maintenance shop, one of several available sources ignited the mixture and the explosion occurred. Possible ignition sources in the boiler room include the pilot light on the operating boiler, the squirrel cage fan, the floor fan at the entrance of the boiler room, and electrical equipment in the boiler room. The force of the explosion caused the overstress cracking observed on the bottom half of the crack.

Emergency Response

The command post was established quickly and suitably identified. The incident commander took immediate control by implementing a predesignated emergency response plan that established proper communications and initiated the notification of Piedmont, the electric company, and other emergency response agencies within the Winston-Salem

Gas company personnel, although not equipped or permitted by law to respond to emergencies in the same manner as fire and police personnel, must respond expeditiously to emergencies and must be prepared to promptly initiate those actions necessary to ensure that gas is not escaping and endangering emergency response personnel or adjacent buildings. In response to this accident, the first gas company representative arrived on scene 40 minutes after the explosion, 32 minutes after the gas company was notified of the accident. Even with a representative on scene, no action was taken by the gas serviceman to stop the flow of gas, and an additional 22 minutes passed before a gas company supervisory representative arrived. Gas flow to the Sheraton was not stopped until 35 minutes after the arrival of a supervisory representative. Gas flow could have been stopped within 5 to 10 minutes after the arrival of the first gas company employee; however, almost 1 hour elapsed after the arrival of the first gas company employee and the time gas flow to the Sheraton was stopped. Piedmont's actions to stop the flow of gas to the Sheraton were not timely or expeditious. Consequently, in its coordination with local emergency response agencies for emergency preparedness and in employee training programs, Piedmont must ensure that any employee who responds to an emergency is knowledgeable of his/her responsibilities during these situations and is trained to work closely with local response agencies.

Although the incident commmander had some knowledge of the dangers of natural gas, he was not sufficiently knowledgeable about the flammability limits and migration potential of natural gas. His decision to use firefighters to check for gas odors in adjacent buildings was not prudent since the firefighters were not adequately equipped or trained to detect migrating gas. The incident commander's decision to delay gas detection tests along the service line until there was sufficient light to see the building rubble was made because he did not perceive the dangers to the firefighters

from possible gas leaks and the potential for subsequent explosions. Had the incident commander been knowledgeable of the potential dangers to firefighters, he would have recognized the importance of directing Piedmont to conduct the gas survey tests. The incident commander also would have found a way to illuminate the areas in which gas detection tests needed to be made and to satisfy his concerns for the safety of gas company personnel.

Although the incident commander knew Piedmont crews had gas detection equipment on hand, he did not direct them to conduct the surveys of the adjacent buildings. The Piedmont crews conducted these surveys because their emergency plan required it. Other than directing Piedmont to turn off the gas to the Sheraton, the incident commander did not have any other expectations of assistance Piedmont could provide. Other fire department officials, including the fire chief, indicated that the fire department's policy was to defer to the gas company in natural gas emergencies.

The fire department, when assuming control of an accident scene involving natural gas, must actively assert that control. The incident commander must be aware of the capabilities and assistance that can be provided by the gas company and other supporting agencies and organizations. The incident commander and the firefighters also must be knowledgeable about the properties of natural gas that are likely to be encountered under emergency conditions. While the incident commander should seek the advice of the gas company, the incident commander must have the proper training and knowledge to be able to actively direct the resources available in the most effective manner. If the incident commander involved in the accident had used gas company personnel more effectively, the potential exposure of firefighters and their equipment to explosive concentrations of gas would have been quickly assessed with necessary protective action taken.

Gas Meter Installation

If the gas meter had not been located in a pit that also opened directly into the boiler room, the accident likely would not have occurred. When the meter installation was designed in 1964, Piedmont recognized some danger of placing the meter in the pit by using a security valve rather than a pressure relief valve to protect against overpressurization and possible rupture of customer piping. The security valve stops the flow of gas to the customer whereas the pressure relief valve vents gas to the atmosphere. In the case of a catastrophic failure upstream of the security valve, gas would be released directly into the pit until a valve on the distribution line was closed.

Current Federal regulations, 49 CFR 192.353(b), published in 1970, require that inside meters be located in a well-ventilated place and not less than 3 feet from any source of ignition. The direct openings in the basement wall into the pit effectively placed the gas meter within the boiler room. Other than the squirrel cage fan, the gas meter and piping likely were not within 3 feet of any potential ignition source. Section 192.355(b) requires that a customer's service regulator and relief valve be located where gas from the vent can escape freely into the atmosphere and away from any opening into the building. Section 192.357(d) also requires that each regulator that might release gas in its operation be vented to the outside atmosphere.

The Safety Board recognizes that the pit and meter arrangement at the Sheraton likely satisfied both provisions. The top of the pit, being covered by a metal grate, was open to the atmosphere. Natural gas, being less dense than air, normally rises and would be expected to vent through the top of the pit, away from the ventilation openings into the boiler room. Since the squirrel cage fan was drawing air into the boiler room from the pit, sufficient dispersion of leaking gas into the atmosphere is questionable at best. Consequently, the Safety Board believes that the placement of the gas meter set in a pit with openings directly to the boiler room was a poor engineering design and was inherently dangerous. The Safety Board believes that Piedmont should have recognized at the time the gas meter was installed the dangers such an arrangement presented and, therefore, should have installed the meter in a safer location.

The Safety Board commends Piedmont for surveying existing meter installations to determine the number of other meters installed in pits. Although Piedmont does not plan to relocate these meters, the Safety Board urges Piedmont to closely monitor the condition of the gas equipment at these installations and to reevaluate the location of these meters with respect to building openings.

Gas Company Operations and Maintenance Plan

Under 49 CFR 192.605, the operating and maintenance plan must include, in part, instructions for employees covering operating and maintenance procedures during normal operations and repairs. The engineering letters that serve as Piedmont's Operations and Maintenance Plan offer little in the way of guidance to the district's employees. The engineering letters tend to delegate responsibilities to the districts and departments within the general office and to itemize specific tasks to be performed; but they frequently do not detail how a task should be performed, nor do they specify the criteria to complete the task. Consequently, the Board does not believe that the engineering letters meet the requirements of 49 CFR 192.605.

For those engineering letters that are reproductions of the Federal regulations without clarifying comments, such as those for atmospheric corrosion, the districts are left to develop their own individual interpretations and plans for implementation. Although Piedmont has indicated that such regulatory provisions are sufficiently clear and do not require any comment, the absence of any guidance from the general office can easily lead to many different interpretations and a lack of consistency among the districts, or even to ignoring a particular provision.

