



NATIONAL TRANSPORTATION SAFETY BOARD

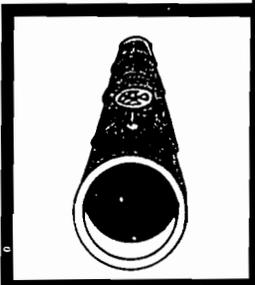
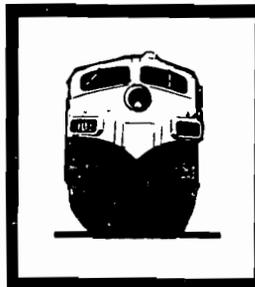
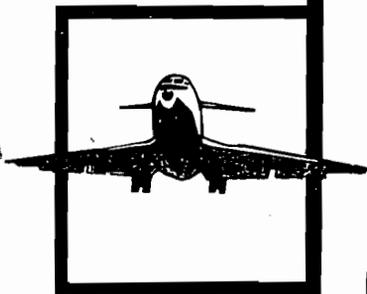
WASHINGTON, D.C. 20594

PIPELINE ACCIDENT REPORT

**UNION LIGHT, HEAT AND POWER COMPANY
NATURAL GAS EXPLOSION AND FIRE
SIMON KENTON HIGH SCHOOL
INDEPENDENCE, KENTUCKY
OCTOBER 9, 1980**

NTSB-PAR-81-1

UNITED STATES GOVERNMENT



TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB-PAR-81-1	2. Government Accession No. PB81-207102	3. Recipient's Catalog No.	
4. Title and Subtitle Pipeline Accident Report—Union Light, Heat and Power Company, Natural Gas Explosion and Fire, Simon Kenton High School, Independence, Kentucky, October 9, 1980		5. Report Date April 28, 1981	
		6. Performing Organization Code	
7. Author(s)		8. Performing Organization Report No.	
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Accident Investigation Washington, D.C. 20594		10. Work Unit No. 3096-A	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594		13. Type of Report and Period Covered Pipeline Accident Report October 9, 1980	
		14. Sponsoring Agency Code	
15. Supplementary Notes The subject report was distributed to NTSB mailing lists: 8A, 8F and 17.			
<p>About 11:55 a.m., on October 9, 1980, a 2-inch-diameter compression coupling located on the upstream side of a gas meter set assembly in the boilerroom of the Simon Kenton High School in Independence, Kentucky, pulled out of its connection with a 2-inch-diameter gas service line. Natural gas at 165-psig pressure escaped through the 2-inch-diameter opening and, seconds later, exploded and burned. A basement wall was blown down, an adjacent classroom was damaged, and one student was killed. About 30 minutes later, a second explosion occurred which injured 37 persons and extensively damaged the school. The gas service line was connected to a 4-inch-diameter gas main owned by the Union Light, Heat and Power Company, which was uprating the gas main by controlled pressure increases at the time of the accident.</p> <p>The National Transportation Safety Board determines that the probable cause of the accident was the overpressuring and ensuing separation of an unrestrained compression coupling in the school service line which allowed natural gas to escape and ignite. Inaccurate company records failed to show that the school service line was connected to a 4-inch-diameter gas main being uprated to a higher pressure system.</p> <p>Contributing to the severity of the first explosion and to the occurrence of the second explosion was the absence of an excess flow valve which would have rapidly shut off the gas flow after the pipe had separated.</p> <p>Contributing to the second explosion was the inability of the gas company personnel to rapidly locate and shut off a buried valve at the school service line connection to the gas main. The valve could not be located because its buried valve box lid was not uncovered in the course of the gas company's prior annual inspections.</p>			
17. Key Words uprating gas main; controlled pressure increases; increments; meter set assembly; meter; regulator; relief valve; compression coupling; double regulator systems; microfiche records; Lower Explosive Limit (LEL); excess flow valve; pressure chart; throttle valve; curb valve; 4-inch-diameter plug valve; boilerroom; complete shutdown; evacuation		18. Distribution Statement This document is available to the public through the National Technical Information Service-Springfield, Virginia 22161 (Always refer to number listed in item 2)	
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 38	22. Price

CONTENTS

SYNOPSIS	1
INVESTIGATION	1
The Accident	1
Events Preceding the Accident.	13
Injuries to Persons	15
Damage to Pipeline	16
Other Damage.	16
Pipeline System	16
Meteorological Information	22
Medical and Pathological Information.	22
Survival Aspects	22
Tests and Research.	22
Other Information	23
ANALYSIS	25
The Accident.	25
Curb Valve	26
Company Records	26
Compression Coupling	26
Excess Flow Valves.	27
Gas Odorization	28
Gas System Shutdown.	29
CONCLUSIONS	29
Findings	29
Probable Cause	30
RECOMMENDATIONS	30
APPENDIXES	33
Appendix A—Investigation and Hearing	33
Appendix B—Union Light, Heat and Power Company Microfiche Record	34
Appendix C—Excerpts from 49 CFR Parts 191 and 192	35
Appendix D—List of Accidents.	36

**NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594**

PIPELINE ACCIDENT REPORT

Adopted: April 28, 1981

**UNION LIGHT, HEAT AND POWER COMPANY
NATURAL GAS EXPLOSION AND FIRE
SIMON KENTON HIGH SCHOOL
INDEPENDENCE, KENTUCKY
OCTOBER 9, 1980**

SYNOPSIS

About 11:55 a.m., on October 9, 1980, a 2-inch-diameter compression coupling located on the upstream side of a gas meter set assembly in the boilerroom of the Simon Kenton High School in Independence, Kentucky, pulled out of its connection with a 2-inch-diameter gas service line. Natural gas at 165-psig pressure escaped through the 2-inch-diameter opening and, seconds later, exploded and burned. A basement wall was blown down, an adjacent classroom was damaged, and one student was killed. About 30 minutes later, a second explosion occurred, which injured 37 persons and extensively damaged the school. The gas service line was connected to a 4-inch-diameter gas main owned by the Union Light, Heat and Power Company, which was uprating the gas main by controlled pressure increases at the time of the accident.

The National Transportation Safety Board determines that the probable cause of the accident was the overpressuring and ensuing separation of an unrestrained compression coupling in the school service line which allowed natural gas to escape and ignite. Inaccurate company records failed to show that the school service line was connected to a 4-inch-diameter gas main being uprated to a higher pressure system.

Contributing to the severity of the first explosion and to the occurrence of the second explosion was the absence of an excess flow valve which would have rapidly shut off the gas flow after the pipe had separated.

Contributing to the second explosion was the inability of the gas company personnel to rapidly locate and shut off a buried valve at the school service line connection to the gas main. The valve could not be located because its buried valve box lid was not uncovered in the course of the gas company's prior annual inspections.

INVESTIGATION

The Accident

On the morning of October 9, 1980, employees of the Union Light, Heat and Power Company (gas company) were uprating 1/ a 4-inch-diameter gas main from the gas system's station 123 to station 264 in Independence, Kentucky. (See figure 1.) The gas main's operating pressure was being increased from 60 to 200 psig in increments of

1/ "Uprating" means to qualify a gas facility for a new, higher operating pressure, usually by increasing the pressure in increments and checking for leakage at each step, before operating the facility at the new higher pressure.

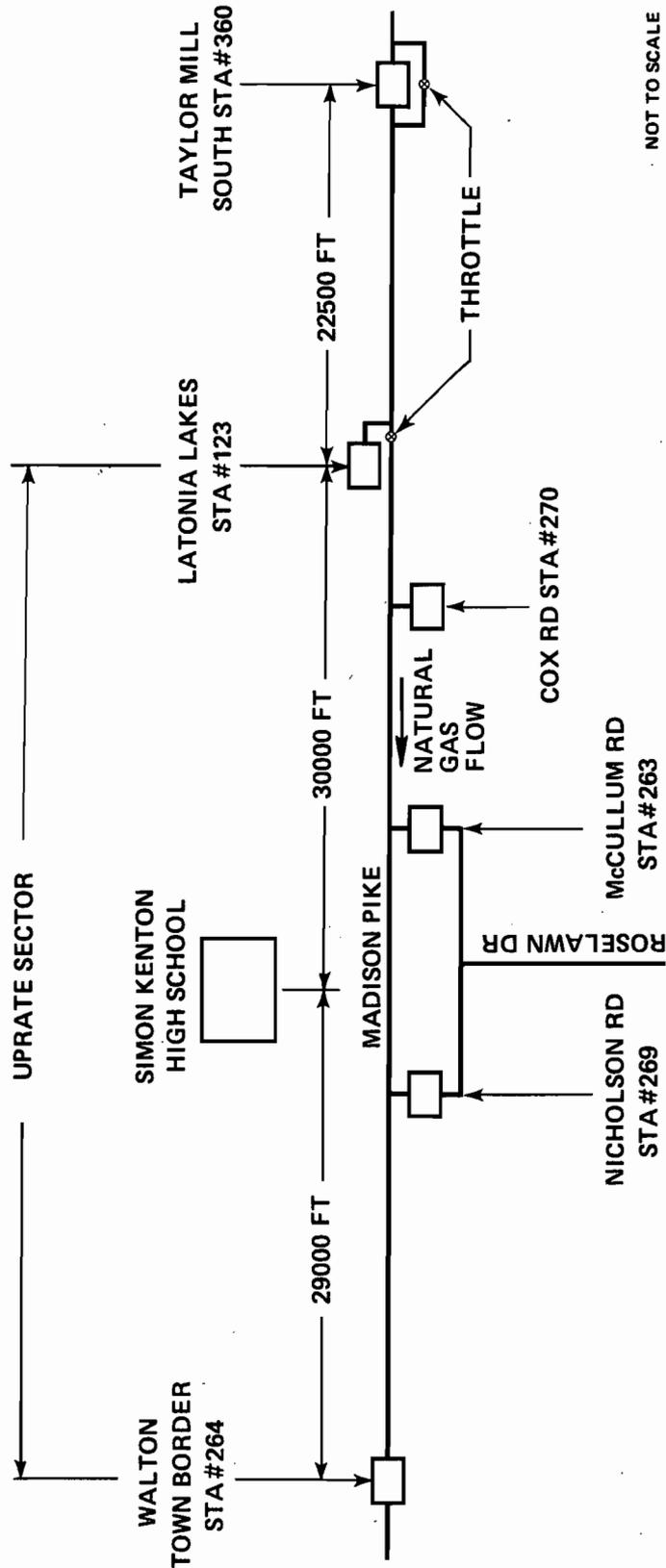


Figure 1.--Plan view of updated pipeline section.

approximately 35 psig. The gas main had many customer service lines connected to it. In preparation for the line uprating, the gas company's pressure crew, using microfiche customer connection records, had replaced the single regulators at the gas meter set assemblies on all of the known service line connections to the gas main with double-regulator systems as mandated by 49 CFR 192.195 to protect against accidental overpressure. The double regulators were designed to handle the anticipated 200-psig line test pressure; the single regulators were not.

The service line to Simon Kenton High School was connected to the 4-inch-diameter gas main. (See figure 2.) However, because the gas company's records (see appendix B) showed that the school's service line was connected to a 2-inch-diameter gas main that ran parallel and adjacent to the 4-inch-diameter gas main, the school's single regulator was not replaced.

When the pressure crew increased the gas main's pressure to 165 psig, the 2-inch-diameter compression coupling located on the upstream side of the school's gas meter set assembly (see figure 3) disconnected from its lower nipple (see figure 4), allowing natural gas to be released at an initial pressure of 165 psig into the school's boilerroom. (See figure 5.) Approximately 5 seconds later, at about 11:55 a.m., the gas exploded, demolishing a wall that separated the boilerroom from a classroom. (See figure 6.) The cement blocks blown from this wall by the force of the explosion struck and fatally injured a student who was in the classroom. The teacher and the other students in the classroom escaped unharmed; however, the classroom was heavily damaged by the explosion and an ensuing fire.