Maintenance and Inspection of Meter Sets

The maintenance crews, meter "prover" test crew, and the meter reader all had entered the pit between May 1986 and December 1987 but had failed to observe and note conditions within the pit that affected the gas piping and equipment. Although the steel reinforcing plate and channel beam had not yet been installed in May 1986, the deterioration of the north pit wall should have been apparent to the meter test crew conducting the prover tests. Two annual maintenance inspections were conducted after the steel plate to reinforce the north pit wall had been installed in July 1986. Yet neither maintenance report sheet had any notations about the steel plate, the channel beam extending directly over the gas meter, or the condition of the north wall of the pit. The maintenance crews apparently did not question why the plate was installed, did not inspect the condition of the pit to determine if Piedmont equipment was affected, and did not report the presence of the plate to anyone in the district office.

Despite the meter reader being the one employee who entered the pit at regular intervals, he had little awareness of the conditions of the pit. He was aware of the channel beam only because it interfered with reading the meter. He too did not recognize the possibility that gas piping might be adversely affected by the crumbling wall.

The failure of these employees to observe and recognize conditions that adversely affected the gas piping constitute serious deficiencies in Piedmont's maintenance and inspection program. If these employees had reported the conditions to a supervisor, a thorough followup inspection of the pit likely would have uncovered the corroding area of the service line at the pit wall and the accident could have been prevented.

Corrosion and Leakage Programs

Although the corrosion control and leakage survey programs are the responsibility of the Corrosion and Leakage Department in the general office, the two programs are independently run without any meaningful coordination, analysis, or oversight. The Corrosion and Leakage

Department has implemented effective data collection and recordkeeping practices, relying heavily on computerized records. The department, however, has not been innovative in utilizing this capability to analyze the data and to evaluate the effectiveness of the cathodic protection and leakage survey programs. For example, the department does not routinely evaluate leakage survey results for cathodically protected pipe as a check on the effectiveness of the cathodic protection for the pipe. Similarly, the department does not use substandard pipe-to-soil potential readings to identify areas that may have inadequate cathodic protection and, therefore, may be more susceptible to leakage.

While the Corrosion and Leakage Department has responsibility for the corrosion and leakage programs, it has not initiated a structured oversight program that has well-defined procedures and objectives. Although Piedmont has defined categories of service areas and corresponding leakage survey frequencies, the Corrosion and Leakage Department does not routinely review the service area classifications of each district to confirm that service areas are being properly and consistently classified. The department has not developed written procedures that delineate the responsibilities of the leak technicians and the district superintendents concerning the classification of service areas. In the absence of written procedures, there is no guidance to resolve differences in evaluations between the district superintendent and the leak technician.

There is no mechanism currently in place that enables the Corrosion and Leakage Department to follow up on repairs made to reported leaks. Although the department receives a report of leak repairs from each district, the department does not, as a matter of practice, have the leak technicians spot-check repairs. The department does not have a program in place to ensure that district servicemen who conduct leak tests on repairs are qualified and performing satisfactorily. While the department has an effective program for reporting leaks, the department has not effectively initiated measures to determine that leaks have been repaired.

The department exercises even less oversight for the cathodic protection program. Corporate management has determined that cathodic protection programs, from supervision of the corrosion technicians to estimating budgets, should be the responsibility of the district superintendents. With the exception of reviewing each district's budget and notifying the districts monthly of the test points to be checked, the Corrosion and Leakage Department has no assigned role in the districts' performance of corrosion protection. To provide effective oversight of the cathodic protection program, the department should establish written criteria for selecting test points, their number, and designating the points for testing each year. The department should evaluate test readings taken over a period of time to assess the effectiveness of the cathodic protection programs within each district. The department should monitor the performance of the corrosion technicians and the districts to enhance the effectiveness of the program.

Piedmont does not have an effective atmospheric corrosion control program. Its traditional approach to atmospheric corrosion control has been to paint exposed piping and equipment on an as-needed basis. Without a structured program, Piedmont's current approach is not sufficient. The lack of a structured and well-defined atmospheric corrosion program led to the difference of expectations between the general office and the Winston-Salem district office manager regarding the use of meter readers to inspect for atmospheric corrosion. Since the accident, Piedmont has indicated that meter readers have been instructed to inspect for atmospheric corrosion. However, without well-defined goals and objectives and adequate training for meter readers, the fundamental problem remains.

Employee Training and Qualification

Technical training of employees, both for initial qualification and recurrent training, is conducted using technical schools, consultant-prepared short courses, in-house training lectures, video tapes, and on-the-job training (OJT). The designation of a training manager in the general

office and the formation of a joint management/union committee to formulate and maintain an employee training program are positive indications of Piedmont's efforts. Although resources and the organizational structure apparently exist for a coordinated training effort, the lack of written policy regarding training goals and training needs has compromised to a considerable extent several aspects of Piedmont's training efforts. Other than the apprenticeship program for entry level service department employees, training goals and needs have not been defined.

Among the shortcomings observed by the Safety Board was the lack of continuity and purpose to the different training programs. With the exception of the apprenticeship program for entry-level service employees, the overall training program uses several types of educational and training resources without discernible reasons for their selection or implementation. For example, position descriptions for nonunion employees do not specify training and education qualifications, nor is that information otherwise available. Consequently, there is no apparent effort to schedule training to meet initial qualifications or to maintain current qualifications. Training for the leak and corrosion technicians is often left solely to the initiative of the employee. For union employees, there has been no corporate assessment of the training needs of union employees beyond the apprenticeship program. Although training lectures about the engineering letters, Federal regulations, new equipment, and safety practices are given to union employees, there is no discernable indication that the company coordinates the lecture content, documents the information discussed, or provides followup for absent employees. The training lectures may be used for certain training areas, but the lack of written direction undermines their usefulness.

Piedmont also has not made a concerted effort to assess the effectiveness of the training offered. The company conducts mock emergency drills in each district to evaluate the emergency response performance of the district operations department. However, the drills could be more realistic if they were conducted at times other than normal business hours and if municipal emergency response agencies participated. Graded examinations were given for certain technical courses; however, minimum passing grades were not normally required or expected. The effectiveness and benefits of other types of training have not been evaluated in a systematic manner, such as in terms of improved employee performance or system operations.

The principal qualification and training for union employees is OJT. Although extensive use of this method is not unusual in the pipeline and natural gas industries, the Safety Board has pointed out in other accidents [4] that reliance on OJT has shortcomings for preparing employees to deal with emergencies and for ensuring standardization in the level of knowledge or work skills among employees. This is not to say that OJT does not have a useful place in a comprehensive training program. OJT, as conducted in the apprenticeship program, permits entry level service employees to learn about more advanced jobs while earning basic pay and serving as productive employees for the company. OJT included in a program for training of more advanced employees, including nonunion employees, is a valuable method to assure site-specific knowledge of an installation. However, the Safety Board is concerned that the OJT practices at Piedmont have been used in place of other training activities that are less dependent upon low employee turnover for effectiveness. The Safety Board also is concerned that the lack of written goals and objectives for the OJT program does not identify performance standards for the employee and does not otherwise promote a consistent level of performance throughout the company. The success of Piedmont's current OJT program requires the retention of key personnel, something that Piedmont so far has been able to do.

Piedmont's use of outside schools and consultants offers the potential to improve significantly the effectiveness of employees when general education can upgrade work performance. This

[4] Pipeline Accident Reports--*Lonestar Gas Company Gas Explosion and Fire, Fort Worth, Texas, March 12, 1986* (NTSB/PAR-87/03); and *Williams Pipeline Company, Liquid Pipeline Rupture and Fire, Mounds View, Minnesota, July 8, 1986* (NTSB/PAR-87/02).

potential cannot be fully realized until Piedmont's management provides a systematic plan to guide the use of these outside resources. Ideally, the plan should correlate the subject matter of these instructional resources with the specific technical work and task needs of employees.

Effective training practices normally use motivational factors that were not present in the video training tapes about the engineering letters. This training could be improved by using imaginative production techniques and "motivational events" that maintain active participation on the part of the trainee.[5] The video training tapes do not include intrinsic methods to stimulate the employee's interest in learning solely from the materials themselves. Any viewer motivation to study and learn would have to result from company motivation and advancement policy or from direction by supervisors.

Although Piedmont has attempted to implement an active training program, the company's efforts have been compromised through a failure to integrate the elements of its training activities. First and foremost, the company has not identified initial qualifications and recurrent training needs for its employees. Consequently, the training program cannot be directed systematically to the needs of individual employees. Secondly, without written and structured employee performance standards, Piedmont has no means of evaluating the effectiveness of the training as it is used on the job. Therefore, the Safety Board is concerned that the company has not demonstrated enough familiarity with basic training principles.

Gas Company Liaison with the Fire Department

Although Piedmont has made a concerted effort to offer training to the Winston-Salem Fire Department and other fire departments within the company's operating area, the training has emphasized the properties and hazards of natural gas. While the training has provided important information, it has not educated the fire departments about the capabilities Piedmont can provide in pipeline emergencies. To establish proper liaison with public officials, operators need to identify and explain what specialized equipment and expertise their personnel can provide in emergency situations. Pipeline operators also need to determine what fire department officials view as important for firefighters to know. Pipeline operators and public officials will only then be able to know and expect what the other can provide in emergency situations.

Beyond providing the basic information about natural gas, Piedmont did not ensure that the Winston-Salem Fire Department knew and understood what capabilities Piedmont could provide. Had Piedmont done so, it is unlikely the incident commander would have used firefighters to survey adjacent buildings for gas or delayed the gas detection tests along the service line.

The Safety Board has issued numerous recommendations urging training of emergency responders and greater coordination between pipeline operators and emergency response agencies. Most recently, as a result of its investigation of a natural gas explosion and fire at Sharpsville, Pennsylvania, on February 22, 1985,[6] the Safety Board recommended that the American Society of Mechanical Engineers Gas Piping Standards Committee (ASME) and the American Petroleum Institute (API):

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[5]Schneider, W., "Training High-Performance Skill: Fallacies and Guidelines," *Human Factors*, 1985, pp. 285-300.

[6]Pipeline Accident Report--*Natural Fuel Gas Pipeline Company, Natural Gas Explosion and Fire, Sharpsville, Pennsylvania, February 22, 1985* (NTSB/PAR-85/2).

P-85-32

> Develop, in coordination with national associations of emergency response agencies, guidelines for operators of pipelines describing the circumstances under which local emergency response agencies should be called to respond to pipeline emergencies and to take initial lifesaving measures, and describing the type and extent of training that should be provided to local emergency response agencies as first responders to pipeline emergencies.

A corresponding recommendation (P-85-33) to the International Association of Fire Chiefs, Inc., the International Society of Chiefs of Police, and the International Society of Fire Service Instructors recommended that they cooperate with the ASME and the API in the development of these guidelines. All recipients have expressed a willingness to cooperate in the development of guidelines. However, the ASME and API have not yet met with or solicited information from the emergency response associations. The Safety Board is concerned that the joint efforts envisioned by these recommendations has not proceeded as quickly as the Board had hoped. While the Board is currently holding the recommendations in an "Open--Acceptable Action" status, the Board is again urging the ASME and API to commit the necessary resources to fulfill the objective of the Board's recommendations.

Notification Actions of Gas Company

Piedmont has contended that it did not report the accident earlier than March 1 to OPS because the investigation by the Winston-Salem Fire Marshal's Office determined the source of gas to be within the basement, as announced on January 27. Since gas leaking from piping within the basement would not be within the jurisdiction of Federal regulation, Piedmont concluded that this accident was not a reportable incident under 49 CFR 191.3 and that there was no need to comply with the telephonic notification requirements of 49 CFR 191.5. A reportable incident is defined under 49 CFR 191.3 as "an event that involves a release of gas from a pipeline" and other specified criteria, including estimated property damage of $50,000 or more. According to Piedmont's interpretation, telephonic notification is not required unless the operator has determined that the release of gas from a regulated pipeline caused the injury, fatality, or property damage. However, Piedmont's interpretation is inconsistent with longstanding policy of the OPS and its predecessor, the Office of Pipeline Operations (OPSO). The OPSO stated in Advisory Bulletin No. 77-3 dated March 1977:

> Although information provided in a telephonic notice may be relevant to determining fault of the leak . . ., the act of giving notice merely indicates that an accident occurred and a gas leak may have been involved.

In Advisory Bulletin No. 77-6, dated June 1977, the OPSO further stated :

> It is necessary that telephonic notice of leaks . . . be made promptly in order to determine the need for an investigation in a timely manner . . . OPSO recognizes that information available during the early stages of an accident may not be complete and that specific cause of the leak may not be known. However, the telephonic notice should be made if there is reason to believe that gas is involved.

The telephonic notification requirements are intended to facilitate timely investigations for the protection of persons and property. The interpretation offered by Piedmont does not facilitate the investigative process, but in fact requires an investigation to simply determine whether an accident meets the definition of a reportable incident. Since the advisory bulletins were mailed to all

pipeline operators and certified State enforcement agencies, Piedmont, as a responsible operator, should have been knowledgeable of the interpretations.

Additionally, several facts should have caused Piedmont to suspect that gas had been released from the service line. The platoon supervisor from engine company 7 was able to hear a loud hissing noise over the noise of the diesel engine on his truck even though a Piedmont employee stated that he could not hear anything when standing 15 feet from the pit. This same Piedmont employee also obtained the one positive gas reading when conducting the bar-hole tests. Despite that a second reading was taken immediately without gas being detected, the fact that one positive reading was obtained after the gas had been off for 3 1/2 hours at a location nearly 90 feet from the pit should have caused Piedmont to question how and why the one positive reading occurred. With the recovery of the gas meter on January 21 and examination of the pit, Piedmont knew that the service line in the pit had ruptured. During testing of the security valve on January 27, a comment made by a Piedmont serviceman about recording a decrease of 2 psi in the gas pressure for the distribution line between 2:30 a.m. and 4 a.m. is another indication that Piedmont was aware of a problem on the gas system. Certainly with the discovery of the corroded section of the service line in the pit on February 1, Piedmont must have recognized the corroded service line as a possible source of the leak and should have made the proper telephonic notification.