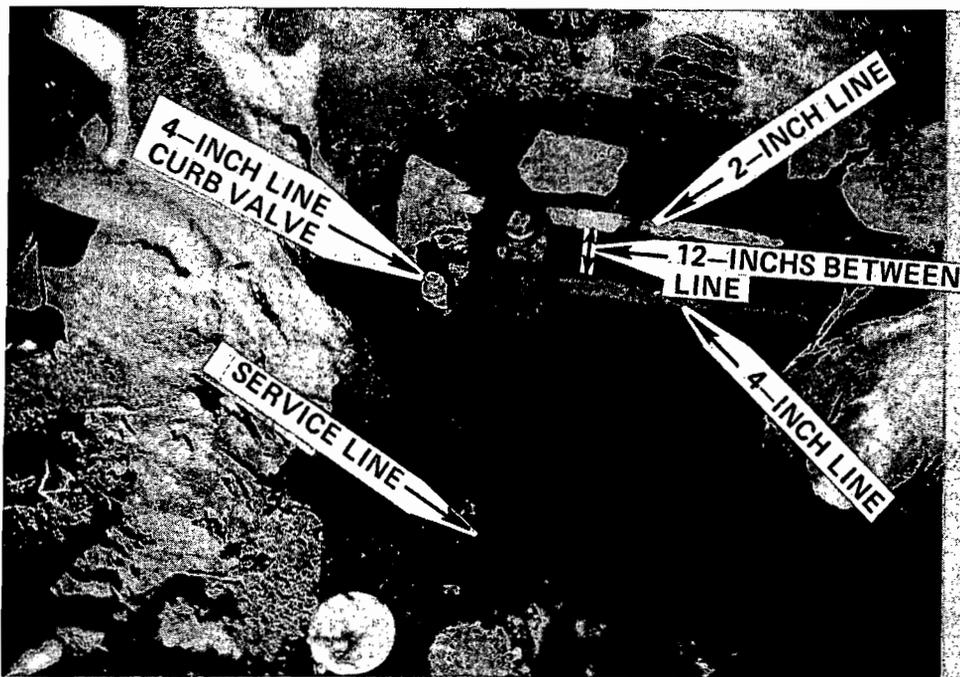


Figure 2.— School service line connection to 4-inch-diameter gas main.

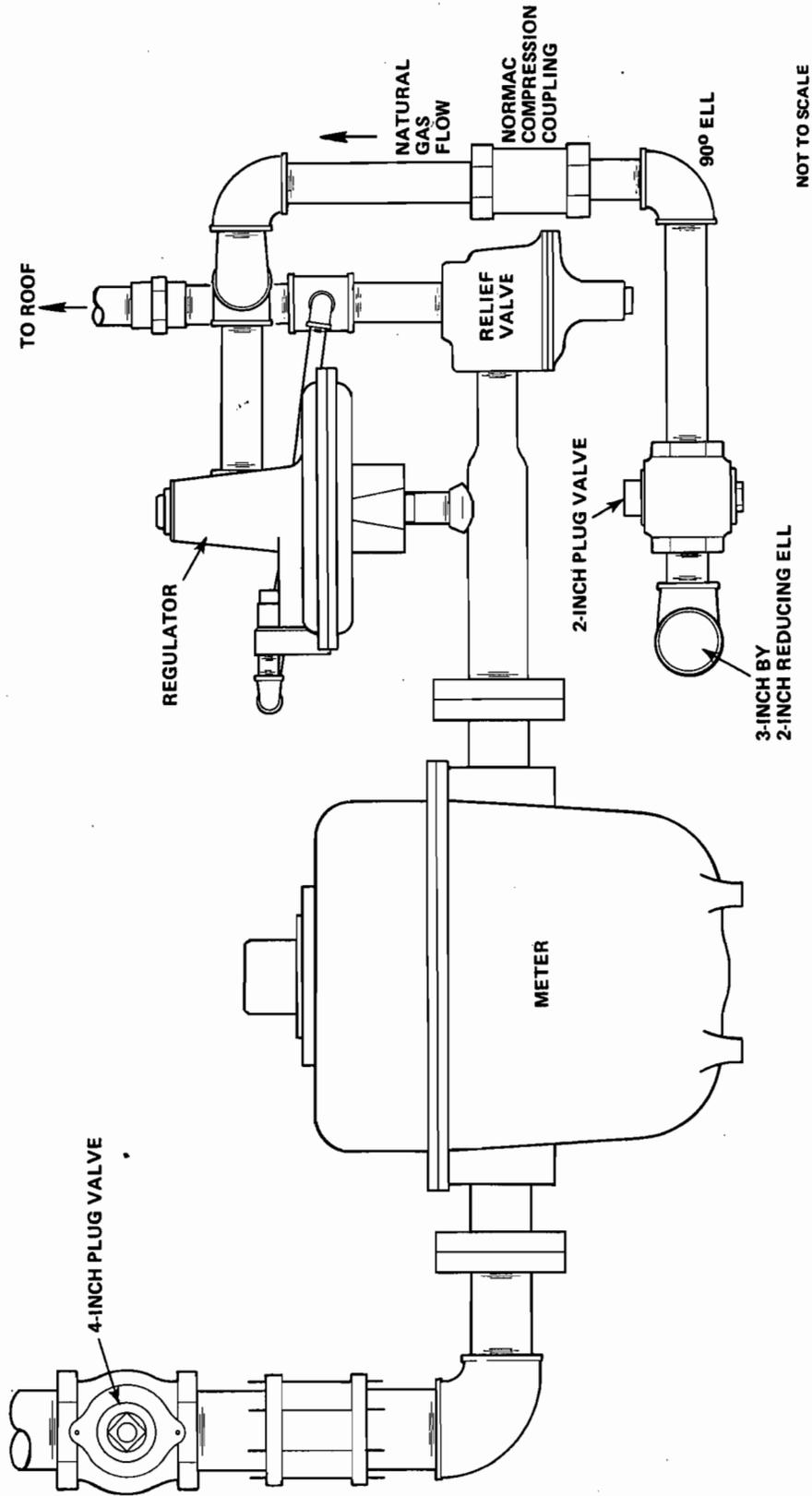


Figure 3.— Gas meter set assembly in boilerroom at Simon Kenton High School.

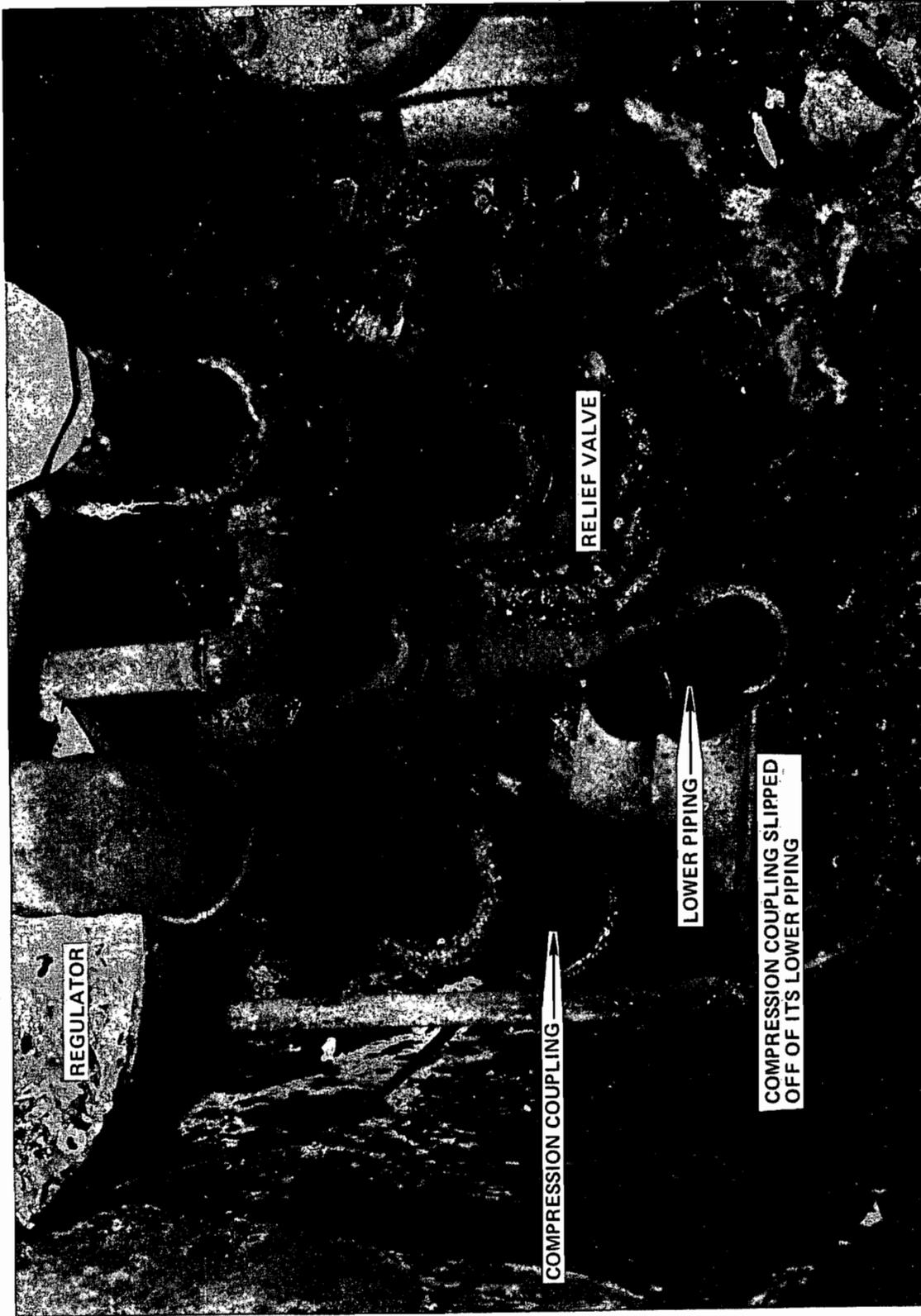
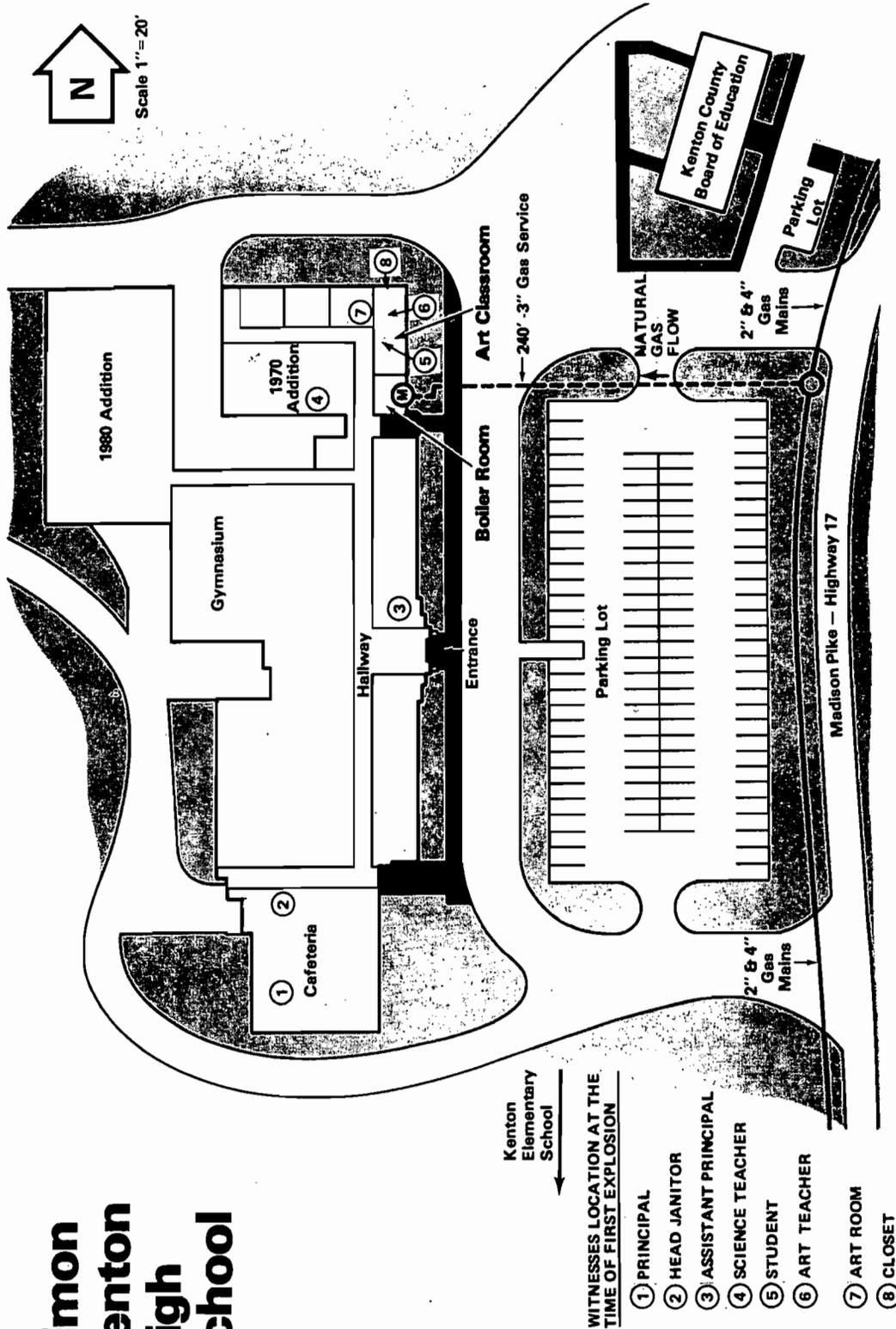


Figure 4.— Separation between compression coupling and 2-inch-diameter gas service line.

Simon Kenton High School



WITNESSES LOCATION AT THE TIME OF FIRST EXPLOSION

- ① PRINCIPAL
- ② HEAD JANITOR
- ③ ASSISTANT PRINCIPAL
- ④ SCIENCE TEACHER
- ⑤ STUDENT
- ⑥ ART TEACHER
- ⑦ ART ROOM
- ⑧ CLOSET

Figure 5.— Plan view of Simon Kenton High School.