The Safety Board believes that notwithstanding Piedmont's inconsistent interpretation of the definition for reportable incident, Piedmont had sufficient information on the day of the accident to strongly indicate that the incident should be reported. The positive bar-hole test reading indicated a leak and should have prompted Piedmont to conduct more extensive testing. With the subsequent recovery of the gas meter, regulator, and particularly the cracked and corroded section of the service line, Piedmont had very strong evidence that a reportable incident occurred and yet did not make the proper notification. The Board believes that an operator should provide telephonic notification if there is the slightest possibility that an accident meets the definition of a reportable incident, one that involves the release of gas.

DOT Pipeline Safety Program

Employee Training and Qualification.--The lack of a focused and effective program to establish minimum qualifications and training for Piedmont's employees contributed to the events leading to this accident. The failure of pipeline operators to develop and conduct training programs to qualify their employees has been a long-standing problem. From 1971 through 1986, the Safety Board has investigated 18 major pipeline accidents in which inadequate employee training contributed to the accident.

In 1985 and 1986, the Safety Board investigated two pipeline ruptures experienced by the same operator, the first in Beaumont, Kentucky, and the second in Lancaster, Kentucky.[7] As a result of its findings in these accidents, the Safety Board recommended that RSPA:

> P-87-2
>
> Amend 49 CFR Parts 192 and 195 to require that operators of pipelines develop and conduct selection, training, and testing programs to annually qualify employees for correctly carrying out each assigned responsibility which is necessary for complying with 49 CFR Parts 192 or 195 as appropriate.

[7]Pipeline Accident Report--*Texas Eastern Gas Pipeline Company Ruptures and Fires at Beaumont, Kentucky, on April 17, 1985, and Lancaster, Kentucky on February 21, 1986* (NTSB/PAR-87/1).

In response to the recommendation, the OPS published an Advanced Notice of Proposed Rulemaking (ANPRM), Docket Number PS-94, Pipeline Operator Qualifications, on March 23, 1987. In its comments, dated May 14, 1987, to the ANPRM, the Safety Board expressed:

> Incorrect human performance has already caused or contributed to the severity of many pipeline accidents with most of the errors involved being linked to inadequate training by operators. Today, pipeline operators are reducing the number of experienced personnel they employ as a part of their overall effort for reducing operating costs, and less experienced personnel are now responsible for more of the decision making and supervisory workload. Consequently, it is imperative that the Office of Pipeline Safety require operators to develop, through job/task analyses, employee qualifications for all activities addressed by the regulations, that employees be trained in the proper performance of assigned tasks, and that employees be periodically tested to demonstrate that they understand and are able to perform their assigned responsibilities."

The OPS has indicated that a Notice of Proposed Rulemaking will be published in the fall of 1988. The Safety Board classified Safety Recommendation P-87-2 as "Open--Acceptable Action."

The absence of definitive employee qualifications and evaluation of employee performance within Piedmont contributed to this accident and underscores once again the urgent need for the OPS to establish effective training and evaluation standards for both liquid and gas pipeline operators.

NCUC Enforcement Capabilities.--Although the section appears to have sufficient staff to inspect and monitor normal pipeline operations in the State of North Carolina, the Safety Board is concerned that NCUC inspectors are working at their maximum capabilities. However, any unanticipated situation, such as a major accident investigation workload, that removes an inspector from his assigned field work will adversely affect the pipeline safety program. Consequently, the NCUC should reevaluate the staffing levels of the Pipeline Safety Section not only on the basis of normal inspection activities, but also on the basis of other activities, such as investigations, training, and special enforcement actions requiring additional monitoring of an operator.

Compliance with Federal Regulations--The NCUC and the OPS have not taken sufficient enforcement actions against Piedmont to ensure its compliance with the corrosion protection and telephonic notification requirements. When the Federal safety standards for gas pipelines became effective in 1971, operators were given 5 years to place pipelines in areas of active corrosion under cathodic protection. The NCUC properly took action in the early 1970s to review the corrosion protection plans for the operators in the State. However, the NCUC failed to advise Piedmont in a timely manner of the inadequacies in its corrosion plan, and this left the company in a difficult position. Although Piedmont learned that its plan did not meet the intent of the regulations slightly less than a year before the compliance date, the NCUC assessed a $1,000 penalty against Piedmont for failure to designate areas of active corrosion on pipelines installed before August 1, 1971, and failure to place these pipelines under cathodic protection by August 1, 1976. Despite the NCUC assessment against Piedmont in 1977, Piedmont still had not satisfied the corrosion protection requirements when the accident occurred. Over 8 years had passed from the detection of the 1979 corrosion leak on the section of distribution line including Knollwood Street until it was completely under cathodic protection by March 1988. The detection of a second leak in 1984 apparently did not cause Piedmont to reassess its priorities to place the distribution line under cathodic protection more promptly. Recognizing that nearly 12 years had passed since the initial deadline for compliance with these requirements, the Safety Board does not believe that Piedmont has made an adequate effort to comply with the corrosion protection requirements.

The NCUC, knowing the historical problems Piedmont has had with complying with corrosion protection standards, should have continued to monitor its progress closely beyond 1979. Although the NCUC noted in its inspection reports for 1986 and 1987 of the Winston-Salem district that Piedmont had not complied with the corrosion protection requirements for all of its pipeline, the NCUC has taken no subsequent enforcement action. As a result, Piedmont has not been motivated to comply with the corrosion protection regulations in a timely manner.

Piedmont also failed to comply with the telephonic notification requirements for this accident. In response to the OPS notice of probable violation and proposed civil penalty, Piedmont claimed that it had made a good faith effort to comply with the regulations. Based on the investigation of the fire marshal and the advice given by the NCUC section chief regarding the notification of the DOT, Piedmont contended the penalty was not justified.

The decision of the OPS to close the case was apparently made after the chief of the southern regional office had verified with the NCUC section chief that Piedmont had been told that it was not necessary to notify the DOT. The OPS decision to close the case on these grounds appears to circumvent the OPS longstanding policy to pipeline operators to provide telephonic notification if there is reason to believe that gas is involved. The lack of documentation in the OPS case file also demonstrates that the OPS did not conduct a thorough investigation. While the OPS did verify that the NCUC section chief had told Piedmont that it was not necessary to contact the DOT, the OPS case file does not indicate that the OPS interviewed any Piedmont officials regarding the company's notification procedures, or that the OPS contacted other sources, such as the Winston-Salem fire marshal or the Safety Board, for information. Consequently, the Safety Board believes that the OPS not only failed to aggressively pursue this case with Piedmont to determine when Piedmont should have first suspected natural gas might be involved but that it also ignored its own policy to operators for providing telephonic notification.

The problem with operator compliance and DOT enforcement of the telephonic notification requirements is not new. As a result of its investigation of a gas explosion in Monongahela, Pennsylvania, on March 13, 1977, the Safety Board recommended that the Materials Transportation Bureau (MTB) of the DOT:

> P-77-15
>
> Enforce the notification requirements as stated in 49 CFR 191.5 in view of the continuing noncompliance of pipeline operators.

Along with the recommendation, the Board also referenced 12 other accidents that were investigated from January to July 1977 in which operators were late in providing notification. MTB's response in December 1977 indicated that enforcement actions were initiated in 7 of the 12 cases referenced by the Board. MTB also stated that it would continue to review telephonic reports for compliance, determine if more definitive requirements were needed, and clarify the intent of the existing requirements through its advisory bulletins to operators and industry associations. The Board classified Safety Recommendation P-77-15 as "Closed--Acceptable Action."

As a result of its investigation of the explosion and fire at Cordele, Georgia, on February 21, 1980,[8] the Safety Board recommended that the American Gas Association and the American Public Gas Association:

[8]Pipeline Accident Report--*Municipal Gas Department of Cordele, Georgia, Explosion and Fire, at Cordele, Georgia, February 21, 1980* (NTSB/PAR-80/5).

P-80-43

> Notify its members systems of the known particulars of the Cordele, Georgia, accident and report and advise them to review 49 CFR 191.5, Telephonic Reporting of Leaks, Accidents, and Other Related Failures, to ensure that appropriate instructions have been issued to their employees regarding the reporting requirements.

The American Gas Association, of which Piedmont is a member, notified its member companies of the accident and the recommendation. The American Public Gas Association forwarded copies of the Board's report and recommendation to all publicly owned distribution systems in the United States. The Board has classified Safety Recommendation P-80-43 as "Closed--Acceptable Action."

As a result of the posture of both the NCUC and the OPS in these instances, there is little reason for pipeline operators to be concerned about the possibility of strong sanctions for failing to comply with Federal regulations. Consequently, a pipeline operator may be more inclined to ignore those regulations that it finds costly or inconvenient. The Safety Board has previously addressed this issue in its investigation of the pipeline rupture in Mounds View, Minnesota,[9] by stating:

> The manner in which the OPS has used its sanctions has been insufficient to motivate compliance with pipeline safety regulations. For any regulatory program to be effective, it must have and use sanctions designed to motivate compliance.

Consequently, the Safety Board recommended that the OPS:

P-87-21

> Increase the use of sanctions which reflect the gravity of the violation and the operator's compliance history as a means for motivating operator compliance with Federal pipeline safety standards.

On May 9, 1988, the RSPA responded to the Board's recommendation and indicated that it had reviewed its Part 190 enforcement procedures and had requested that Congress amend the limitations on civil penalties. The Board believes that the RSPA currently has the authority to fit proper and reasonable sanctions to violations and the Board is concerned that RSPA's use of existing authority could be more aggressive. In urging the RSPA to look further at its ability to levy sanctions as the violations warrant, the Board classified Safety Recommendation P-87-21 as "Open--Unacceptable Action."

Since the NCUC has been certified by the DOT to enforce the gas pipeline safety regulations within North Carolina, the DOT has the responsibility to insure that certified State agencies are using enforcement authority effectively in obtaining compliance with Federal safety standards.

[9]Pipeline Accident Report--NTSB/PAR-87/02.

CONCLUSIONS

Findings

1. Gas which fueled the explosion escaped from the corroded section of the horizontal service line enclosed within the north pit wall.

2. Corrosion of the service line likely was caused by atmospheric conditions and may have been aided by electrolytic action.

3. Corrosion severly reduced the wall thickness of the service line over time and penetrated the service line in at least two small areas which leaked long before final failure.

4. Gas escaping from the corrosion holes in the service line entered the pit through the cracked pit wall and most, if not all, vented safely to the atmosphere through the grate on top of the pit.

5. The bed of the pit settled over time, which caused the transfer of the gas meter's weight to the service line and the introduction of stresses in the service line.

6. Continued settlement of the pit bed resulted in the complete transfer of the weight of the meter to the service line.

7. Much of the load imposed on the service line by the weight of the meter was transferred through the service line to the horizontal section that penetrated the pit wall.

8. Inward shifting of the north pit wall likely induced stresses in the horizontal section of the service line which exited the north pit wall.

9. Continued corrosion reduced the wall thickness of the service line segment within the pit wall until it could no longer withstand the stresses imposed by the weight of the meter, the pressure of the gas, and the shifting of the north pit wall.

10. The service line failed at the top of the pipe from overstress fractures in an area of heavy corrosion and reduced wall thickness.

11. The larger quantity of gas escaping under about 60 psig from the fractured pipe was blown into the pit and into the openings of the building's basement.

12. When quantities of gas sufficient to create an explosive mixture had entered the boiler and maintenance shop rooms, one of several available sources ignited the mixture.

13. The incident commander's failure to use gas company personnel to survey the surrounding area and buildings for natural gas and his decision to delay gas company personnel from conducting gas detection tests along the service line potentially exposed firefighters and equipment to explosive pockets of natural gas.

14. Piedmont did not provide timely notification to the National Response Center of the gas accident as required by 49 CFR section 191.5.

15. Piedmont failed to fully recognize at the time the meter set was installed at the Sheraton the dangers of placing the meter in the pit and the need to relocate the meter to a safer location.

16. Piedmont's engineering letters do not provide adequate guidance to company personnel and do not meet the intent of 49 CFR 192.605 for Operating and Maintenance Plans.

17. Oversight, accountability, and evaluation within Piedmont's general office and its district offices are not well-defined and delineated for inspection of meter sets, corrosion control, leakage surveillance, and atmospheric corrosion of exposed piping.

18. Piedmont does not have an adequate program for detecting and controlling atmospheric corrosion.

19. By failing to identify initial qualifications and recurrent training needs for its employees, Piedmont does not have a focused and effective training program.

20. Piedmont's existing training procedures do not evaluate the effectiveness of its training program, and Piedmont does not systematically schedule and plan that training.

21. Employee training at Piedmont has been fragmented by not integrating training efforts with training goals.

22. Meter readers were not trained to observe and recognize conditions that adversely affect the safe operation of gas company equipment.

23. Although Piedmont depends on on-the-job training for service employees, the company does not have formal or written procedures to ensure the employee knows what is expected and that the employee is meeting those expectations.

24. Piedmont's efforts to establish and maintain liaison with the Winston-Salem Fire Department did not adequately acquaint the fire department with Piedmont's abilities to assist in a natural gas incident as required under 49 CFR 192.615(c).

25. The North Carolina Utilities Commission's pipeline safety program only has sufficient staff to meet the normal operational responsibilities of the pipeline safety program.