Explosion Area

North Wing of Simon Kenton High School

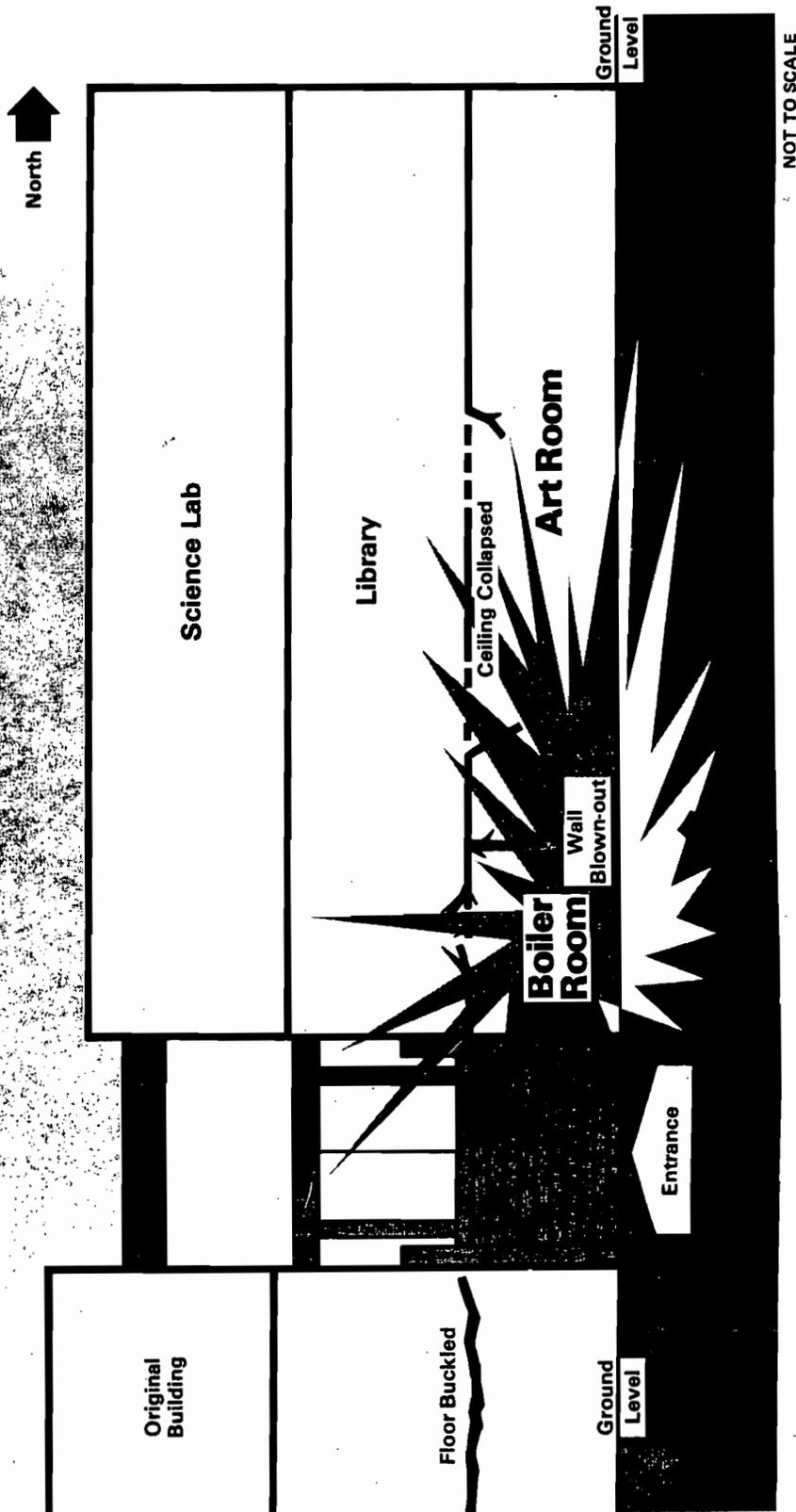


Figure 6.— Partial profile view of Simon Kenton High School showing origin of 11:55 a.m. explosion.

About 12 noon, and 25 minutes before the second explosion, some of the gas company employees involved in the gas main uprating were passing by the school where they saw police and fire emergency units and the fire in the building. The employees decided that natural gas might have caused the explosion and might be feeding the fire. One employee unsuccessfully tried to locate visually the lid on the curb box containing the valve 2/ that controlled the gas supply to the school's service line. (See figures 7 and 8.) He then used an electronic detector in another unsuccessful effort to locate the buried curb box. Meanwhile, another employee contacted the gas company's dispatcher by radio and requested that the pressure control supervisor be informed of the fire. He also asked for information concerning the curb box location. A third employee went to the window of the boilerroom to try to locate the gas meter from which the service line could be traced back to the street. (See figure 9.)

Between 12:10 p.m. and 12:15 p.m., the pressure control supervisor, who was en route to station 123, overheard the radio conversation about the fire and notified the dispatcher by radio to order the pressure foreman who was at the throttle valve 3/ at station 123 to reduce pressure on the 4-inch-diameter main. The pressure foreman had also heard the radio conversation and immediately ordered the pressure crew at station 123 to close completely the throttle valve to reduce the pressure on the line rapidly. The pressure foreman then left for the accident site; while en route, he ordered the pressure crewmembers located at station 264 to secure the station and report to the school.

About 12:15 p.m., the pressure foreman arrived at the school where he met the pressure control supervisor. At this time, there were six gas company personnel at the accident site; five were attempting to locate the curb box by the use of electronic locators and spotting bars, 4/ and the sixth stood by the radio for information and instructions. The efforts to locate the curb box were hampered by parked emergency vehicles and cars, and the curb box could not be located at that time. Some of the gas company employees went to the school boilerroom window to determine if a valve at the gas meter set assembly could be reached and closed. They told nearby firefighters not to put the natural gas fire out, but to let it burn. Flames were burning out of the top half of the boilerroom window and rolling up against the school walls to the second and third floors, although not much fire was actually burning in the boilerroom itself.

About 12:20 p.m., a gas company construction and maintenance crew arrived at the accident site and they also began to search for the curb box where the pressure foreman said his electronic detector indicated that the curb box might be located. At this time, at the boilerroom window, gas company personnel saw through the heavy smoke and flames a 4-inch-diameter plug valve (see figure 10) in a vertical run of pipe. With firefighters directing water to the window and on the backs of three gas company employees, the

2/ A curb valve or curb cock is a manually operated valve to stop the flow of natural gas through a gas service line and is installed as a safety control in case of fire or other damage to the premises. Curb valves have a rectangular or square head for turning with a curb cock wrench or long-stem key with handle. These valves are generally located near the curb or property line in a readily accessible location.

3/ A throttle valve is a valve temporarily used to control the increase or decrease of pressure in a pipeline segment, usually at incremental steps.

4/ A spotting bar is a long, slender, steel rod with a tee handle on top and a hardened steel tip at the end. It is used to punch a hole in the ground to locate underground facilities.



Figure 7.—Curb valve box.

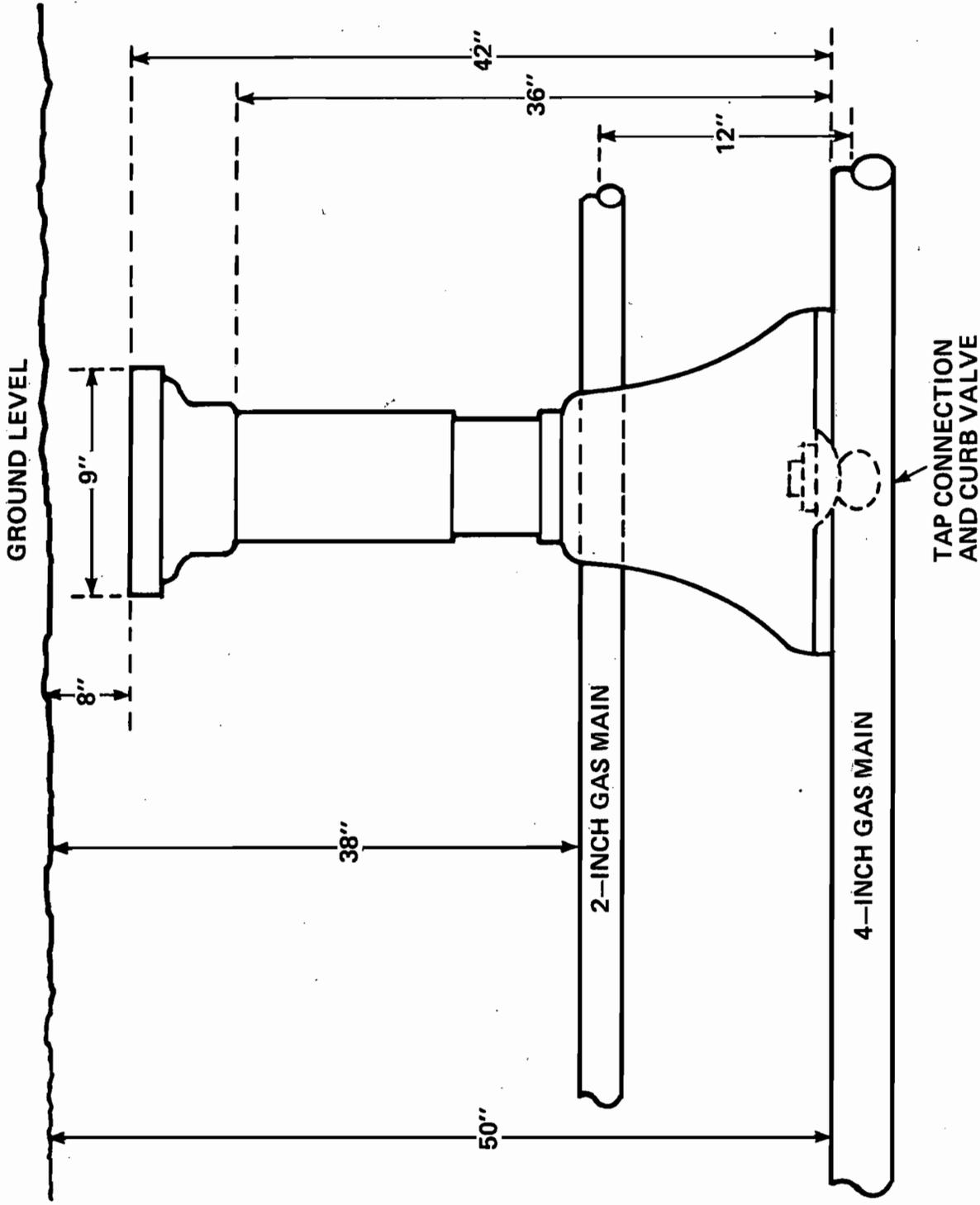


Figure 8.--Profile view of curb valve box assembly.

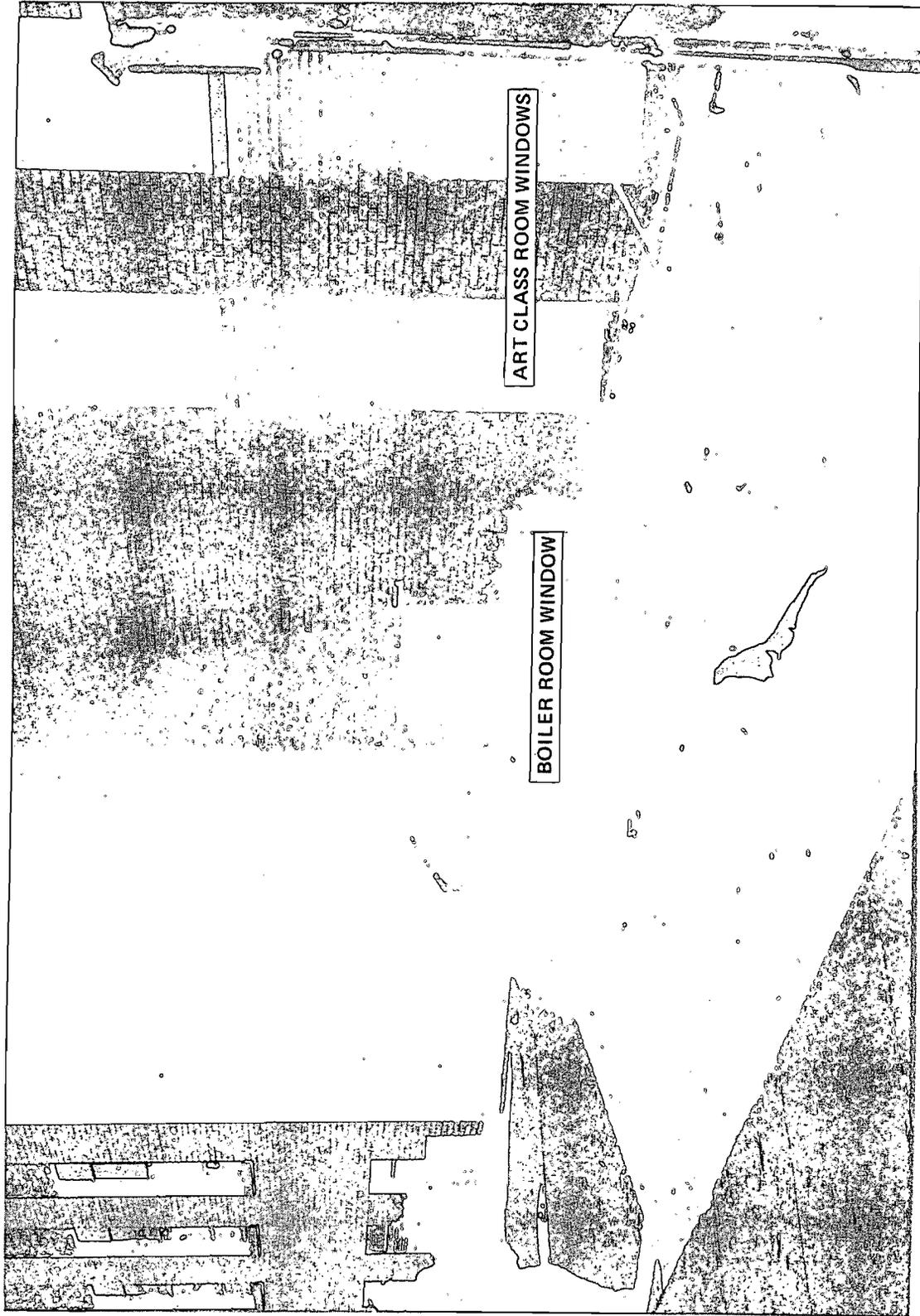


Figure 9.--Boilerroom window.