26. The North Carolina Utilities Commission has not used enforcement sanctions effectively to motivate Piedmont to comply with Federal pipeline safety standards.

27. The Office of Pipeline Safety withdrew an enforcement action against Piedmont Natural Gas Company without sufficient investigation and cause.

28. RSPA, while having the authority to impose proper and reasonable sanctions, is not aggressively exercising its authority to levy effective and meaningful sanctions against pipeline operators.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the natural gas explosion was corrosion failure of the gas service pipeline at the north wall of the meter pit. Contributing to the explosion was the placement of the gas meter and piping in a pit that had direct openings into the building's boiler room. Contributing to the corrosion failure of the service line was the failure of the gas company to provide adequate direction and training for its inspectors to recognize conditions that adversely affected gas company equipment.

RECOMMENDATIONS

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

--to Piedmont Natural Gas Company:

Relocate gas meters installed in pits that are adjacent to building openings. (Class II, Priority Action) (P-88-4)

Develop comprehensive operating and maintenance procedures that define employee responsibility, accountability, evaluation, and coordination for: inspection and maintenance of meter sets and corrosion control, leakage surveillance, and atmospheric corrosion control programs. (Class II, Longer Term Action) (P-88-5)

Develop written operational policy and objectives for employee training. (Class II, Priority Action) (P-88-6)

Conduct a review of all existing training and, consistent with established training policy and objectives, develop and implement training programs that enable employees to correctly carry out each assigned responsibility which is necessary to comply with the requirements of 49 CFR Part 192. (Class II, Priority Action) (P-88-7)

Develop and coordinate emergency response preparedness plans with local emergency response agencies that identify the capabilities to the gas company to assist in an incident that involves natural gas. (Class II, Priority Action) (P-88-8)

Revise emergency action plans to include Federal notification procedures for incidents that involve releases of natural gas and that meet U.S. Department of Transportation criteria. (Class II, Priority Action) (P-88-9)

--to the city of Winston-Salem:

Develop and coordinate emergency response preparedness plans with local gas company officials to identify and fulfill the knowledge and training needs of the emergency response agencies for incidents that involve natural gas. (Class II, Priority Action) (P-88-10)

--to the North Carolina Utilities Commission:

Increase the staffing level of the Pipeline Safety Section to provide sufficient resources for responding to responsibilities beyond programmed inspection activities. (Class II, Priority Action) (P-88-11)

Review its use of sanctions against noncomplying gas operators to ensure that its sanctions reflect the gravity of the violation and the operator's compliance history as a means for motivating operator compliance with Federal and State pipeline safety standards. (Class II, Priority Action) (P-88-12)

--to the Research and Special Programs Administration:

Monitor the staffing levels of the certified State pipeline inspection agencies and require staffing level increases sufficient to respond to responsibilities beyond programmed inspection activities. (Class II, Priority Action) (P-88-13)

--to the American Gas Association:

Notify member companies of the circumstances of the natural gas explosion in Winston-Salem, North Carolina, on January 18, 1988, and recommend that each company survey existing gas meter installations and relocate those that are in pits adjacent to building openings. (Class II, Priority Action) (P-88-14)

In addition, the Safety Board reiterated the following safety recommendations:

--to the American Society of Mechanical Engineers Piping Standards Committee and the American Petroleum Institute:

Develop in coordination with national associations of emergency response agencies, guidelines for operators of pipelines describing the circumstance under which local emergency response agencies should be called to respond to pipeline emergencies and to take initial lifesaving measures, and describing the type and extent of training that should be provided to local emergency response agencies as first responders to pipeline emergencies. (P-85-32)

--to the Research and Special Programs Administration:

Increase the use of sanctions which reflect the gravity of the violation and the operator's compliance history as a means for motivating operator compliance with Federal pipeline safety standards. (P-87-21)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ James L. Kolstad
Acting Chairman

/s/ Jim Burnett
Member

/s/ John K. Lauber
Member

/s/ Joseph T. Nall
Member

/s/ Lemoine Dickinson, Jr.
Member

James L. Kolstad, Acting Chairman, dissented on the probable cause.

October 25, 1988

APPENDIXES

APPENDIX A

INVESTIGATION

1. The National Transportation Safety Board was notified of the accident at 1 p.m., on February 29, 1988, by a representative for Travco Hotels, Inc., who was inquiring about the status of the Board's investigation. The Board received notification of the accident through the National Response Center in Washington, D.C., on March 1, 1988. Two investigators from the Safety Board's Washington, D.C., headquarters conducted the initial on-site investigation on March 10-11, 1988.

2. Parties to the investigation were the Piedmont Natural Gas Company, the North Carolina Utilities Commission, the City of Winston-Salem, Travco Hotels, K & W Cafeterias, and Dresser Industries.

3. A staff-conducted deposition was held in Winston-Salem, North Carolina, on May 19 and 20, 1988. A technical review of the facts developed for preparation of the pipeline accident report was conducted at the Board's headquarters in Washington, D.C., on August 26, 1988; all parties to the accident investigation attended.

APPENDIX B

TESTS AND RESEARCH

Metallurgical Testing.--The following specimens were examined in the Safety Board's materials laboratory:

- Item A--a 2-inch gas service line pipe section recovered from the pit. The pipe section contained a crack in the upstream end, a deflected 90° elbow, and a Dresser Series-90 compression coupling at the downstream end;

- Item B--a 2-inch gas service line section recovered from the pit with an unthreaded end that had been separated from the compression coupling;

- Item C--three contiguous sections of the coated 2-inch gas service line that were removed from the buried service line northeast of the pit;

- Item D--a 4-inch tee with a 3/8-inch pipe and stopcock valve and plug recovered from the boiler room; and

- Item E--two flanges recovered from the pit which were similar to those used as leg supports for gas meter support plates.

Item A had been permanently deformed at the 90° elbow, bending the vertical pipe section with the compression coupling toward the north wall of the pit by approximately 20°. (See figure 5.) Deformation also occurred at the crack, resulting in the upstream pipe section bending about 13° down and 10° to the east.

All of the deformation in the horizontal pipe length of item A was localized in the area of the crack with visible deformation at the crack ends. The circumferential crack extended approximately 75 percent around the pipe. When viewed from the upstream side, the crack extended from the 10:30 o'clock position clockwise to the 6:30 o'clock position. (See figure 6.) The crack faces were separated about 0.25 inch along much of the crack length.

Severe corrosion damage to the outer surface of item A extended about 0.75 inch on both sides of the crack and had significantly reduced the pipe wall thickness. The intact area of the pipe between the crack ends exhibited only minor corrosion attack. Measurements at three positions on the crack face established that corrosion had reduced the thickness of the pipe wall by 0.06 to 0.14 inch, from a nominal wall thickness of 0.151 inch. Corrosion had thinned the pipe wall at four locations along the crack face to a knife edge. (See figure B-1.) The combined length of these four locations was approximately 50 percent of the total crack length. The remaining crack length, other than the ends of the crack, were heavily corroded and contained characteristics of tensile shear overstress. The crack ends also exhibited tensile shear overstress characteristics but were only lightly corroded.