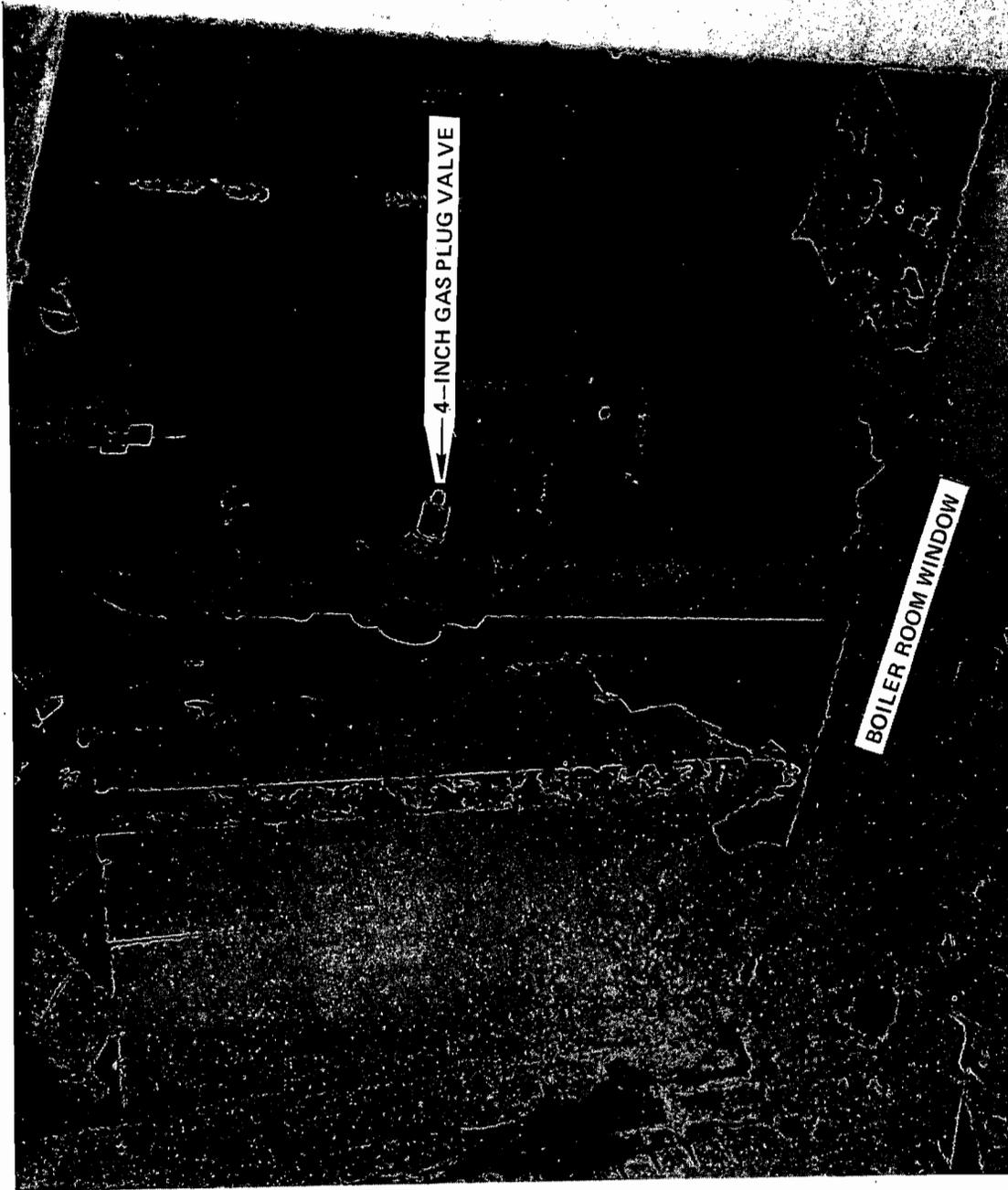


Figure 10.-- Four-inch-diameter gas valve shutoff to boiler.

employees were able to close the valve about 12:25 p.m. However, because the plug valve was located downstream of the compression coupling, its closing had no effect on the escaping natural gas. A gas company employee again cautioned firefighters located at the boilerroom window not to put out the fire until the curb valve could be located and closed.

Natural gas continued to escape from the open pipe and to rapidly diffuse throughout the school. About 12:25 p.m., approximately 30 minutes after the first explosion, another gas explosion occurred, injuring 37 persons, mostly firefighters. This explosion, described by witnesses as 10 times greater than the first explosion, damaged floors, doorways, and walls in the building. Although the natural gas was odorized as required by 49 CFR 192.625, no one had reported smelling natural gas inside or outside the school building before, during, or after the explosions and fire.

After the second explosion, the search to locate the curb box continued; an underground metal structure was located by the use of the electronic detector, but it was soon determined to be a metal culvert, not the valve box. A gas company employee directed an off-duty Independence policeman, who had brought a backhoe to the site, to begin digging along the general area of the gas main starting from the south edge of the school driveway and working in a southwesterly direction. Gas company employees resumed their search for the service line with their electronic detector; however, electronic interference caused excessive static which reduced the detector's effectiveness.

About 1:25 p.m., the gas company's construction and maintenance foreman arrived at the site and attempted to locate the service line using similar electronic equipment and searching a wider area. The school's architect arrived at the scene and showed where the ditch was located for the service line from the school to the gas main. Meanwhile, the construction and maintenance foreman had detected an underground metallic structure and requested the backhoe operator to excavate near a utility pole line, first at a point closer to the road, and finally in the berm of the road in line with the detected structure. Part of the service line was exposed and, a few minutes later, the backhoe bucket struck the lid of the curb box 8 inches below the ground surface. (See figure 8.) Gas company employees removed the lid and turned off the curb valve with a wrench, stopping the flow of natural gas to the school. The fire in the boilerroom went out at 1:40 p.m., 1 hour 45 minutes after the first explosion.

Events Preceding the Accident

The gas company was uprating the 4-inch-diameter gas main so it could carry more gas needed to serve new customers on the line. At 7:25 a.m., on the morning of the accident, the gas company's pressure crewmembers increased pressure on the gas main to approximately 200 psig from station 360 (Taylor Mill South) to the throttle valve located at Station 123. (See figure 1.) This segment had already been uprated successfully; however, it was necessary to bring this segment up from its existing operating pressure of 60 psig to a pressure of 200 psig to use it as a pressure reservoir for the next section. At 7:50 a.m., the pressure crew, using the throttle valve at station 123, raised the pressure in the next segment (59,000 feet) to 94 psig.

According to the pressure chart which was set at station 123 to indicate the pressure increases, the uprating of the pipeline segment started just after 7 a.m. at a pressure of 60 psig. (See figure 11.) Gas company employees later found that the chart

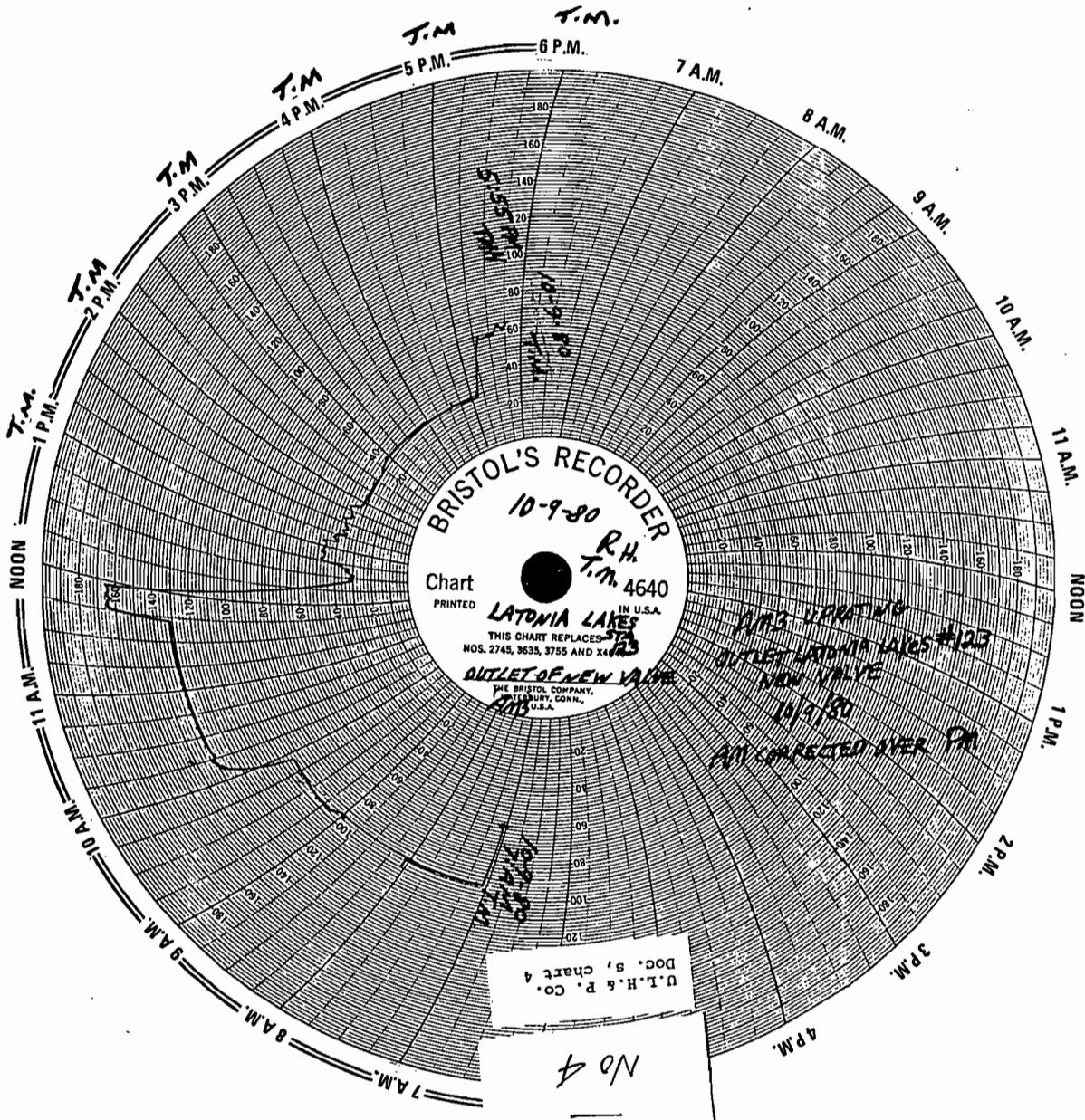


Figure 11.— Pressure recording chart at station 123 throttle valve.

did not turn as time progressed, because it was not tight enough on the chart wheel hub. The chart was therefore advanced by hand to the correct time and tightened at 8:15 a.m. The chart should have indicated a curved line from 7:05 a.m. to 8:15 a.m., similar to the line from 9:55 a.m. to 10:10 a.m.