When the crack faces were mated closely together, two areas of corrosion penetration of the pipe wall were identified. (See figure B-2.) The larger area, centered at the 3 o'clock position, was an irregularly shaped perforation approximately 0.9 inch long and having an estimated area of 0.067 square inch. The crack edges in this area had a knife edge consistent with corrosion penetration of the pipe wall. The area of the second and smaller perforation was located at the 5 o'clock position and estimated to be 0.0076 square inch.

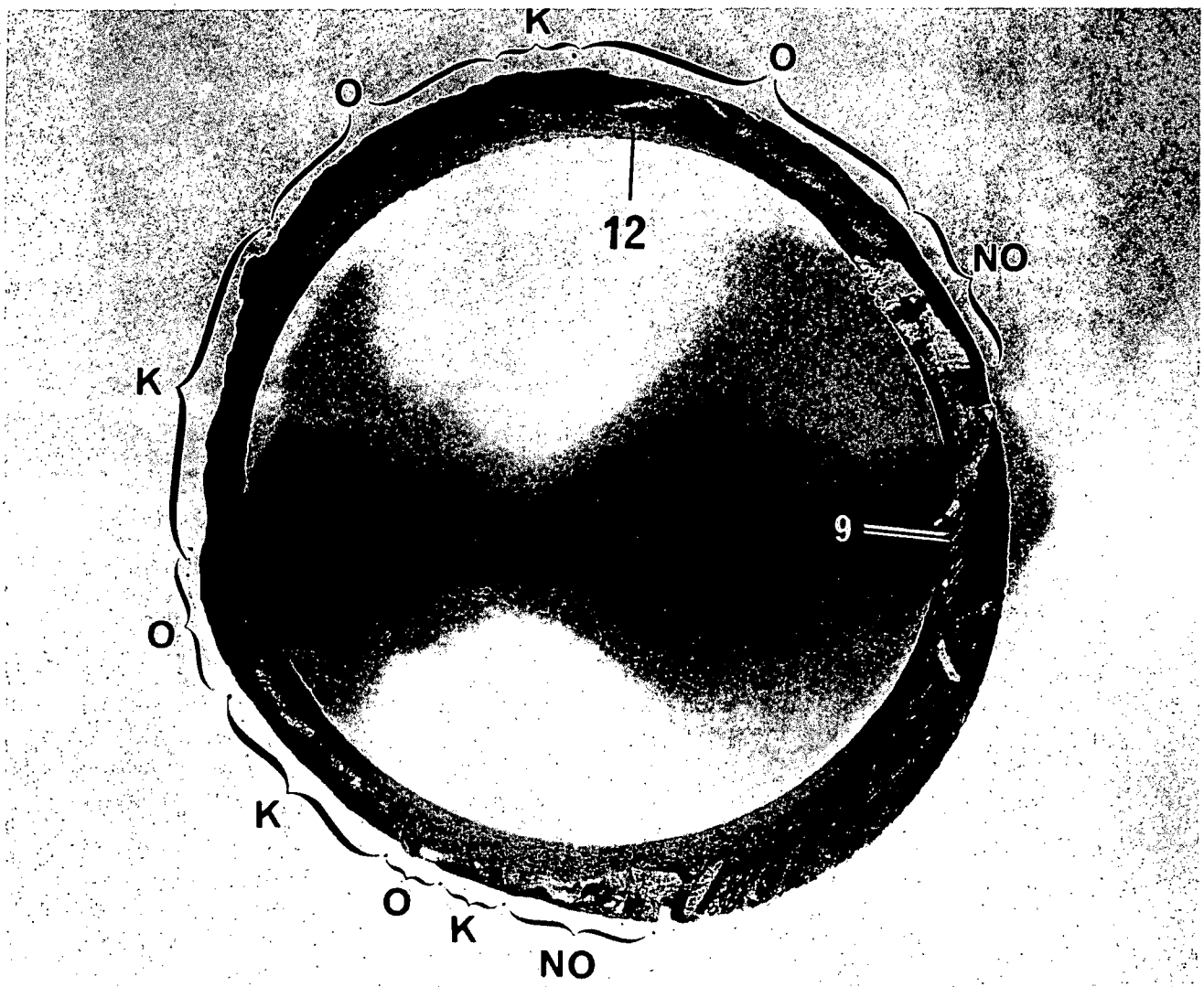

Figure B-1.--Photograph at 2X of the upstream crack face. Corrosion thinned knife edges denoted by bracket "K." Heavily corroded overstress fracture areas at bracket "O" and highly corroded overstress at bracket "NO."

Figure B-2.--Photograph of the 3 o'clock area of the crack with faces marked. Corrosion perforation at bracket "P." Arrow indicates direction of flow.

The unthreaded end of item B that had been connected to the compression coupling had a single unpainted band around the pipe end that extended downstream between 0.7 and 1.0 inch. The orientation within the pit would have the maximum width of the unpainted band approximately facing the west pit wall and the minimum width facing the east pit wall. The compression coupling's rubber-like seal that contacted the outer diameter of the inserted end of item B had two minor cuts on the inner surface. Both cuts were along a circumferential step in the seal surface with the top of the step on the upstream side. The positions of the cuts when oriented to the unthreaded end of item B were found to bracket the minimum width of the unpainted band.

An arc-shaped mark approximately 2 inches long was found on the exterior surface of item B at the edge of the paint line. The position of this mark faced the north wall of the pit. The shape, length, location, and configuration of the mark suggests that it had been made by the inner edge of the compression coupling nut contacting the surface of item B at an approximate angle of 15° between the nut and the pipe.

The end of item B which originally had been installed in the coupling was out-of-round. The flattened side of the pipe faced the north wall of the pit. Measurements of the maximum ovality of the pipe end and the inner diameter of the coupling nut established that the pipe end would not fit into the coupling in its present condition. This was further confirmed by attempts to fit the separated coupling nut onto the pipe end. An abraded/contact mark extended 18 inches down the

pipe length of item B on the flattened side and included the portion of the pipe originally inserted into the coupling.

Examination of item C, the three contiguous sections of the coated service line, indicated that the coating on the first two pieces had been gouged along a continuous line approximately 33 inches long. The gouging had completely penetrated the coating at several locations. A hole measuring 0.9 inch long and 0.6 inch wide was found in the pipe wall of the second piece at the end of the gouge. A thin flap of metal that was approximately the same size of the hole was folded inside the pipe and attached to one edge of the hole. The edges of the hole were thinned to a knife edge consistent with corrosion perforation of the pipe. Corrosion products and attack also were noted at other locations along the gouge. There was no apparent corrosion attack where the coating material was intact.