At 8:15 a.m., the pressure was 94 psig. Pressure crewmembers checked station 264 for leaks at that pressure. Another pressure crew checked stations 269 (Nicholson), 263 (McCullum), and 270 (Cox Road) for leaks. Three leak survey crews, using one mobile leak survey unit 5/ and two backpack flame ionization units, 6/ patrolled the gas main and its service lines when it was holding at 94 psig and found five leaks; two were repaired and the other three were evaluated and classified as not potentially hazardous. The mobile unit was used to survey the pipeline along Highway 17-Madison Pike and the backpacks were used to survey the service lines connected to the gas main.

The evaluation of the leaks was in conformance with 49 CFR 192.553(a)(2) which states "Each leak detected must be repaired before a further pressure increase is made, except that a leak determined not to be potentially hazardous need not be repaired, if it is monitored during the pressure increase and it does not become potentially hazardous."

At 9:50 a.m., the pressure crew at station 123, using the throttle valve, increased the pressure to 130 psig. At 10:20 a.m., the pressure crew at station 264 again monitored the operation during the uprating to 130 psig, and also checked the piping at 130 psig for leaks. The other pressure crews monitored stations 269, 263, and 270 for proper operation and checked the piping at this pressure for leaks; no additional leak indications were found and the three previously detected leaks were again evaluated in accordance with the Federal regulations and again were found not to be potentially hazardous. At 11:45 a.m., the increase in pressure from 94 to 130 psig was completed.

About 11:45 a.m., the pressure crew, using the same throttle valve at station 123, started to increase pressure from 130 to 165 psig, the next to the last step to attain the final pressure of 200 psig. The pressure at the outlet of the throttle valve reached 165 psig at approximately 11:50 a.m. (See figure 11.) Once again the leak survey crews began to check the system, and shortly thereafter, the explosion occurred at the school.

Injuries to Persons

<u>Injuries</u>	<u>School Students</u>	<u>Gas Company Personnel</u>	<u>Emergency Personnel</u>	<u>Total</u>
Fatal	1	0	0	1
Nonfatal	0	2	35	37
Total	1	2	35	38

5/ A mobile leak survey unit is a unit installed in a vehicle and consisting of a cylindrical pipe with holes attached to the front bumper, a small sump pump, and instruments for analyzing and recording samples of natural gas in air collected directly above underground pipelines. This unit is adjusted to traffic exhaust fumes.

6/ A backpack flame ionization unit is a portable unit designed to detect natural gas in air. It is lightweight and can be carried by one person who on the average can survey 8 miles or 230 services per day.

Damage to Pipeline

There was no damage to the gas company pipeline or the school service line. The fire heated but did not permanently damage the gas meter set assembly in the boilerroom.

Other Damage

The first explosion and fire, which caused the fatality, was concentrated in the boilerroom. (See figure 12.) The second explosion and fire caused the greater damage to the building structure, hallways, and classrooms. The hallway of the second floor directly over the classroom and boilerroom was heavily damaged. (See figure 13.) Two-inch-thick doors at the stairwell on the north end of the older portion of the school were blown off their hinges. Hangars, wires, and metal frames from the ceiling were blown downward, indicating that natural gas had accumulated above the false ceiling before the explosion occurred. On the third floor above the boilerroom, papers on bulletin boards and on top of student desks were burned. However, there was no damage to the wood cabinets or other items in those rooms.

Pipeline System

The gas meter set assembly and the updated 4-inch-diameter gas main were owned and operated by the Union Light, Heat and Power Company, a subsidiary of the Cincinnati Gas and Electric Company. The 4-inch-diameter gas main had been installed in 1967. At the same time, a 2-inch-diameter gas main was installed 1 foot above the 4-inch-diameter main in the same ditch. Both mains were installed underneath Highway 17-Madison Pike with a cover of approximately 50 inches of dirt over the 4-inch-diameter main and 38 inches over the 2-inch-diameter main. (See figure 8.) Gas company records indicated that after installation the 4-inch-diameter gas main was hydrostatically tested satisfactorily at 720 psi for 1 hour and air-tested for 72 hours at 100 psi.

The 4-inch updated line had the following specifications:

- API 5L Grade B steel
- 4 1/2-inch outside diameter (OD)
- 0.188-inch wall thickness
- electrical resistance weld (ERW)
- 46 feet lengths
- 8.64 lbs/ft
- 2,300 psig mill test pressure
- 2,920 psig internal pressure at minimum yield strength

The steel, coated and wrapped service line was owned by the Kenton County Board of Education. The service line was mostly 3-inch-diameter pipe except where it joined the 4-inch-diameter gas main and the gas meter set assembly at each end. Gas company officials stated that at the time of installation the service line was pressure-tested in accordance with company procedures; however, neither the Board of Education nor the gas company could locate any test or specification records.

The gas meter set assembly contained a Rockwell Model 3,000 meter with flanges, a Fisher Controls Company type S201-761 regulator, a Fisher Controls Company type 289H relief valve, and a Normac (Norton McMurray Manufacturing Company) bead-tip



Figure 12.— Damaged boilerroom and art classroom.



Figure 13.— Damaged upper hall floors in Simon Kenton High School.

compression coupling. The meter set assembly was located in the boilerroom near a water heater and a boiler. Ventilation was accomplished by louvers in a window in the outside wall. The boilerroom was located on a lower level of the school which was a half basement. The boilerroom window was located about 4 feet above the floor. The meter set assembly was located by this window and below ground level. The school's service line entered the building through the boilerroom wall about 1 foot above the floor. From the point where it entered the building, the 3-inch-diameter line was reduced to 2 inches in diameter and then connected to the rest of the pipe fittings and components which included the compression coupling, the regulator, the relief valve, and the meter. (See figure 3.)

The gas company does not have a strict policy concerning the location of gas meter set assemblies; however, according to the gas company, almost all of these installations are located on the outside of the buildings they supply. Title 49 CFR Part 192 does not have specific requirements for the location of a gas meter set assembly. Kentucky Energy Regulatory Commission (KERC) regulations allow a utility company to install meters either inside or outside, depending on company preference or the preference of its customers. However, the 1980 edition of the American Society of Mechanical Engineers (ASME) Guide for Gas Transmission and Distribution Piping Systems states that ". . . gas meters should not be located in confined engine, boiler, heater or electrical equipment rooms. . . or similar locations. . ."

The gas meter was located on the low-pressure side of the system, downstream of the regulator. The meter had a maximum working pressure of 100 psig with a capacity of 1,450 cubic feet per hour (cfh) at 1/2 inch of water column (w.c.) pressure and 3,000 cfh at 2 inches of w.c. pressure. One psig is approximately equal to 27 inches of w.c. at standard conditions of 60° F and 1 atmosphere pressure.

The meter at the school had registered the passage of 24,500 cubic feet of gas since the last reading on September 19, 1980, 19 days before the accident. The meter was normally subjected to pressures of 9 inches of w.c., which is less than 1 psig, although it was designed to withstand a maximum working pressure of 100 psig.

The regulator was located on the upstream side of the meter. The regulator's design pressure was 125 psig and its pressure setting on the meter inlet was 5 to 10 inches of w.c., or approximately 1/5 to 1/3 psig. The regulator reduced the pressure of the natural gas coming into the school at 60 psig to approximately 10 inches of w.c., or approximately 1/3 psig into the meter. If an appliance in the school demanded more gas through the meter, the regulator opened up enough to supply the demand and kept the regulator's low-pressure side at approximately 10 inches of w.c. However, if the pressure on the regulator's high-pressure side increased, more gas than normal would enter the low-pressure side so there would be an increase in pressure and gas flow on the low-pressure side.

The increase in pressure on the upstream side of the regulator from 60 psig to 165 psig led to an increase in pressure on the low-pressure side of the regulator from approximately 10 inches of w.c. to approximately 12 to 15 inches of w.c., which is negligible. An increase to 15 inches of w.c. on the regulator's downstream side would not have caused venting because the relief valve located between the regulator and the meter was set at 21 inches of w.c. The only result would have been a slight overfiring of the boiler which probably would not have damaged the boiler, the meter, or the relief valve.

Relief valves are connected to regulators to protect the downstream system from overpressure if regulators fail. With the relief valve set at 21 inches of w.c., or approximately 3/4 psig, the valve was capable of venting 13,500 cfh of gas and, therefore, was capable of handling any failure of the regulator. The flow rate of the escaping gas at 165 psig was estimated to be approximately 10,000 cfh.

The Normac compression coupling was a boltless type coupling with a recommended working pressure of 25 psig for an unrestrained gas line and 125 psig for a restrained gas line. 7/ The piping adjacent to the compression coupling at the school was only partly restrained. The bottom nipple and piping coming through the wall were restrained from moving downward because they were supported by the wall. However, the top nipple and piping connected to the regulator, relief valve, and meter were restrained only by the weight of these units and, consequently, were not completely restrained. Compression couplings of this type are not generally designed for, nor intended to be used as, restraints against a pullout, such as the one caused at the school by the increase in pressure to 165 psig.

Compression couplings have been used by gas distribution companies for many years, and millions of these couplings are in use. The couplings provide a simple means of joining pipe ends quickly, while allowing for some angular deflection and thermal expansion and contraction. The ends of the pipe lengths to be joined are inserted a specified distance into the couplings. A dependable gas-tight seat is then achieved by the compression of a gasket-type material against the pipe; the nuts on the coupling are tightened with a wrench, which forces the gasket against the retaining cup and the pipe. Various means of installing these fittings are used, but the attaching and sealing is always done by the compression of a gasket of the inserted pipe end. When properly installed, the fittings will satisfactorily absorb stresses initiated by expansion and contraction, provided the pipe is not moved a distance greater than the distance it was inserted beyond the coupling gasket.

A compression coupling of this type requires a much lower tensile force to pull apart than is required for a threaded or welded joint. This factor can be an advantage if the compression coupling is in a service line located outside of a building which has a gas meter inside. If such a service line were hit by some outside force, the line would pull apart outside of the building, not inside at the meter where an explosive mixture could be generated within minutes. Economy and speed of installation are also advantages of compression couplings. Couplings are an inexpensive means to join pipe with a minimum of labor and without special equipment.

There are no Federal regulations regarding the specific use of compression couplings in gas meter set assemblies; however, the KERC had, in part, adopted National Fire Protection Association Code No. 54 which refers to compression couplings and their installation, and states that they should be restrained when installed. The KERC also has adopted the USAS B31.8-1968 "Gas Transmission and Distribution Piping Systems" Code. 8/ This code also had the same requirement of bracing for compression-type couplings.

7/ An unrestrained pipe is a pipe that has no provisions at the installation to prevent movement of that piping.

8/ The USA standard code for pressure piping is sponsored by the American Society of Mechanical Engineers. (ASME).

The curb box assembly consisted of a cast-iron box frame and lid and a round box bowl, lower center and upper center. (See figure 8.) The round box bowl and centers provided access from the ground surface to the top of the valve, and the square frame and lid provided protection from surface traffic. An excess flow valve ^{9/} was not installed on the service line, nor was it required to be by Federal or State regulation.

After the accident, the school's service line connection to the 4-inch-diameter gas main was fully uncovered. It was found that the service line was installed at the same level as the 2-inch-diameter gas main; however, before the service line reached the 2-inch-diameter gas main, it had been bent downward and connected to the 4-inch-diameter gas main. (See figure 2.) Gas company records did not show this connection. Instead, the gas company had a microfiche record which indicated that the school's service line was connected to the 2-inch-diameter gas main. (See appendix B.) There were no drawings or records other than the microfiche record.

The information contained in the microfiche record was probably obtained from gas company field personnel. The gas company has a blank form which is designed for recording data to be accumulated in the gas company's computer system. A field employee enters the information on the form and sends it to the gas company's engineering department where the information is entered into a computer system. A printout of the information entered into the computer is not sent back to the originator of the information to check for errors.

After the accident, the gas company began to double-check the uprated 4-inch-diameter gas main to ensure that no other customers were unknowingly connected to it. Gas company crews made a pressure test on every service area by raising the pressure on both gas mains to different levels to determine which gas main a service line was connected to. During the pressure test, each service was checked with a gauge. The gas company found four residential customers and a church whose connection to the 4-inch-diameter gas main were not shown in company records. These customers were actually connected to a 2-inch-diameter line (not the 2-inch-diameter gas main discussed previously) which was interconnected with the 4-inch-diameter gas main. Because of the interconnection, these customers had also been subjected to the increased pressures during uprating. This overpressure did not cause any leaks; however, no similarly installed unrestrained compression couplings were in the gas meter set assemblies at these five locations. At the point where the two lines interconnected, the gas company installed a regulator station after the accident and then replaced the service lines and regulators which had been erroneously subjected to the high pressure during the initial uprating.

The gas company did not have any written plans that stated conditions under which the pipeline system should be shut down completely. However, the gas company had previously shut down lines where the company had a backup feed source. No procedures for shutting down the segment being uprated were contemplated by the gas company and no verbal instructions to that effect were issued. A gas company official said that the company's position is that a complete shutdown is a dangerous practice because of the possibility of forming a gas-air mixture with a potential for explosion. The company believes that air could enter a shutdown gas system by way of open home appliances and, to avoid this entry of air, it is necessary to maintain a positive pressure in the system.

^{9/} An excess flow valve is a safety device usually installed at the connection of the service line with the gas main. The valve automatically and rapidly shuts off the gas at the main if the gas flow exceeds a predetermined rate.

Meteorological Information

At the time of the accident, the temperature was in the 70's with clear skies and moderate winds from the northeast.

Medical and Pathological Information

One person sustained fatal injuries from concrete blocks blown out of a wall by the first explosion. The second explosion injured 37 persons. The injured were taken to local hospitals, and most of them were treated and released on the same day.

Survival Aspects

Witnesses and emergency response personnel stated that no one detected the odorized natural gas inside or outside the building before or after the explosions occurred. Examination of company records for odorization of natural gas tests, performed before and after the accident, indicated that the level was satisfactory. A Safety Board investigator who arrived at the site later in the day smelled odorized natural gas.

Shortly before noon, most of the 1,120 students and 65 teachers and administrators were having lunch in the cafeteria, which was located at the opposite end of the school from where the boilerroom was located. (See figure 5.) At about 11:55 a.m., the school fire alarm sounded throughout the school building. The school staff immediately began an orderly evacuation of the building. Some of the students were directed to the front parking lot and others to the tennis court area located at the back of the school building. Shortly afterward, the students were taken to the Kenton County Elementary School parking lot, about two blocks away. No one in the cafeteria had heard the first explosion or detected the fire and smoke at the time of the fire alarm.

At the time of the first explosion, an art class with 12 students and a teacher was being held in the room adjacent to the boilerroom. The teacher and some of the students stated that there was a very loud hissing noise that lasted about 5 seconds before the explosion which blew out the wall that separated the boilerroom from the classroom and caused the only fatal injury. The explosion also showered debris on the other students and the teacher, but no one was injured seriously. (See figure 12.) The teacher and the students left the room through a walk-through closet into another room and escaped through windows within seconds after the first explosion.

The first units of the Independence Volunteer Fire Department arrived at the accident site between 4 and 5 minutes after the school alarm sounded. Approximately 18 fire departments with about 10 trucks responded to the call.

Tests and Research

The compression coupling with the attending piping above it had moved upward by approximately 4 inches, causing a vertical separation. (See figure 4.) The 165-psig gas pressure on the 90° ell in the 2-inch-diameter line exerted a total force of 553 lbs ($2.067'' \text{ I.D.} \div 2 = 1.033$) ($1.033^2 \times 3.1416 \times 165 \text{ psig} = 553 \text{ lbs}$) which pulled the pipe out of the coupling. After the separation, there was a completely open orifice 2.067 inches in diameter pointed toward the boilerroom ceiling through which the natural gas at 165-psig pressure flooded the boilerroom. It was estimated that the volume of the gas coming out of the lower nipple after pullout was approximately 56 standard cubic feet per second and

its velocity unexpanded within the pipe was 135 mph. The velocity of the natural gas escaping out of the open hole was approximately 425 mph. The gas burned further away from the open end of the 2-inch pipe where the gas velocity and volume and concentration permitted sustained combustion. Flames were concentrated outside the boilerroom window where there was a sufficient amount of oxygen to sustain combustion.

The meter set assembly was removed and analyzed by an independent consultant retained by the Safety Board. Metallurgical examination of the individual components of the meter set assembly (meter, regulator, relief valve, compression coupling, compression-made adapters, vent system, valves, pipes, pipe fittings) showed that they all functioned in accordance with the manufacturers' recommendations.

Metallurgical examination of the compression coupling indicated that it was a malleable bead-tip coupling. The installation procedures stated that the coupling nuts should be torqued to 160 ft-lbs. During the test, the compression coupling nuts were loosened one at a time and then retightened. The bottom nut required a torque of 60 ft-lbs to loosen, and 105 ft-lbs to retighten; the top nut required 105 ft-lbs to loosen, and 41 ft-lbs to retighten. A Normac representative stated that the recommended torque of 160 ft-lbs contains a safety factor of 5, so the tests revealed that for the 10-year-old coupling, the measured loosening and retightening torques were adequate to insure proper sealing, but not to prevent pullout. As with the relief valve, the position of the compression coupling below the level of the regulator caused it to be shielded by the regulator from the flames outside the window, and therefore the heat damage was minimal. The coupling gaskets were still resilient, and the exposed metal surfaces showed no signs of having been heated.

Other Information

Curb Valves.—Title 49 CFR 192.365 requires that each service line have a shutoff valve in a readily accessible location, but these regulations did not become effective until after the installation of the service line involved in this accident. However, industry code ASA B31.8-1963, which was in effect at the time of installation, regarding the location and accessibility of service line valves, states the following:

849.13, Location of Service Shut-Offs.

- (a) Service shut-offs shall be installed on all new services (including replacements) in a readily accessible location.
- (b) Shut-offs shall be located upstream of the meter if there is no regulator, or upstream of the regulator, if there is one.
- (c) All gas services operating at a pressure greater than 10 psig, and all services 2 inches in diameter or larger, shall be equipped with a shut-off located on the service line outside of the building, except that whenever gas is supplied to a theater, church, school, factory or other building where large numbers of persons assemble, an outside shut-off in such case will be required regardless of the size of the service or of the service pressure.

- (d) Underground shut-off shall be located in a covered durable curb box or standpipe, which is designed to permit ready operation of the valve. The curb box or standpipe shall be supported independently of the gas service line.

KERC regulations, under Section 22, Subsection 4(a)3, require that all curb valves be inspected annually for accessibility. The KERC also requires, under Section 22 of 807 Kentucky Administrative Regulation (KAR) 50:015, General Rules, that "at intervals not to exceed one (1) year . . . the curb box on service shall be inspected for accessibility."

The gas company stated that it conducts an annual public building inspection of all schools and churches in its service area. Company records indicated that the Simon Kenton High School was last inspected on December 3, 1979. The inspection record shown to Safety Board investigators was a computer readout sheet with minimal information on it. Nothing was provided on the inspection form to indicate that accessibility to the curb shutoff valve was checked as part of this annual inspection; however, gas company officials said that this was part of the inspection. The inspection form of December 3, 1979, indicated that no irregularities were found.

The District Highway Department Engineer and his staff, who are responsible for maintenance and repair for Kenton County highways, indicated that nothing had been done in the vicinity of the street valve box lid since December 3, 1979, that would have caused the lid to become covered with dirt, if it were not covered at the time of the gas company's last inspection. The Kenton County Board of Education building is located on the school grounds, approximately 150 feet from the street curb valve. The school superintendent said that school personnel had not made any changes that would have caused the street valve box lid to become covered with dirt.

KERC Investigation.—The KERC's investigation of this accident, its public hearing into this accident, and its participation in the Safety Board's public hearing revealed the following six probable violations of KERC regulations:

1. The gas company's system maps and records did not show that the school's service line was connected to the 4-inch-diameter gas main.
2. The service line to the high school, a church, and other residences had no primary regulators for reducing gas pressure from the 4-inch-diameter gas main.
3. The service line into the school included a compression coupling upstream of the meter set assembly which was not properly strapped or braced.
4. The curb valve on the school's service line was covered with earth and sod which concealed its location.
5. The gas company's written emergency plan did not contain any provisions for emergency shutdown and pressure reduction.
6. The curb valve on the service line to the school was not checked for accessibility on December 3, 1979, or within the period of a year before the date of the accident.

The KERC concluded that the gas company had violated KERC regulations and assessed a penalty of \$100,000 which the gas company paid.

Training.—The gas company has a "Public Education of Fuel Gases" program available to any public service, civic, corporate, educational, fraternal, or social organization upon request. The purpose of this program is to provide the public with a general understanding of the gas company's facilities within the community, of the chemistry and characteristics of the fuels, and of safety practices and procedures in handling and using the fuels.

In 1979 and 1980, approximately 478 personnel from various groups, mostly professional and volunteer firefighters, attended these programs. Participants were told, among other things, that no water should be directed to the point of leak on a natural gas pipe because the water might enter the pipe and create an additional hazard. They were also told that at the point of leak, the natural gas should be allowed to burn freely and water should be used only to protect the surrounding structures. However, the Independence Volunteer Fire Department, which was the first to arrive at the accident scene, had not attended any of the training programs.

ANALYSIS

The Accident

Because the gas company did not have a record to show that the school's gas service line was connected to the 4-inch-diameter gas main instead of the 2-inch-diameter gas main, the pressure crew did not install a double regulator on the school's gas meter set assembly in the boilerroom in preparation for the gas main uprating.

Witnesses stated that they heard a loud hissing noise for approximately 5 seconds before the first explosion. The pressure reached in the confined space of the boilerroom in 5 seconds would have been around 1 1/2 atmospheres, which is approximately 22 pounds per square inch absolute (psia), or 8 psia above the normal atmospheric pressure of 14 psia. The air in the boilerroom would have been displaced by the escaping natural gas, which was too rich to burn directly in the boilerroom. A gas-air mixture of between 5 percent (lower explosive limit (LEL)) and 15 percent is required for ignition. When an LEL is reached, the mixture does not just explode at room temperature, however. The surface containing the 5 percent mixture--the leanest mixture that can explode--must touch a spark, a flame, or something that is hot, and the temperatures of ignition must be between 1,000° to 1,500° F before the gas-air mixture will ignite. The natural gas most likely was ignited by one of the two boiler burners (pilots). The first explosion sent pressure waves in all directions. After this explosion, the concentration of natural gas in the boilerroom was too rich to sustain combustion so the fire was concentrated outside the boilerroom window where there was sufficient oxygen for the gas to burn.

After the first explosion, however, some of the gas was burning at the boilerroom window and the rest of the gas, too rich to burn, was going into other parts of the building under pressure and was forming burnable and explosive mixtures at various places and floor levels. This was a turbulent distribution of natural gas forming pockets capable of exploding if they were ignited, while others were capable of burning if ignited. Throughout the building were sources of ignition, such as switches and other electrical devices, as well as the flame coming from the boilerroom; therefore, it was not

possible to determine the exact source of ignition of the second explosion. This explosion, described by witnesses as 10 times greater than the first explosion, was probably due to the ignition of several natural gas pockets located throughout the building. The second explosion probably was a sequence of explosions which occurred in fractions of seconds when the natural gas pockets were ignited and produced pressure waves traveling at speeds of at least 1,000 to 1,500 mph. In some instances, a 10-percent gas-air mixture produces a pressure wave that can travel about 10,000 mph.

The first explosion occurred 15 minutes after the increase of pressure from 130 to 165 psig. The second explosion some 30 minutes later, occurred a few seconds after the gas company employees closed a 4-inch-diameter plug valve downstream of the meter and regulator inside the boilerroom. However, this closure of the line downstream of the meter and regulator probably had no effect since the pulled out nipple was no longer in line with the regulator piping and was simply blowing gas under pressure at the ceiling.

Curb Valve

The curb valve box lid, and therefore the valve itself, was not found and closed until at least 1 1/2 hours after the first explosion and 1 hour after the second explosion. Gas company personnel were at the accident site 5 minutes after the first explosion, and if they had been able to locate and close the curb valve rapidly, the second explosion with its large number of injuries and heavy damage to the school might not have occurred.

Gas company officials said that the accessibility to the curb valve was checked during the annual inspection of the school on December 3, 1979. However, since there is no provision on the inspection form for checking accessibility to curb valves, and since no activity that would have caused the curb box lid to become covered with 8 inches of earth was reported in the area after the inspection, the Safety Board concludes that the curb valve box had been inaccessible for some time before the December 3, 1979, inspection.

Company Records

The microfiche record that showed the service line was connected to the 2-inch-diameter gas main was incorrect. Once the information was entered into the computerized record, it apparently was not rechecked for accuracy. After this accident, five other buildings were found to be connected to a gas main other than the one shown by gas company records. The Safety Board believes that the gas company should develop a system for verifying its installations and recording them accurately in its records.

Title 49 CFR Part 192 does not require gas companies to keep old records; however, the Materials Transportation Bureau (MTB) of the Research and Special Programs Administration of the U.S. Department of Transportation issued an Advance Notice of Proposed Rule Making in the November 20, 1979, Federal Register (Docket No. PS-61) concerning maps and records. The Safety Board commented that, although there are many reasons for the lack of accurate records, the MTB should require operators to maintain accurate records because of their safety, economic, and engineering importance. The Safety Board believes that the MTB should expedite the final rulemaking.

Compression Coupling

The compression coupling separated from its connected piping when the increase in natural gas pressure pulled it free from the piping connection. The coupling was found

completely separated from the nipple beneath it. An unrestrained compression coupling is not recommended by manufacturers for use when the two pipes that are inserted into the coupling can be pulled apart by longitudinal forces. Couplings should be used only when the piping which goes into them from both ends is completely restrained from separation or if the coupling itself is of the restraining type. The industry code in effect at the time of this pipeline installation, ASA B31.8 1963 Section 834.4(b), states:

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.