The plug from the stopcock valve of item D was fractured at the retaining nut stem at the base of the plug. The nut stem fracture face exhibited typical features of an overstress separation.

The two flanges listed in item E were severely corroded. The tubular section connected to each flange were almost completely consumed by corrosion.

Noise Tests.--A test was arranged for the 4-inch pipe with the stopcock valve to determine the noise level of air escaping through the 3/8-inch valve with the plug in the open position and with the plug completely removed. At pressures ranging from 5 to 50 psi with the valve plug inserted open and then with the plug removed, noise levels were barely audible at low pressures and did not exceed conversational speech levels at the high test pressures. Even though the air pressure was measured several feet upstream of the 3/8-inch valve, the pressure at the valve was far in excess of the normal gas pressure of 8 inches wc, or 0.29 psi.

Compression Coupling Tensile and Pressure Tests.--The upstream service line pipe/compression coupling joint, as found from the gas service line, was loaded along its longitudinal axis on a tensile machine until the inserted pipe separated from the coupling. A peak load of 2,050 pounds was required to cause the pipe to begin to move from the coupling.

Examination of the coupling gasket and pipe, after separation, revealed no obvious damage to the gasket or pipe. A light circumferential contact mark was noted on the pipe exterior surface 3/4 inch downstream of the paint line. This location was the approximate original location of the coiled wire armor on the gasket.

A compression coupling test joint was assembled from a new series 90 coupling and two new pipe sections to simulate the coupling joint in the pit as it likely existed when it was initially installed. The "upstream" pipe was inserted approximately 2 to 3 inches into the test coupling. The "downstream" pipe end was inserted to the same depth and offset angle indicated by the paint line on the actual downstream pipe. The "downstream" coupling nut was tightened by a procedure recommended by Dresser and intended to duplicate the relative positions of the accident coupling body and nut.

After the test coupling joint was sealed on both ends and the pipe segments were restrained from relative longitudinal movement, the test coupling joint held an internal pressure of 60 psig for 5 minutes without any indication of a drop in pressure or a leak at either end of the coupling. After internal pressure was increased to 65 psig, the test coupling joint again held for 5 minutes without any indication of a leak or drop in pressure.

The test coupling joint was then placed in a tensile machine and loaded as the accident coupling. During initial loading of the test coupling, the angular offset between the partially

inserted pipe and the coupling was reduced by movement of the pipe within the coupling. The peak load of 671 pounds again occurred when relative longitudinal movement was noted between the partially inserted pipe and the coupling. Inspection of the gasket after testing showed that a short length of the coiled gasket armor had been displaced toward the gasket.

Compression Coupling Deflection Tests.--Dresser conducted independent deflection tests on a fabricated series 90 compression coupling joint. Dresser reported that a 2-inch pipe was inserted to a depth of 3/4 inch at one end of the coupling. A second 2-inch pipe was fully inserted at the other end of the coupling. An unmeasured force was applied to the center of the coupling body, or perpendicular to the pipe, until the pipe disengaged from the coupling. The pipe end was flattened, resulting in an elliptical cross-section. An arc-shaped mark, similar to that found on the section of the gas service line also was imprinted about 1 inch from the pipe end. Abrasion marks at the pipe end 180° from the arc-shaped mark also were noted.

APPENDIX C

FEDERAL PIPELINE SAFETY STANDARDS

The minimum safety standards for transporting natural and other gases by pipeline are contained in 49 CFR Parts 191 and 192. The development and enforcement of these standards are the responsibility of the Office of Pipeline Safety, which is a part of the Research and Special Programs Administration of the Department of Transportation. In part, these regulations are:

191.3 defines "incident" as an event that involves a release of gas from a pipeline and results in estimated property damage of $50,000 or more.

191.5 (a) requires each operator to give notice at the earliest practicable moment following discovery of each incident defined in 191.3.

192.353 (c) requires each meter installed within a building to be located in a ventilated place and not less than 3 feet from any source of ignition.

192.355 (b) requires that a customer's service regulator vent and relief valve be located in a place where gas from the vent can escape freely into the atmosphere and away from any opening into the building.

192.357 (d) requires that each regulator that might release gas in its operation vented to the outside atmosphere.

192.457 (b) requires that each operator determine areas of active corrosion by electrical survey for bare or coated distribution lines installed before August 1, 1971.

192.479 (b) requires that for pipelines installed before August 1, 1971, each operator determine areas of atmospheric corrosion and take remedial measures, such as coating the pipe, to prevent atmospheric corrosion.

192.481 requires each operator to evaluate the condition of each on-shore pipeline exposed to the atmosphere at intervals not exceeding 3 years and to take the necessary remedial action to maintain protection against atmospheric corrosion.

192.603 (b) requires each operator to establish a written operating and maintenance plan.

192.605 (a) requires each operator to include instructions in the operating and maintenance plan that cover operating and maintenance procedures during normal operations and repairs.

192.615 (c) requires each operator to establish and maintain liaison with appropriate fire, police, and other public officials to learn the responsibility and resources of each government organization that may respond to a gas pipeline emergency, and to acquaint the officials with the operator's ability in responding to a gas pipeline emergency.

192.723 (b) requires that each operator conduct leak surveys on distribution lines in business districts not exceeding 15 months, but at least once each calendar year. Leakage surveys outside principal business areas must be made at intervals not exceeding 5 years.

APPENDIX D

MAJOR PIPELINE ACCIDENTS INVESTIGATED BY THE SAFETY BOARD CONCERNING EMPLOYEE TRAINING

Location	Date	Report No.
Pittsburgh, Pennsylvania	November 17, 1971	PAR-72-02
Clinton, Missouri	December 9, 1972	PAR-74-03
Williamsport, Pennsylvania	January 25, 1977	PAR-77-04
Independence, Kentucky	October 9, 1980	PAR-81-01
Long Beach, California	December 1, 1980	PAR-81-04
San Francisco, California	August 25, 1981	PAR-82-01
Portales, New Mexico	June 28, 1982	PAR-83-01
Hudson, Iowa	November 4, 1982	PAR-83-02
West Odessa, Texas	March 15, 1983	PAR-84-01
Bloomfield, New Mexico	May 26, 1983	PAR-83-04
Fairfax County, Virginia	October 13, 1983	PAR-84-03
South Charleston, West Virginia	October 17, 1983	PAR-84-04
Sharpsville, Pennsylvania	February 22, 1985	PAR-85-02
Beaumont, Kentucky & Lancaster, Kentucky	April 27, 1985 February 21, 1986	PAR-87-01
Kaycee, Wyoming	July 23, 1985	PAR-86-01
Derby, Connecticut	December 6, 1985	PAR-86-02
Fort Worth, Texas	March 12, 1986	PAR-87-03
Mounds View, Minnesota	July 8, 1986	PAR-87-02

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