Before the accident, when the pressure in the gas system was 60 psig, the existence of the compression coupling in the unrestrained line constituted an imprudent practice in view of the manufacturer's recommendations. After the increase in pressure due to the uprating project, the lack of a double regulator violated 49 CFR 192.197(c)(1). (See appendix C.)

Although 49 CFR 192.273 requires that pipelines be designed and installed so that the joints can sustain any longitudinal pull or thrust forces which are caused by contraction or expansion of the pipeline or by anticipated external or internal loading, these regulations were not in effect when the school's compression coupling and gas meter set assembly were installed. Many other such installations probably exist in this gas system and others nationwide. The Safety Board believes that gas companies should check all existing unrestrained compression couplings on gas meter set assemblies to make sure they were installed in accordance with the manufacturer's recommendations.

The Safety Board is aware that beyond the requirements of 49 CFR Part 192 concerning the location of gas meter set assemblies, the operator of a pipeline system should have the right to weigh such considerations as the probability of vandalism, sabotage, third-party damage, cost, and lack of adequate space in densely built areas. However, at a site, such as the Simon Kenton High School, it would have been better to install the gas meter set assembly outside the building. The installation of the meter set assembly outside the building would have prevented or diminished the severity of this accident.

Excess Flow Valves

If an excess flow valve had been installed at the service line's connection with the gas main or anywhere on the service line upstream of the gas meter set assembly, the severity of the first explosion may have been lessened and the second explosion may have been avoided. However, a possibility exists that the amount of gas escaping under an initial pressure of 165 psig from the 240-foot, 3-inch-diameter service line from an excess flow valve to the school boilerroom could have provided enough fuel for an explosion, but not of the magnitude experienced. The second explosion, fueled by gas escaping for over 30 minutes, would not have occurred if an excess flow valve has been installed. The Safety Board pointed out the value of excess flow valves in a 1971 special study, "Effects of Delay in Shutting Down Failed Pipeline Systems and Methods of Providing Rapid Shutdown" (NTSB-PSS-71-1). The Safety Board also discussed this need

in its accident reports of service line ruptures in Lake City, Minnesota, on October 30, 1972, 10/ and in New York City, on April 22, 1974. 11/ In both reports the Safety Board noted that the use of an excess flow valve might have shut off the flow of natural gas after the service lines were ruptured and the resultant explosions and loss of life and property might have been either averted or their severity reduced.

On May 16, 1973, the Safety Board recommended that the MTB undertake a study of fail-safe devices which will stop the flow of gas from ruptured lines. 12/ As a result of this recommendation, the MTB contracted for a study on the "Rapid Shutdown of Failed Pipeline Systems and Limiting of Pressure to Prevent Pipeline Failure Due to Over Pressure." The study, completed in October 1974, concluded that excess flow valves on high-pressure gas distribution systems would improve safety, that they are available and technically feasible, and that they are economically feasible. On April 19, 1976, the Safety Board recommended that the MTB expedite its review of the study and determine what regulatory action was necessary concerning the use of excess flow valves. 13/ The MTB is still reviewing the matter to determine what regulatory action it may take.

The Safety Board has investigated 13 other pipeline accidents since 1972 in which automatic shutoff devices could have prevented the accident. (See appendix D.) As a result of these investigations, the Safety Board is conducting a "special study" titled "Excess Flow Valves in Gas Distribution Systems." The purpose of this special study is to collect and analyze sufficient data to characterize the conditions under which excess flow valves offer safety benefits at reasonable cost. It is expected that the study will be primarily concerned with the use of these devices in high pressure gas distribution service lines, although their potential for use in low pressure service lines may also be explored.

Notwithstanding the pendency of the foregoing study, the Safety Board believes that at least in the case of larger service lines on high pressure systems (typically supplying schools, churches, and other places of public assembly) in which large quantities of gas could be released in a short time in the event of a service line rupture, the element of risk outweighs the countervailing considerations, such as cost and maintenance problems which might be developed by the study as valid objections to universal installation of excess flow valves. Accordingly, the Safety Board believes that MTB should initiate rulemaking on a priority basis to require the installation of excess flow valves on service lines to places of public assembly.

Gas Odorization

After the accident, a Safety Board investigator smelled odorized natural gas at the excavation site, which indicates that the natural gas was properly odorized. However, witnesses and emergency response personnel stated that none smelled natural gas inside or outside the building before or immediately after the explosions occurred. Because natural gas is lighter than air, it tends to form pockets at room ceilings, especially at corners. The natural gas escaping into the school building formed such pockets, and people walking

10/ "Pipeline Accident Report-Northern States Power Company, Lake City, Minnesota, October 30, 1972" (NTSB-PAR-73-1).

11/ "Pipeline Accident Report-Consolidated Edison Company, Explosion at 305 East 45 Street, New York, New York, April 22, 1974" (NTSB-PAR-76-2).

12/ Safety Recommendation P-73-2.

13/ Safety Recommendation P-76-11.

to the rooms and up and down the halls, particularly during the time between the first and second explosions, would not have smelled it; therefore, the smell of natural gas went undetected.

Gas System Shutdown

Title 49 CFR 192.615(a) requires that each operator establish written procedures to minimize hazards resulting from a gas pipeline emergency. Subsection 192.615(a)(6) requires that an emergency shutdown procedure be a part of these written procedures. The subject regulations were applicable to the uprating of the gas main, but the gas company did not have such written procedures.

The gas company believes that a complete shutdown is a dangerous practice. It maintains that there is a possibility of forming a gas-air mixture with a potential for explosion. The gas company believes that air could enter a shutdown gas system by way of open home appliances and, to avoid this entry of air, it is necessary to maintain a positive pressure in the system.

The Safety Board reviewed its pipeline accident reports and found no reports indicating that an explosion had occurred as a result of a complete pipeline shutdown. The Safety Board believes that, under certain conditions when a complete shutdown is performed, there is more of an economic burden to the gas companies than a potential danger to the public at large because gas company employees have to shut off the gas to each customer, individually, which is a major task when part of a city or town is involved. Afterward, when service is restored, gas company personnel have to purge the lines and restore the natural gas service to each customer. The Safety Board is aware of some companies' objections to complete shutdown, but it believes that in this case the decision to shut down would have been the better one because damage to the school and injuries to persons could have been far greater if the second explosion had occurred later and involved more gas.

CONCLUSIONS

Findings

1. Gas company employees were not aware that the school's service line was connected to the 4-inch-diameter gas main which was being uprated.
2. Incorrect data in the gas company's records led the uprating crew to believe that the school's service line was connected to the 2-inch-diameter gas main instead of the 4-inch-diameter gas main.
3. The gas company does not have a good procedure for verifying raw data before it is entered in any of the computerized records.
4. Gas company personnel doing the uprating were not aware that the school's service line was connected to the 4-inch-diameter line which was being uprated; therefore, a double regulator for reducing the high-pressure natural gas entering the school was not installed in the service line as required by 49 CFR 192.197(b)(c).
5. The gas company's employees at the accident site were not aware of, and could not quickly determine, the location of the street curb shutoff valve, which was unmarked and buried 8 inches in the ground.

6. The second explosion could have been prevented if the gas company personnel had been able to locate the curb box and close the valve promptly.
7. The gas company's inspection program, a part of an annual gas detection survey, failed to determine that the curb box lid was not accessible.
8. The curb shutoff valve had not been inspected for accessibility for several years; in violation of Kentucky Energy Regulatory Commission regulations.
9. The compression coupling separated from the adjacent piping because the manufacturer's installation recommendations for the use of that type of coupling were not followed so that excessive gas pressure on the 90° ell allowed movement of all the piping located downstream of the coupling.
10. No gas company procedures existed for shutting down the entire system or part of it in an emergency.
11. Some of the emergency response personnel who responded to the accident had not received any instructions or training on how to control a gas-fed fire.
12. A properly designed and installed excess flow valve may have prevented this accident or, at the least, lessened its severity.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the overpressuring and ensuing separation of an unrestrained compression coupling in the school service line which allowed natural gas to escape and ignite. Inaccurate company records failed to show that the school service line was connected to a 4-inch-diameter gas main being uprated to a higher pressure system.

Contributing to the severity of the first explosion and to the occurrence of the second explosion was the absence of an excess flow valve which would have rapidly shut off the gas flow after the pipe had separated.

Contributing to the second explosion was the inability of the gas company personnel to rapidly locate and shut off a buried valve at the school service line connection to the gas main. The valve could not be located because its buried valve box lid was not uncovered in the course of the gas company's prior annual inspections.

RECOMMENDATIONS

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

—to the Union Light, Heat and Power Company:

Improve company procedures for identifying all service lines connected to natural gas distribution systems to be uprated, and include in areas where there are more than one gas main the procedure of testing

pipelines by pressure differential, which will locate those customers who cannot be located by routine procedures. (Class II, Priority Action) (P-81-1)

Include procedures for rapid and complete shutdown in an emergency in written company uprating plans. (Class II, Priority Action) (P-81-2)

Incorporate a specific requirement for curb box inspections in the company's annual gas meter/regulator inspections, in accordance with the Kentucky Energy Regulatory Commission regulations. (Class II, Priority Action) (P-81-3)

Revise installation procedures for gas meter set assemblies installed inside of a building to require that the shutoff valve is located on the outside of the building. This requirement should be carried out for new installations and routine replacements, and where possible, for priority retrofitting of installations serving schools, churches, hospitals, and other places of public assembly. (Class II, Priority Action) (P-81-4)

Provide adequate training for gas company employees who are in charge of public building inspections so that all company facilities are properly inspected. (Class II, Priority Action) (P-81-5)

Conduct a system-wide inspection of unrestrained compression couplings on gas meter set assemblies for conformance with the manufacturer's installation recommendations and all pertinent regulations. (Class II, Priority Action) (P-81-6)

Institute quality controls to increase the accuracy of company records, including verification of field reports and of written records and maps transferred to computerized records. (Class II, Priority Action) (P-81-7)

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

Expedite final rulemaking on Docket No. PS-61 regarding the maintenance of maps and records, and include a provision for the retention of maps and records. (Class II, Priority Action) (P-81-8)

Initiate rulemaking to require the installation of excess flow valves on all newly installed or renewed high-pressure gas distribution system service lines with priority given to service lines supplying schools, churches, and other places of public assembly. (Class II, Priority Action) (P-81-9)

During routine annual inspection activities, verify gas company compliance with 49 CFR 192.615(a)(6) and enforce this regulation where it is needed. (Class II, Priority Action) (P-81-10)

--to the American Gas Association:

Advise its member companies of the circumstances of this accident, and urge them to include in their training programs information for their own personnel and local firefighting personnel regarding the hazards of

secondary explosions or fire which may exist if the gas supply is not shut down. (Class II, Priority Action) (P-81-11)

Advise its member companies to check unrestrained compression couplings on gas meter set assemblies in buildings for conformance with the manufacturer's installation recommendations and industry standards. (Class II, Priority Action) (P-81-12)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ G. H. PATRICK BURSLEY
Member

PATRICIA A. GOLDMAN, Member, filed the following concurring and dissenting statement:

I concur with the majority on this case with the following exception:

I do not believe the recommendation, which requests the Department of Transportation to "Initiate rulemaking to require the installation of excess flow valves. . ." is justified at this time.

The Safety Board is currently conducting a special study to "collect and analyze sufficient data to characterize the conditions under which excess flow valves offer safety benefits at reasonable cost." I supported initiation of this study because there is much controversy surrounding the use of excess flow valves and because the study is designed to be an objective, comprehensive examination of all side of this issue. Also, the study will consider a range of alternative solutions including voluntary as well as mandatory use of these valves.

Consequently, I believe any excess flow valve recommendations should be deferred until the study is completed.

/s/ PATRICIA A. GOLDMAN
Member

April 28, 1981

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety Board was notified of the accident at 1:40 p.m., e.d.t., on October 9, 1980. The Safety Board immediately dispatched a pipeline safety specialist from its Washington, D.C., headquarters to the accident site.

Parties to the investigation were the Department of the Treasury, Bureau of Alcohol, Tobacco and Firearms; The Office of the State Fire Marshal; the Kentucky Energy Regulatory Commission; and the Union Light, Heat and Power Company.

2. Public Hearing

A 3-day public hearing was held in Edgewood, Kentucky, beginning on December 2, 1980. Parties represented at the hearing were the Kentucky Energy Regulatory Commission; the Union Light, Heat and Power Company; the State Fire Marshal; the Materials Transportation Bureau of the U.S. Department of Transportation; and the Kenton County Board of Education.

APPENDIX B

COPY OF THE UNION LIGHT, HEAT AND POWER COMPANY MICROFICHE RECORD

THE UNION LIGHT, HEAT AND POWER COMPANY										ACTIVITY DATE 9/31/80		CURRENT DATE 10/07/80		J B		ULH&P					
ADDR	STREET NAME	COMMUNITY NAME	SERVICE SIZE	YR	N	S	SR	COCK LOC	HOUSE LINE	INTERSECTING STREET	MAIN	CC	B	V	F	FEED	S	L	IDENT		
			KND LN		R	T	TAP				SZ	K	D	CB	Y	T	L	LINE	F	S	NO
3	MADISON CT	COVNCTN	1 PL 4	79	M	A	4WJCL	7WJCL	7NNHL	51SSCL MADISON	2	S	2	YY	Y	M	N		Y	308404	
5	MADISON CT	COVNCTN	1 PL 2	79	M	A	5WJCL	7WJCL	11NSHL	117SSCL MADISON	2	P	2	YY	Y	Y	N		N	008774	
7	MADISON CT	COVNCTN	1 PL 1	78	M	A	6WJCL	7WJCL	1SSHL	170SSCL MADISON	2	P	4	YY	Y	Y	N		N	008775	
9	MADISON CT	COVNCTN	1 PL 1	78	M	A	6WJCL	7WJCL	1SNHL	189SSCL MADISON	2	P	4	YY	Y	Y	N		N	008776	
11	MADISON CT	COVNCTN	1 1/2 S 4	30	N	A		6WJCL	17NNHL	227SSCL MADISON	4		YY	Y	Y	N		N	008777		
13	MADISON CT	COVNCTN	1 PL 2	78	M	A	5WJCL	6WJCL	18NNHL	221SSCL MADISON	2	P	4	YY	Y	Y	N		N	358004	
	MADISON PK	INDPNCE	2 SPC 1	70	N	A	3WJCL	4WJCL	24NNHL	336NNCL SIDNEY DR	2		3	YY	N	Y	N		N	316326	
	NS MADISON PK	KNT VLE	11/4 CU 10	53	B	A	5NNCL			OFF LATONIA	6		3	YY	Y	N	N		Y	024579	
	NS MADISON PK	KNT VLE	11/4 S 10	39	B	A	4NSCL	1SNCL		6WJCL LATONIA	6		3	YY	Y	N	N		Y	024580	
	NS MADISON PK	FT WRT	3/4 CU 40	65	N	A	9SSCL	13NNCL	17ZEHL	249ECL LAREVIEW	4		3	YY	N	N	N		Y	053174	
	NS MADISON PK	COVNCTN	3/4 PL 40	73	N	A	8EECL	10WJCL		125SSCL KYLES LN	4	S	6	YY	N	N	N		Y	346370	
	NS MADISON PK	INDPNCE	3/4 PL 40	72	B	A	10EECL	12WJCL	4NNHL	26NNCL PELLY RD	3	S	3	NN	N	N	N		N	344024	
386	MADISON PK	FT WRT	3/4 CU 36	63	N	A	9SSCL	9NNCL	NNHL	1038NNCL DUDLEY PK	4		YY	N	N	N		N	024127		
393	MADISON PK	FT WRT	3/4 PL 112	74	B	A	3SSCL	31WJCL	37NNHL	906ECL HORSEBRACH RD	4	S	3	YY	Y	N	N		Y	024128	
394	MADISON PK	FT WRT	3/4 CU 31	63	N	A	5EECL	6WJCL	31NSHL	99NNCL HORSEBRACH RD	4		3	NN	N	N	N		N	024129	
395	MADISON PK	FT WRT	3/4 CU 27	63	N	A	4EECL	4WJCL	2SNHL	142NNCL HORSEBRACH RD	4		3	YY	N	N	N		Y	024130	
THIS SERVICE ALSO SERVICES										#503S HORSE BRANCH RD SEE SKETCH											
396	MADISON PK	FT WRT	3/4 CU 43	68	N	A	8EECL	21WJCL	65NNHL	468NNCL HIGHLAND TER	4		3	NN	N	N	N		N	300063	
397	MADISON PK	FT WRT	3/4 CU 3	64	N	A	9EECL	12EECL	1NNHL	435NNCL HIGHLAND	4		2	NN	Y	N	N		N	024131	
398	MADISON PK	FT WRT	1 PL 6	79	N	A	6EECL	12EECL	16SSHL	585NNCL HIGHLAND	4	S	4	YY	N	N	N		N	359954	
399	MADISON PK	FT WRT	3/4 CU 34	64	N	A	8EECL	8WJCL	13NNHL	51SSCL LAKEVIEW DR	4		NN	Y	N	N		N	024132		
404	MADISON PK	FT WRT	3/4 CU 4	63	N	A	WEHL	WEHL	24NNHL	84SSCL LAKEVIEW DR	2		2	NN	Y	N	N		N	024133	
406	MADISON PK	FT WRT	1 PL 3	79	N	A	4NSCL	1NSCL	19EWCL	OFF LAKEVIEW DR	2	S	4	YY	N	N		Y	359858		
427	MADISON PK	FT WRT	3/4 CU 20	63	N	A	3NSCL	90EECL	WECL	3NNCL LAKEVIEW DR	2		3	YY	Y	N	N		N	030000	
428	MADISON PK	KENT CO	3/4 CU 37	68	N	A	9EECL	10WJCL	8SSHL	23NNCL LAKEVIEW DR	4		4	NN	N	N	N		N	299668	
430	MADISON PK	FT WRT	3/4 CU 1	64	N	A	9EECL	9EECL	2NNHL	116NNCL N LAKEVIEW	4		3	NN	Y	Y	N		N	024134	
432	MADISON PK	FT WRT	3/4 CU 9	70	N	A	6EECL	15EECL	1SNHL	397NNCL LAKEVIEW DR	4		3	YY	N	N	N		N	325141	

ADDR	STREET NAME	TAX AREA	RATE	TAX	METER	MAP NO#	INSPE	KWIC	IDENT
3	MADISON CT		0100	K 001	000000	801E01-08	79055		308404
5	MADISON CT		0100	K 001	000000	801E01-08	79055		008774
7	MADISON CT		0100	K 001	146866	801E01-08	7908C		008775
9	MADISON CT		0100	K 001	145676	801E01-08	7908C		008776
11	MADISON CT		0100	K 001		801E01-08	79055		008777
13	MADISON CT		0100	K 001	00000M	801E01-08	7908C		358004
	MADISON PK		3200	K 017		804W01-40			316326
	NS MADISON PK		0200	K 028		802W01-57			024579
	NS MADISON PK		0200	K 028		802W01-57			024580
	NS MADISON PK		0200	K 026	000000	802W01-52			053174
	NS MADISON PK		0100	K 039		802W01-51	79055		346370
	NS MADISON PK		3200	K 017		804W01-35			344024
386	MADISON PK		0200	K 026	000000	802W01-44			024127
393	MADISON PK		0200	K 026	000000	802W01-44			024128
394	MADISON PK		0200	K 026	000000	802W01-44			024129
395	MADISON PK		0200	K 026	000000	802W01-44	79055		024130
396	MADISON PK		0200	K 026	000000	802W01-44			300063
397	MADISON PK		0200	K 026	000000	802W01-44			024131
398	MADISON PK		0200	K 026	000000	802W01			359954
399	MADISON PK		0200	K 026	000000	802W01-44			024132
404	MADISON PK		0200	K 026	000000	802W01-44			024133
406	MADISON PK		0200	K 026	000000	802W01			359858
427	MADISON PK		0200	K 026	000000	802W01-44			030000
428	MADISON PK		0300	K 018		802W01-52			299668
430	MADISON PK		0200	K 026	000000	802W01-44			024134
432	MADISON PK		0200	K 026	000000	802W01-44			325141

Actual Copy Highlighted for Purpose of Readability

APPENDIX C

EXCERPTS FROM 49 CFR PARTS 191 AND 192

§ 192.195 Protection against accidental overpressuring.

(a) *General requirements.* Except as provided in § 192.197, each pipeline that is connected to a gas source so that the maximum allowable operating pressure could be exceeded as the result of pressure control failure or of some other type of failure, must have pressure relieving or pressure limiting devices that meet the requirements of §§ 192.199 and 192.201.

(b) *Additional requirements for distribution systems.* Each distribution system that is supplied from a source of gas that is at a higher pressure than the maximum allowable operating pressure for the system must—

(1) Have pressure regulation devices capable of meeting the pressure, load, and other service conditions that will be experienced in normal operation of the system, and that could be activated in the event of failure of some portion of the system; and

(2) Be designed so as to prevent accidental overpressuring.

§ 192.197 Control of the pressure of gas delivered from high-pressure distribution systems.

(a) If the maximum actual operating pressure of the distribution system is under 60 p.s.i.g. and a service regulator having the following characteristics is used, no other pressure limiting device is required:

(1) A regulator capable of reducing distribution line pressure to pressures recommended for household appliances.

(2) A single port valve with proper orifice for the maximum gas pressure at the regulator inlet.

(3) A valve seat made of resilient material designed to withstand abrasion of the gas, impurities in gas, cutting by the valve, and to resist permanent deformation when it is pressed against the valve port.

(4) Pipe connections to the regulator not exceeding 2 inches in diameter.

(5) A regulator that, under normal operating conditions, is able to regulate the downstream pressure within the necessary limits of accuracy and to limit the build-up of pressure under no-flow conditions to prevent a pressure that would cause the unsafe operation of any connected and properly adjusted gas utilization equipment.

(6) A self-contained service regulator with no external static or control lines.

(b) If the maximum actual operating pressure of the distribution system is 60 p.s.i.g., or less, and a service regulator that does not have all of the characteristics listed in paragraph (a) of this section is used, or if the gas contains materials that seriously interfere with the operation of service regulators, there must be suitable protective devices to prevent unsafe overpressuring of the customer's appliances if the service regulator fails.

(c) If the maximum actual operating pressure of the distribution system exceeds 60 p.s.i.g., one of the following methods must be used to regulate and limit, to the maximum safe value, the pressure of gas delivered to the customer:

(1) A service regulator having the characteristics listed in paragraph (a) of this section, and another regulator located upstream from the service regulator. The upstream regulator may not be set to maintain a pressure higher than 60 p.s.i.g. A device must be installed between the upstream regulator and the service regulator to limit the pressure on the inlet of the service regulator to 60 p.s.i.g. or less in case the upstream regulator fails to function properly. This device may be either a relief valve or an automatic shutoff that shuts, if the pressure on the inlet of the service regulator exceeds the set pressure (60 p.s.i.g. or less), and remains closed until manually reset.

(2) A service regulator and a monitoring regulator set to limit, to a maximum safe value, the pressure of the gas delivered to the customer.

(3) A service regulator with a relief valve vented to the outside atmosphere, with the relief valve set to open so that the pressure of gas going to the customer does not exceed a maximum safe value. The relief valve may either be built into the service regulator or it may be a separate unit installed downstream from the service regulator. This combination may be used alone only in those cases where the inlet pressure on the service regulator does not exceed the manufacturer's safe working pressure rating of the service regulator, and may not be used where the inlet pressure on the service regulator exceeds 125 p.s.i.g. For higher inlet pressures, the methods in paragraph (c) (1) or (2) of this section must be used.

(4) A service regulator and an automatic shutoff device that closes upon a rise in pressure downstream from the regulator and remains closed until manually reset.

APPENDIX D

ACCIDENTS IN WHICH AUTOMATIC SHUTOFF DEVICES COULD HAVE FAVORABLY INFLUENCED OUTCOME

For applicable accidents prior to 1972, see page 2 of Report No. NTSB-PSS-71-1, "Effects of Delay in Shutting Down Failed Pipeline Systems and Methods of Providing Shutdown."

<u>Accident Date</u>	<u>Location</u>	<u>Event</u>	<u>Pressure</u>	<u>Casualties</u>	<u>Pipeline Type</u>
10/30/72	Lake City, Minn.	Pullout	36 psig	6 fatal	3/4" steel
10/31/72	Maple Grove, Minn.	Coupling Pullout	60 psig	17 inj.	1" steel
2/15/76	Rudolph, Wisc.	Pullout Comp. Coupling	35 psig	1 fatal	Valve on 3/4" steel
6/19/76	Enola, Pa.	Outside Force Damage	52 psig	3 fatal	3/4" steel
8/24/76	West Hartford, N.Y.	Outside Force Damage	22 psig	1 fatal	1" steel
12/10/77	Tempe, Ariz.	Outside Force Damage	38 psig	1 fatal	1 3/4" P.E.
2/6/78	Oxon Hill, Md.	Vandalism	20 psig	6 inj.	3/4" steel
6/5/79	Detroit, Mich.	Bypassed with Hose; Hose Blew Off	--	1 fatal	7/8" plastic
7/25/79	Albuquerque, N.M.	Excavation damage; Comp. Pullout	38 psig	2 fatal	3/4" steel
8/15/79	Seat Pleasant, Md.	Pullout	18 psig	1 inj.	3/4" steel
10/13/79	Chrisman, Ill.	Backhoe hit line	28 psig	1 fatal	1 1/4" steel
10/24/79	Stanardsville, Va.	Backhoe Pullout	15 psig	13 inj.	1 1/4" steel
2/21/80	Cordele, Ga.	Pullout	22 psig	3 fatal, 5 inj.	1" steel